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SUSTAINABLE AGRICULTURE AND CLIMATE SOLUTIONS FOR THE FUTURE OF FOOD SECURITY

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ABSTRACT
Due to reasons such as the increasing world population, climate change, changes in eating habits, unbalanced nutrition, and food waste, some precautions need to be taken for the world's food future. The world population, which was 8 billion in 2023, is expected to reach 9.7 billion in 2050. If important measures are not taken, food inadequacies, negative environmental impacts, and sustainable human life will be seriously affected in response to this population increase. Full compliance with the European Green Deal targets is required for a sustainable world life. The European Green Deal includes plans to keep the global temperature increase around 1.5 ºC, to reduce greenhouse gas emissions by 55% in 2030 compared to 1990, and to become a climate-neutral continent by 2050. It is known that these targets cannot be achieved if current nutrition habits, food waste, land use, water use, and carbon emission habits continue. If habits are not changed, an additional area twice the size of India will be required to feed the growing population by 2050. Considering that food practices constitute 26% of the world's greenhouse gas emissions, significant changes need to be made, and measures need to be taken in the fields of agriculture, animal husbandry, aquaculture, and food. Foremost among these is the significant reduction of food-related emissions through changes in methods, inputs, and technology. In addition, it becomes necessary to make important changes such as returning 1/3 of the food currently wasted in the world to human consumption, a significant change in eating habits, an orientation towards plant-based inputs, and a balanced diet.
Keywords: Carbon emissions**,** climate change**,** food losses**,** nutrition habits**,** population growth

GIDA GÜVENLİĞİNİN GELECEĞİ İÇİN SÜRDÜRÜLEBİLİR TARIM VE İKLİM ÇÖZÜMLERİ

ÖZ
Dünya nüfusundaki artış, iklim değişikliği, yeme alışkanlıklarındaki değişiklikler, dengesiz beslenme ve gıda israfı gibi nedenlerden dolayı, dünyanın gıda geleceği için bazı önlemler alınması gerekmektedir. 2023 yılında 8 milyar olan dünya nüfusunun 2050 yılında 9,7 milyara ulaşması beklenmektedir. Bu nüfus artışına karşı önemli tedbirler alınmazsa, gıda yetersizlikleri, olumsuz çevresel etkiler ve sürdürülebilir insan yaşamı ciddi şekilde olumsuz etkilenecektir. Sürdürülebilir bir dünya yaşamı için Avrupa Yeşil Mutabakatı hedeflerine tam uyum sağlanması gerekmektedir. Avrupa Yeşil Mutabakatı, küresel sıcaklık artışını 1.5 ºC civarında tutmayı, 2030'a kadar 1990'a kıyasla sera gazı emisyonlarını %55 azaltmayı ve 2050'ye kadar iklim nötr bir kıta olmayı içeren planlar

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sunmaktadır. Bu hedeflerin, mevcut beslenme alışkanlıkları, gıda israfı, arazi kullanımı, su kullanımı ve karbon emisyonu alışkanlıkları devam ederse gerçekleşemeyeceği bilinmektedir. Alışkanlıklar değiştirilmezse, 2050 yılına kadar artan nüfusu beslemek için Hindistan'ın iki katı büyüklüğünde ek bir alan gerekecektir. Gıda uygulamalarının dünya sera gazı emisyonlarının %26'sını oluşturduğu göz önüne alındığında, tarım, hayvancılık, su ürünleri yetiştiriciliği ve gıda alanlarında önemli değişiklikler yapılmalı ve önlemler alınmalıdır. Bunların başında, yöntemlerde, girdilerde ve teknolojide değişiklikler yapılarak gıdayla ilgili emisyonların önemli ölçüde azaltılması gelmektedir. Ayrıca, dünya genelinde şu anda israf edilen gıdaların 1/3'ünün insan tüketimine geri kazandırılması, yeme alışkanlıklarında önemli bir değişiklik, bitki bazlı girdilere yönelim ve dengeli bir diyet gibi önemli değişikliklerin yapılması zorunlu hale gelmektedir.
Anahtar kelimeler: Beslenme alışkanlıkları, gıda kayıpları, iklim değişikliği, karbon emisyonları, nüfus artışı

INTRODUCTION

For a sustainable human and living life in the world, the world temperature increase must be kept below 1.5 ºC. To ensure this, very important and priority measures need to be taken. It is predicted that by 2050, an additional 593 million hectares of agricultural land, approximately twice the size of India, will be needed to meet the 56% increase in food demand caused by the growing population (Hertel, 2011). If the current situation remains unchanged, by 2030, an additional planet twice the size of the Earth will be required to eliminate emissions and waste. If carbon emissions are reduced by 30% by 2030, this needs to decrease to 1.5 ºC world sizes . In addition to carbon dioxide, some other Greenhouse Gases (CHG) also have a significant impact on the equivalent carbon emission calculation. The effectiveness levels of CHG gases are given in Table 1 (Chang-Ke et al., 2013). As shown in Table 1, the greatest impact of CHG gases on global temperature increases comes largely from CO_2 emissions from fossil fuels.

Table 1. Components that affect greenhouse gases and equivalent carbon emission effects

Greenhouse Gases (IPCC2007)		*GWP
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrogen Oxide	N_2O	298
HFC	HFC_s	124-14.800
Perfluorocarbons	PFC_s	7.390-12.200
Sulphur Hexafluoride	SF_6	22.800
Nitrogen Trifluoride	NF_3	17.200
*GWP: Global Warming Potential		

Figure 1 shows the impact rates of greenhouse gas components on world CHG emissions. Accordingly, approximately 79.5% of emissions are carbon dioxide, 11.3% methane, 6.1% nitrogen oxides, and the rest 3.1% generated from hydrofluorocarbons (Overview of Greenhouse Gases | US EPA, n.d.).

