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Estimating National Emissions of Greenhouse Gases from Food Systems in Jordan

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Abstract

Global warming has become a main challenge that threatens life on Earth. It is mainly blamed on the unprecedented levels of atmospheric greenhouse gases emanating from natural and anthropogenic sources including food systems that encompass different processes including agricultural practices, food packaging, refrigeration, transportation, and disposal of food waste. Therefore, signatory nations to the Paris Agreement are called upon to assess the contributions of their food systems to national budgets of greenhouse gases and to take necessary actions to reduce these emissions.

In this paper, we present the findings of an attempt to quantify the national emissions of greenhouse gases emanating from food systems in Jordan based on validly published emission rates and locally relevant agricultural data reported by the Jordanian Department of Statistics including cultivated areas, harvested goods, and imported food items. Our calculations revealed that more than 12.5 million tons of carbon dioxide equivalent in 2019 were generated by food systems in Jordan constituting about 47% of the total national emissions in that year. The transportation sector is found to be a main emitter of carbon dioxide???, making imported meat and rice the main generators of carbon dioxide in the food systems in Jordan. Landfilling of food remains or losses generate massive quantities of greenhouse gases with no social gain.

Keywords: *Food systems, Carbon footprint, Global warming, Pollution, Climate change*

1. Introduction

Global warming has become a catalyst that affects all aspects of life on Earth, whether they are political, social, economic, or environmental. In response to growing concerns over the increasing abundances of atmospheric greenhouse gases, tremendous efforts have been spent worldwide to come up with initiatives and regulations that call upon cutting emissions of greenhouse gases (GHGs) including carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, and sulfur hexafluoride to combat global warming.

As a phenomenon, global warming has elicited heated debate among the scientific community, but there is a consensus maintains that the greenhouse effect and its influence over climate change is a real and tangible occurrence (Abu Sada et al., 2015; Salahat and Al-Qinna, 2015; Al-Qinna, 2018), and that humans are contributing to the rise of global temperature by adding greenhouse gases to air. Potential implications of global warming particularly include sea level rise because of thermal expansion of water and melting of the ice cap, storm surges, windstorms, flooding, heat waves, drought, food insecurity, food, and water-borne diseases, vector-borne diseases, intensive power consumption for heating, cooling, water energy, and water stress (Pender, 2008; Hunt, 2010).

Curbing global warming isn't an easy task or a simply achieved goal, but it starts by taking steadfast commitments to reduce emissions of GHGs by creating alternative sources of energy to replace these fossil fuels, removing carbon dioxide from emissions at the source, eliminating the use of chlorofluorocarbons, afforestation, developing agricultural techniques that release less carbon dioxide to the atmosphere, setting rigorous emissions regulations, and changing our dietary regimes as food systems are major sources of certain emissions, particularly methane from livestock and carbon dioxide from machinery and refrigeration.

Food systems include the full spectrum of actors and their interconnected value-adding activities that are involved in the production, aggregation, processing, distribution, consumption, and disposal of food products that come from the agricultural, livestock, forestry, fisheries, and food industries, as well as the larger economic, societal, and natural environments in which they are embedded (Westhoek et al., 2016). Emissions generated by the food systems make up a sizable fraction of all greenhouse gas emissions made by humans and as a result, they play a role in global warming (Vermeulen et al., 2012). Finding ways to lessen the food system's contribution to GHG emissions is consequently a major challenge for its sustainability. Understanding the sources and processes of greenhouse gas emissions across the entire food system is crucial to address and reduce the contributions of the food system to global warming. It's also crucial to comprehend how different approaches to structuring various aspects of the food system can lead to varying amounts of emanated GHGs.

Fertilizers, pesticides, manure, agriculture, and changes in land use combined account for around 24% of global GHG emissions. Other contributions come from later stages

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in the food system including packaging, retail, transport, processing, food preparation, open burning, refrigeration, storage, catering consumption, and waste disposal (Garnett et al., 2016, Li et al., 2022).

Due to its enormous greenhouse gas (GHG) footprint, food loss and waste worsen the climate change challenge. Food waste produces methane, a strong greenhouse gas when dumped in domestic landfills. The relationship between food loss and waste and climate change reveals a crucial connection between agriculture, supply chain resilience, and climate change. In contrast, supply chain resilience and agriculture are both negatively impacted by extreme weather events.