Global temperatures are predicted to increase by 5 ºC by 2100 if precautions are not taken. Figure 2 shows the annual carbon emissions of G20 countries in 2023. Accordingly, the highest per capita emissions are as follows; it is seen that it is in countries such as China, the US, India, Russia, and Brazil and the world total emissions are 52.96 Gt for $CO_{2e,}$ and 39.02 Gt for CO_2 generated from fossil fuels. The EU emissions are 3.22 Gt for CO_{2e} emissions and 2.51 Gt for CO_2 emissions from fossil fuels. Türkiye's emissions are 606 Mt for CO_{2e} emissions and 438 Mt for CO_2 emissions coming from fossil fuels (EDGAR

- The Emissions Database for Global Atmospheric Research, n.d.).

Figure 3 shows the annual CO_{2e} and CO_2 emissions per capita from fossil sources for the Global,
EU and G20 countries in 2023. As seen from the figure, annual emissions per capita among G20 countries are ranked from largest to smallest as KSA, Canada, Russia, Australia, USA, South Korea and China. While EU27 countries are in 11th place, Türkiye is in 13th place. Per capita greenhouse gas emissions (CO_{2e}) in Türkiye are 7.1 tons/year and CO_2 emissions from fossil sources are 5.1 tons/year (EDGAR - The Emissions Database for Global Atmospheric Research, n.d.).

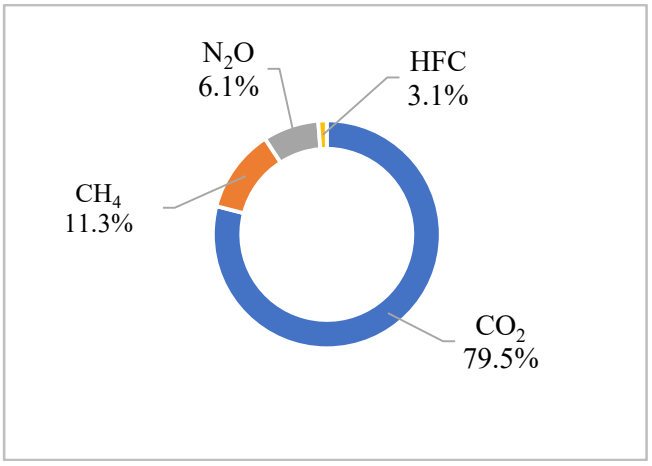

Figure 1. 2023 World greenhouse gas emissions and shares.

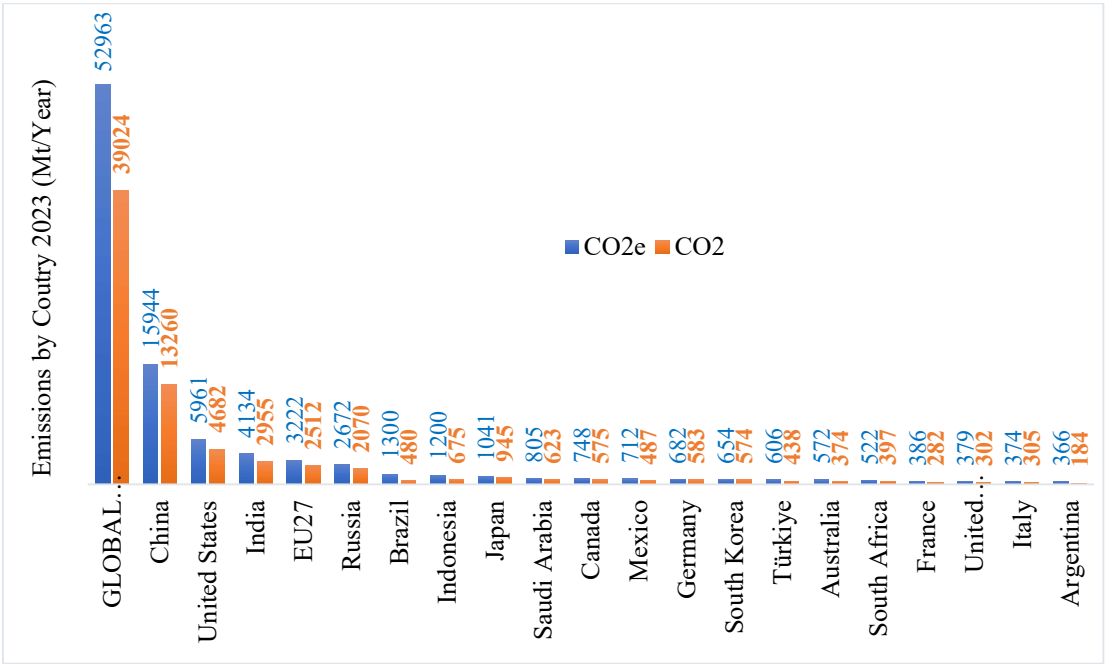

Figure 2. 2023 Annual carbon emissions Global and G20 countries

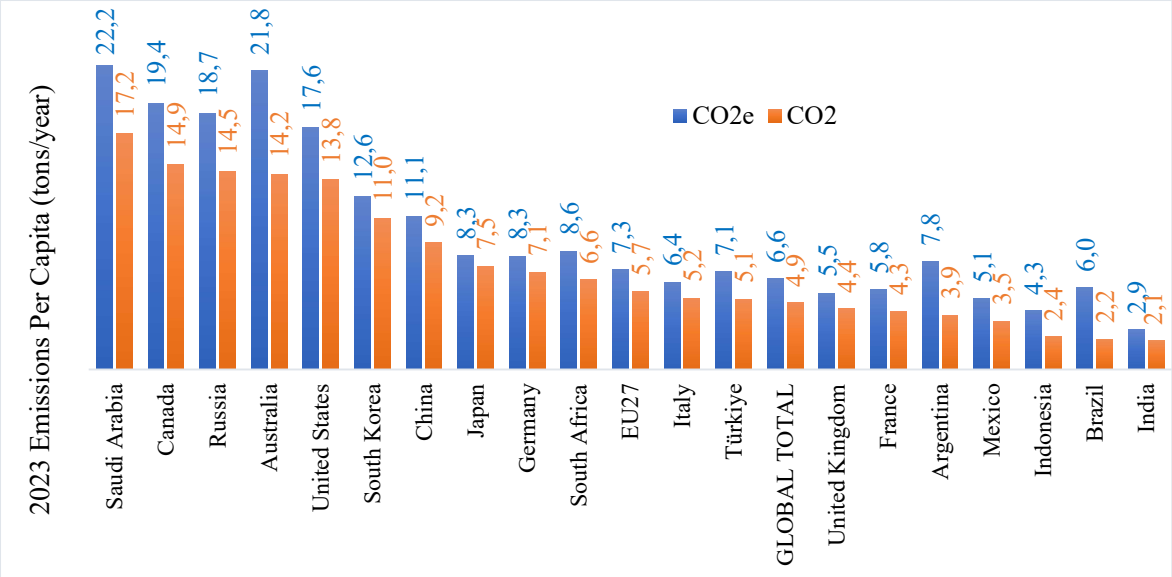

Figure 3. 2023 Annual carbon emissions per capita Global and G20 countries

MATERIALS AND METHODS

In this research, current reports, publications, and statistical data published worldwide and in Türkiye were considered as material. The latest data on food production in the world and Türkiye, food waste, carbon emissions from food, and land used for food were used. As a method, some calculations considered important for the world and Türkiye were made based on the data reported by reliable sources in the world and Türkiye. Türkiye's annual food product production amounts were taken from global and local reports. Most global data in the literature were considered for calculations such as energy, financial values of food, wasted food rates, and carbon footprint. The 26% rate given in the literature was used in the global greenhouse gas emission calculations resulting from total food production. Food quantities produced in Türkiye in 2023 were obtained from the Turkish Statistical Institute (TÜİK) reports. Some data available in the literature were used to distribute Türkiye's food losses based on food type. Some data not yet included in the literature were derived using global data. Examples of these include water consumption corresponding to losses, financial value of food losses, cost of unit lost food, etc. Information about the sources of the data and the calculations is given in the tables for reference. The magnitude of world food losses is described in Table 2, and the details are summarized below. If food waste were a country, it would be the third highest emitter of greenhouse gases after China and the USA. The global volume of food waste is 1.6 billion tons of "End Product Equivalent," and the consumable part is estimated to be 1.3 billion tons (ESG Report 2023 - IFCO Systems, n.d.). The equivalent of 1.3 billion tons of loss is around 1 trillion USD. Carbon emissions corresponding to food losses are 3.3 billion tons/year, and the total amount of additional water used yearly to produce wasted food is 250,000 tons. Table 2 shows the magnitude of food losses, and their distribution based on food categories. According to this, the highest loss is seen in fruits and vegetables, at a rate of 45%. Aquatic products follow the fruit and vegetable groups at a rate of 35%, dairy products, and meat-poultry products at a rate of 20%. It is seen that 43% of the loss occurs in households, 40% in companies and restaurants, 16% on farms, and 2% in production processes. The life cycle of food is defined in six categories: Agricultural production (e.g., fields), postharvest handling and storage, processing, distribution, consumption, and end-of-life. Recycling of residues after the final stage can also be considered a separate category. This last stage brings a series of processes, such as recycling, reuse, upcycling, etc., which need the most work.

Table 2. Distribution of world food wastes by source

Total World Foods		Total Food Losses			Houses			Companies, Restaurants, Shops			Farms			Producers		
Billion Tons	Trillion USD	%	Billion Tons	Trillion USD	%	Billion Tons	Trillion USD	%	Billion Tons	Trillion USD	%	Billion Tons	Trillion USD	%	Billion Tons	Trillion USD
3.9	1.0	33	1.30	0.33	43	0.55	0.14	40	0.515	0.132	16	0.207	0.053	2	0.026	0.007

Fruits and Vegetables	Fish and Seafood	Cereals	Dairy Products	Meat and Poultry
%	%	%	%	%
45	35	30	20	20

1.4 billion hectares of land, corresponding to 28% of agricultural areas, is used to produce wasted food, food waste alone accounts for approximately 8-10% of global greenhouse gas emissions, produced but never consumed foods that can feed 2 billion people. This size is more than twice the number of malnourished people worldwide. The world is losing an important resource for food production (one-third in 40 years, 75 billion tons of soil loss per year), and it is predicted that food production will need to increase by 56% in 2050 to feed the growing world population (The Unpalatable Truth about Food Waste: It's Everywhere | WRAP, n.d.; UNEP, 2021). Figure 4 shows the carbon emissions of some important foods along the supply chain per kg of product. In summary, it is necessary to develop alternative plant sources (especially protein) for the consumption of animal products and to reduce the carbon emission effects by making method and recipe changes in overly processed cocoa and coffee products obtained from tropical plants in high demand (Dwyer, 2023).

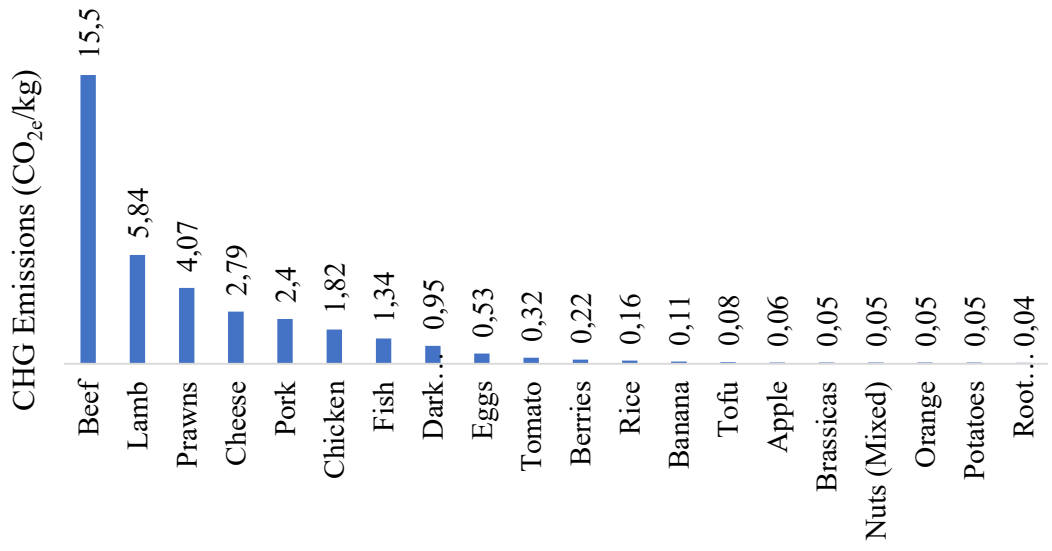

Figure 4. Carbon emissions per unit product of some foods

An example showing the effects of small changes in current consumption habits and food ingredients on carbon emissions can be seen in Figure 5. As can be seen from the figure, carbon emissions decrease by 2/3 when milk is converted from animal to vegetable sources (Mark Maslin, 2021).

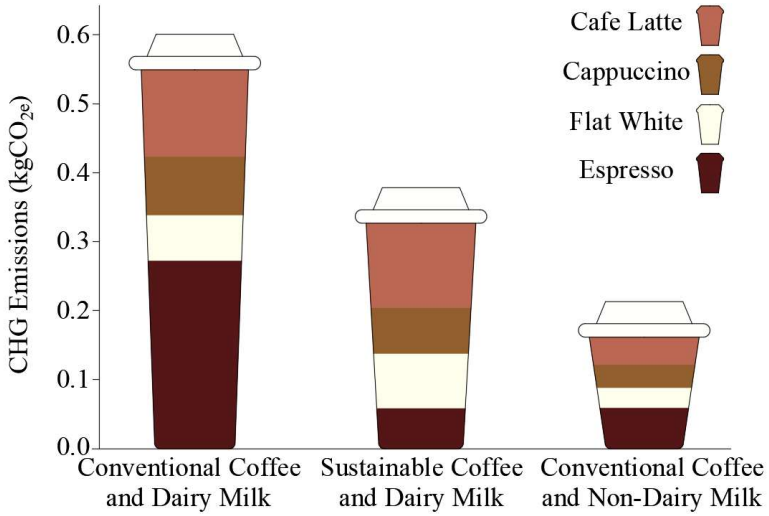

Figure 5. Carbon emissions of some coffee combinations

As seen from the example in Figure 5, considering carbon emissions when making personal food choices can significantly affect world carbon emissions. Based on the result in Figure 4 and as seen from Figure 6, animal resources use a large amount of land for 1,000 kcal of energy needs Alternative animal husbandry practices, alternative animal feeding systems (pastures, peatlands, etc.), and consumption reduction solutions should also be considered.

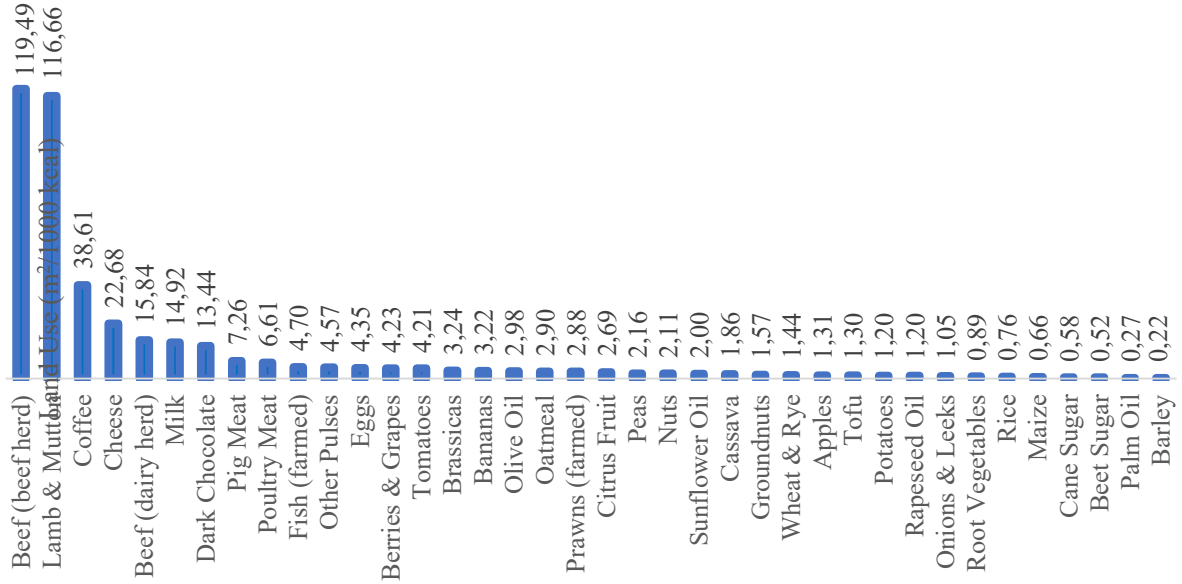

Figure 6. Land uses of some food products per 1,000 kcal

26% of total carbon emissions come from agriculture, food, aquaculture, and livestock processes The necessary solutions should be considered in the distributions in the graph in Figure 7. As seen from the figure, new approaches need to be implemented for producing, transporting, storing, distributing, and using food products, which are responsible for approximately 1/4 of total carbon emissions. Priority measures include taking many measures, such as preventing waste throughout the food chain, changing eating habits, and increasing efficiency with new methods and technologies.

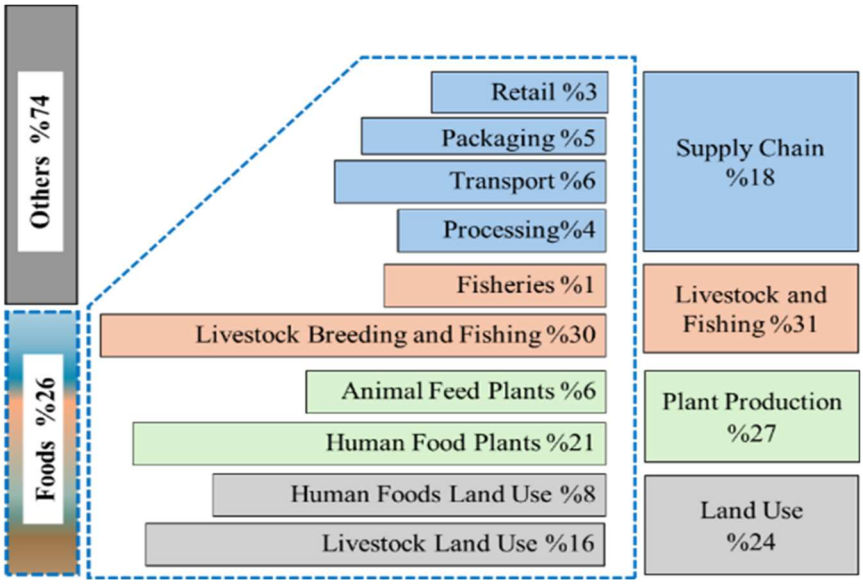

Figure 7. Food products' carbon emissions and sources

RESULTS AND DISCUSSION

Food and nutrition paradoxes

For a sustainable world life, it is recommended that 3 paradoxes be considered. A global consensus should be achieved regarding these paradoxes and necessary measures should be taken accordingly. It is estimated that 55% of adults in Türkiye will be obese or overweight by 2035 (Lobstein et al., 2023). It is estimated that 55% of adults in Türkiye will be obese or overweight in 2035 (Lobstein et al., 2023). 821 million people in the world are facing hunger or malnutrition. 47% of the total plant production in the world is used for human consumption, 40% of the total plant consumption is used for animal consumption or biofuel, 1/3 of the total food (1.3 billion tons/year) is thrown away and the amount of food thrown away is enough to feed 3 times the hungry population of 821 million in the world. Based on these data, three basic food paradoxes can be summarized as follows (Barilla Center FoodandNutrition, 2012).

- Should death from starvation or obesity be preferred?
- Should people, animals, or vehicles be fed with food sources?
- Should food be thrown away, or should malnourished people be fed?

Sustainable food future and human quality of life

Considering some issues such as the increasing world population, adverse environmental effects, and nutritional habits, three important headings of feeding the world population in the future can be summarized as follows:

- Efficiency, savings, new methods,
- Preventing all losses, balanced nutrition,
- Sustainable population growth and fair sharing.

Just as resources are not evenly distributed around the world today, it is stated that the distribution of the growing global food supply by 2050 will probably be unbalanced. Therefore, efforts to increase food supply by 2050 should be paired

with policy initiatives to ensure that benefits are distributed equally to everyone regardless of socioeconomic status.

While global food consumption was 2.65 billion in 2023, it will reach 2.93 billion tons in 2027. The following inferences can be made regarding food and nutritional habits, 2023 average amount of food per capita was 341 kgs/year, western eating habits are depleting the planet faster, and everyone can't become a vegetarian, even if everyone agreed to become vegetarian, the world's agricultural land could not feed more than 10 billion people (Ranganathan et al., 2018), if everyone consumed the average American's diet, the world could feed just 2.5 billion people, it is stated that it is necessary to spend 54 calories of energy to produce 1 calorie of protein from beef (Ritchie, 2020). In summary, significant changes in eating habits and diet systems are required for a sustainable food future, in addition to the measures mentioned above. For a sustainable world and food future, dealing with climate change should be considered a priority issue. Eliminating all factors that cause climate change within a plan is one of the important issues for the world and human life. Some other important topics can be summarized as follows: taking measures to keep the world temperature increase at 1.5 ºC, controlling population growth, especially in developing countries, orientation towards renewable energy sources, reducing food losses, removing waste and residues, changing eating habits, preventing unbalanced nutrition, protection of clean water resources, vegetation and forest areas, productivity increases without increasing agricultural areas. The scientific research clearly shows that global temperature rise must be limited to 1.5 °C above pre-industrial levels to avoid the worst effects of climate change and preserve a habitable planet. The Earth is now about 1.1 ºC warmer than it was in the late 1800's, and emissions continue to rise. It is an inevitable fact that to achieve the net zero emission target, breakthroughs must be made in the food sector, which covers approximately 25% of total carbon emissions. One of the most significant handicaps in this process is the increasing world population. Unless serious measures are taken, it is predicted that by 2050, an additional land area twice the size of India will be needed to meet the world's food needs. For a sustainable food future, important measures such as preventing food waste, changing eating habits, and balancing population growth must be taken.

Priorities for a sustainable food future

At the beginning of all measures, the world's linear economy cycle, which is designed as a Take-Make-Discard, should be transitioned to a waste-free and recyclable model, starting from design, considering reuse at every stage without waste. For a sustainable food future, it is necessary to make plans and studies on the issues summarized as follows, reducing food loss and overconsumption, transition to healthier, more sustainable diets, avoiding converting food and agricultural products into bioenergy, keeping population growth at a certain level, increasing livestock and pasture productivity, seed breeding, effective soil and water management, planting existing lands more frequently, adapting to climate change, linking productivity gains to the protection of natural ecosystems, protection of land and forests, reforestation of unproductive agricultural lands, protecting and restoring peatlands, improving wild fisheries management, improving the productivity and environmental performance of aquaculture, reducing enteric fermentation with new technologies, reducing emissions with improved fertilizers, reducing emissions from released manure, reducing emissions from fertilizers by increasing nitrogen use efficiency, increasing agricultural energy efficiency and switching to non-fossil energy sources, implementation of new methods to sequester carbon in soil. Preferences for natural products with high health perception and biodiversity are increasing in the world. Considering the negative effects of climate change, it is inevitable for food systems to be more sustainable and highly efficient in economic, social, and environmental terms. Additionally, reducing the use of pesticides, antimicrobials, and fertilizers comes to the fore. Developing biological methods and disseminating biotechnical control methods are necessary to reduce these materials. In addition to these, the

expansion of organic agriculture, the consolidation of agricultural lands, the use of geothermal energy in agriculture (geothermal greenhouse), the expansion of agricultural specialization in Organized Industrial Zones, and the support of the use of geothermal resources in plant production, the use of other renewable energy resources in agricultural production, the research for the reuse of waste and residues in agricultural production. Supporting priority projects, raising awareness for the recycling of food waste and residues increasing consumer awareness, and improving farm-to-table and biodiversity come to the fore (T.C. Tarım ve Orman Bakanlığı, n.d.).

World figures

CHG emissions, food losses and their amounts and costs were calculated using the reports, articles and statistical data published worldwide and in Türkiye. Table 3 shows world CHG gas emissions and CHG emissions from food production in 2023. Food losses and resource uses such as carbon emissions, water consumption, land use, and financial provisions corresponding to these losses were calculated collectively and per capita. As seen in Table 3, there is a global food loss of 161 kg per person, and the financial value of this is approximately 41 USD per person. When considered as edible foods and based on the total cost of food loss in the reports, it is seen that the unit cost of lost food is around 256.4 USD/kg. It is seen that the electrical energy generated by food losses is around 2,171 terawatt hours. When a calculation is made based on the current average electrical energy unit prices in the European Union, its financial value is 667 billion USD. It is stated that 3.3 billion tons/year of greenhouse gas emissions are generated in return for the energy used for lost food. It is also stated in the reports that the amount of water used in the life cycle of lost food is 250 million tons. This size is equivalent to the capacity of approximately 100 Olympic pools, each of which is 2.5 million tons.

Table 3. World CHG emissions, food losses, and figures

2023 Figures-World	Volume		Cost	
	Value	Unit	Value	Unit
CHG Emissions	57.4	Gt	5.166	
Food Based CHG (26%)	14.9	Gt		
Total Food Production	3.9	Billion tons	1.00	Trillion USD
Food Losses primary product equivalents	1.6	Billion tons		
Food Losses Edible	1.3	Billion tons	0.33	Trillion USD
Edible Food Losses per capita	0.16	tons/year	41	USD/year
Edible Food Losses unit price			256.4	USD/ton
Water Losses per year	250	Million tons		
Electric Energy Losses per year*	2171	Billion kWh	667	Billion USD
CO_{2e} Emission per year	3.3	Billion Tons		
Land use (28% of World Agricultural lands)	1.4	Billion hectares		
Population	8.05	Billion		
25% Loss Reduction (Assumption)	0.325	Billion tons	83.3	Billion USD
Food Deficit (9.7 billion 2050)	44	%		
Additional Agricultural Land decrease (2050)	16.8	%		

*Average Electric Energy cost for the EU (0.3071 USD/kWh) (Eurostat, 2024).

Türkiye figures

The European Green Deal and Türkiye's Green Transformation Action Plan prepared in parallel with it include a total of 32 targets and 81 actions under 9 main headings (T.C. Ticaret Bakanlığı, 2021). 9 main headings are summarized below. Carbon tax regulations at the border, a green and circular economy, green financing, clean, economical, and safe energy supply, sustainable agriculture, sustainable smart transportation, combating climate change, diplomacy with European Green Deal information and awareness

activities. Distribution of our installed capacity by resources as of the end of May 2024; 29.2% is hydraulic energy, 22.4% is natural gas, 19.8% is coal, 11.1% is wind, 13.6% is solar, 1.5% is geothermal and 2.4% is from other sources (Elektrik - T.C. Enerji ve Tabii Kaynaklar Bakanlığı, n.d.). The decline in the share of non-renewable resources in electricity production continues (Gorgulu, 2022). Türkiye is one of the countries that meets the food needs of its population and exports food products. It ranks 4th in the world in total food production. Türkiye's place in the world food trade can be given in the following order based on some important products; Türkiye alone produces 67% of hazelnuts, 26% of cherries, 27% of figs, and 23% of apricots, and ranks first in the world in these products, ranks 2nd among quince, poppy seeds, melon and watermelon, ranked 3rd among lentils, pistachios, chestnuts, cherries, and cucumbers, ranked 4th among walnuts, olives, apples, tomatoes, eggplants, spinach, and peppers, total crop production is approximately 130 million tons (2022), Türkiye is one of the world's leading countries in terms of agricultural production, 2023 Food Exports: 26.49 billion USD; Imports amounted to: 21.13 billion USD and a positive impact of +5.36 billion USD was created (TÜİK, 2024b). Because 1/3 of the world's food is wasted, the following important data emerge when the situation in Türkiye is examined; according to the 2020 waste report of the Turkish Waste Prevention Foundation, the annual amount of waste generated by households in Türkiye is 7.76 million tons, Türkiye ranks 48th among the 113 countries in the world where the most food waste occurs per capita, Türkiye wastes approximately 15% of its national income (Türkiye İsrafı Önleme Vakfı, n.d.). 1.7 million tons of bread (4.9-6 million pieces per day) go to waste every year. This rate corresponds to 7% of the bread produced, 42% of fruits and vegetables, and 41% of milk and dairy products are wasted (Tekiner et al., 2021). Based on the above data, it is seen that Türkiye has significant savings potential in the fields of Agriculture, Food, Livestock, and aquaculture (Türkiye İsrafı Önleme Vakfı, n.d.). When 2023 data, total food losses, and global data are considered, these figures are seen to be higher. Calculations on this subject are given in detail in the conclusion section. Türkiye's total food product production in 2023 is calculated as 154.5 million tons from TÜİK reports. The distribution of these products is shown graphically based on the main product groups in Figure 8 as tons/year and percentages in total amount. Harvesting, transport, and storage losses of these food products, such as harvesting, storage, and transportation are calculated as approximately 8.65 million tons. These losses are around 6.64% on average. The distribution of these losses is given in the graph in Figure 9. As seen from the graph in the figure, In Türkiye, the highest amount in 2023 was realized in grains with 37.7 million tons, vegetables with 29.1 million tons, dairy products with 21.5 million tons, and sugar beet with 19.3 million tons.

In Figure 9, the loss calculations made by taking Türkiye 2023 data into consideration and the global loss rates of some foods whose loss rates are unknown are given as a pie chart in the form of values. As can be seen from Figure 9; The highest loss in Türkiye in 2023 was in dairy products with 3.22 million tons, grains with 1.86 million tons, and vegetable products with 824 thousand tons.

In Table 4, some calculations have been made and some results have been reached, considering global data such as world carbon emissions, food losses, and land use, as well as some statistical data specific to Türkiye (food production amount, losses, energy unit prices, etc.). In the table, carbon emissions, water use, energy use, and land use data corresponding to food losses are calculated as amounts and financial values. As seen from Table 4, Türkiye's food losses are at the level of 15% of its national income (Türkiye İsrafı Önleme Vakfı, n.d.). By saving this wasted resource, an average cost of 8 b USD, 21 more mega projects (T.C. Ulaştırma ve Altyapı Bakanlığı, 2023) such as "Istanbul Airport" and "Yavuz Sultan Selim Bridge" could be built (Türkiye 2023 National Income 1.118593 trillion USD) (TÜİK, 2024a). Additionally, 1,486 tons of bread per day and 542,455 tons per year are wasted (Türkiye İsrafı Önleme Vakfı, n.d.). Data for Türkiye, calculated by considering reliable

reports and data specific to the world and Türkiye, are summarized in Table 4. Accordingly, approximately 155 million tons of food was produced in Türkiye in 2023, resulting in 178.8 megatons of greenhouse gas emissions. Based on world data, it is calculated that 63 million tons of food loss occurred in Türkiye in 2023 as the Primary Product Equivalent phase, and this amount corresponds to 53 million tons of consumable food. The per capita value of consumable food loss is 603 kgs/year, and based on world food prices, its financial value is calculated to be 155 USD/year per person. It has been calculated that the electrical energy resulting from food loss is 86 billion kWh and its financial value is around 10.6 billion USD. Greenhouse gas emissions corresponding to food losses were calculated to be 131 million tons. The amount of water used for food losses is calculated as approximately 10 million tons/year. This size corresponds to 4 Olympic swimming pools.

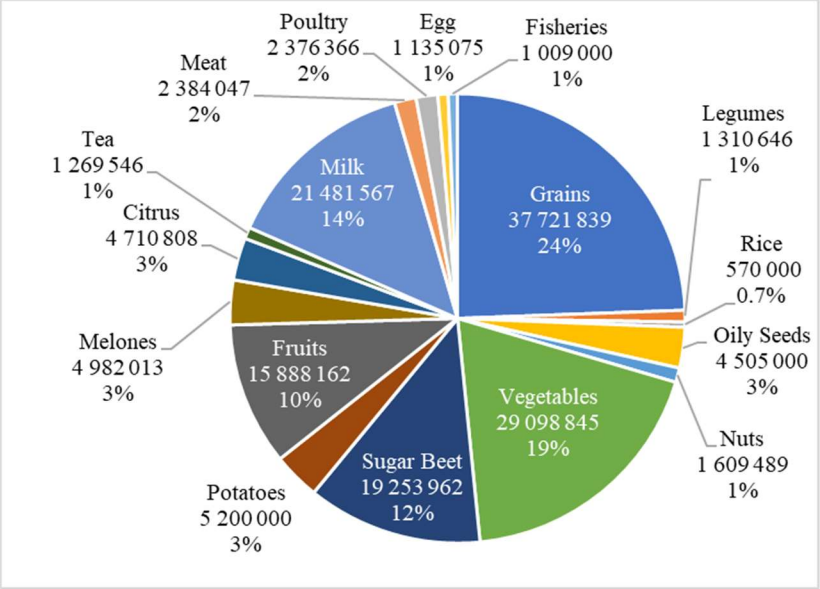

Figure 8. Türkiye food production (kgs) 2023

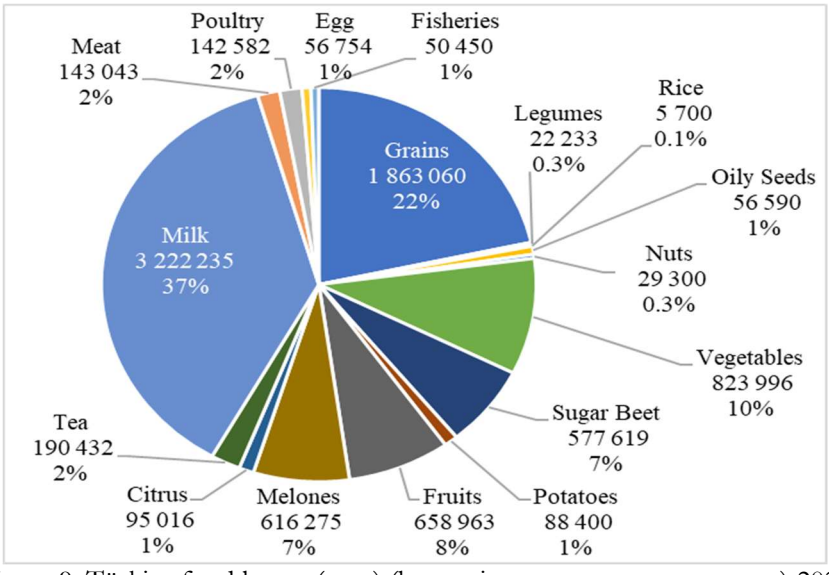

Figure 9. Türkiye food losses (tons) (harvesting, transport, storage, etc.) 2023

Table 4. Türkiye CHG emissions, food losses, and figures

2023 Figures-Türkiye	Volume		Cost	
	Value	Unit	Value	Unit
Gross Domestic Product (GDP)			1.119	Trillion USD
Total Financial Loss (15%) *			0.168	Trillion USD
Mega Investment Average Cost **			8	Billion USD
No of Investment (Mega Project)			21	
CHG Emissions	0.6875	Gt		
Food-Based CHG (26%) ***	0.1788	Gt		
Total Food Production	0.155	Billion tons	39.6	Billion USD
Food Losses Primary Product Equivalents***	0.063	Billion tons	16.3	Billion USD
Food Losses Edible (1/3) ***	0.052	Billion tons	13.2	Billion USD
Edible Food Losses (per capita)	603	kgs/year	155	USD/year
Water Losses per year***	9.9	Million tons		
Electric Energy Losses per year****	86.0	Billion kWh	10.6	Billion USD
CO_{2e} Emission per year***	0.131	Billion tons		
Land use (28% of World Agricultural lands) ***	0.06	Billion hectares		
Population	85.4	Million		

*15% GDP loss assumption (Tekiner et al., 2021).

**Projects cost is changing (0.5 to 22 billion USD) (T.C. Ulaştırma ve Altyapı Bakanlığı, 2023)

***Calculated from global figures

****Türkiye 2023 data (0.1234 USD/kwh) (İnanç, 2024).

CONCLUSION

Considering the data, discussions, and information in the previous sections, the following conclusions can be drawn, considering many variables such as the increasing world population, the increasingly deteriorating world climate, food losses, waste, overconsumption, and operational inefficiencies.

•When a calculation is made considering excessive consumption and wasted food, it can be said that malnourished people have approximately 6 times their food needs.

• By directing food waste to human consumption, the need for additional agricultural land to meet the demands of the growing world population can be largely eliminated. It will also be possible to reduce losses such as labor, energy, carbon emissions, product quality loss, and packaging required for reprocessing.

•Significant productivity increases can be achieved through alternative input, method, and technology changes for foods and their components that cause high carbon emissions.

•By raising awareness about eating habits and balanced nutrition, important health problems caused by overnutrition, and undernutrition can be reduced, as well as fair distribution of resources, and resources allocated to health expenditures can be directed to areas that create more added value.

•Using digital technologies, artificial intelligence, and advanced sensor applications in agriculture, carbon emissions can be reduced by saving water, fertilizer, pesticides, and fuel.

•Using advanced technologies, harvest storage and transportation losses can be significantly reduced.

• Similarly, significant efficiency can be achieved in livestock and aquaculture production with the use of new methods and technologies.

• By developing new generation and environmentally friendly seeds, a higher amount of product can be obtained from the same area and an advantage in the fight against climate change can be achieved.

• The use of agricultural areas for human consumption, the use of natural resources for animal nutrition, and the use of new technologies as alternatives to biofuels used for vehicle fuels.

• Considering that approximately 1/3 of the energy used in food processes is electricity and the remaining 2/3 is natural gas, the processes that operate on natural gas should be converted to electricity through technology change.
• Carbon emissions can be reduced by producing qualified chemicals through upcycling from the exhaust gases of natural gas-powered processes.
• CO_2 and N_2 can be produced from the exhaust gases of natural gas-powered food processes using food process aids such as ammonium bicarbonate or liquefaction.
• Instead of traditional thermal processes, new methods and technologies that consume less energy and are highly efficient (Radio Frequency, Microwave Heating, Infrared Heating, Ohmic Heating, Inductive Heating, etc.) can be used together or separately with conventional methods.
• Considering other important food losses in Türkiye, they can be significantly reduced through awareness raising and RandD studies. Even some foods with a low shelf life (fruits, vegetables, dairy products, etc.) can be transformed into food inputs with a long shelf life using new methods. Examples of these are fruit-vegetable powders, dried fruit, fruit-vegetable concentrates, dairy products with low water activity, using renewable resources such as the sun, etc. Obtaining food ingredients such as sugar and fiber from fruits with more advanced processing methods may also be possible.

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THE DECLARATION OF ETHICS COMMITTEE APPROVAL
This study does not require ethics committee permission or any special permission.

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