2. Study Aim

The previous introductory section has demonstrated that food systems are potent sources of greenhouse gases; therefore, it is vital to assess national emissions of GHGs to come up with practical initiatives to cut them. Therefore, the main objective of this paper is to quantify the contribution of food systems to the national emission inventory of GHGs in Jordan based on the 2019 agricultural statistics and published carbon footprints.

3. Methodology

The mass of Greenhouse gases (MGHGE) emanating from producing vegetables and fruit is estimated by multiplying the annual produced mass (APM) of an item by its carbon footprint (CFP). i.e.:

$$\mathbf{MGHGE = APM \times CFP} \quad \text{.....(1)}$$

Statistics of cultivated land and main crops are procured from the Department of Statistics (Department of Statistics, 2019). The main crops cultivated in Jordan in 2019 were mainly Fruit Trees, Vegetables, and Field Crops. A large portion of the cultivated areas depend on irrigation, which relies intensively on groundwater resources. Areas planted by field crops formed about 49% of the total cultivated area in 2019 followed by fruit trees and vegetables which make up about 36% and 15% of the total cultivated areas in Jordan, respectively.

4. Results and Discussion

4.1 National GHGs Associated with Vegetables and Fruits

Agriculture is an important contributor of carbon dioxide, methane, and nitrous oxide with meat and fisheries being the top producer of greenhouse gases. The total greenhouse gas (GHG) emissions caused directly and indirectly by a kilogram of a food item is termed the "carbon footprint" of that food (Werner et al., 2014). The highest carbon footprints are produced by meat, cheese, and eggs. Fruits, vegetables, beans, and nuts have significantly smaller carbon footprints (Clune et al., 2017). To calculate the national emissions of GHGs associated with the production of vegetables and fruit in Jordan in 2019 due to cultivation, transportation, and food loss we have employed formula (1). The attained quantities are summarized in Table 1.

Jordanians consume various types of vegetables and fruits, but they rely mainly on citrus fruit, dates, olives, wheat (bread), lentils, chick-peas, potatoes, tomatoes, squash, eggplants, cucumbers, cabbages, cauliflower, sweet (bell) peppers, and onion. Other items such as parsley, lettuce, and strawberry, are less common in Jordanians' diet, therefore they don't contribute significantly to the national inventory of greenhouse gases.

Table 1. Greenhouse gas associated with vegetables and fruit production in Jordan in 2019 due to cultivation, transportation, and food loss and waste.

Crop	Annual Production (Ton)	CO2 Footprint (kg/kg) (Werner et al., 2014)			GHG Generated/ CO2 Equivalent (Kiloton)		
		Cultivation	Transportation	Waste	Cultivation	Transportation	Waste
Citrus Fruit	123942	0.70	1.05	0.18	86.8	130.1	21.7
Dates	23375	0.44	0.66	0.11	10.3	15.4	2.6
Olives	214994	0.28	0.42	0.07	60.2	90.3	15.0
Wheat	26361	0.25	0.38	0.06	6.6	9.9	1.6
Maize (Green)	20936	0.28	0.42	0.07	5.9	8.8	1.5
Sorghum	279	0.28	0.42	0.07	0.1	0.1	0.0
Barley	66618	0.30	0.45	0.08	20.0	30.0	5.0
Lentils	153	0.90	1.35	0.23	0.1	0.2	0.0
Chick-peas	4232	0.64	0.96	0.16	2.7	4.1	0.7
Clover trefoil	111610	0.15	0.23	0.04	16.7	25.1	4.2
Potatoes	173653	0.34	0.51	0.09	59.0	88.6	14.8
Tomatoes	601370	0.33	0.50	0.08	198.5	297.7	49.6
Squash	53043	0.36	0.54	0.09	19.1	28.6	4.8
Eggplants	55630	0.51	0.77	0.13	28.4	42.6	7.1
Cucumbers	186317	0.51	0.77	0.13	95.0	142.5	23.8
Cabbages	35074	0.29	0.44	0.07	10.2	15.3	2.5
Cauliflower	46799	0.31	0.47	0.08	14.5	21.8	3.6
Sweet peppers	55771	0.29	0.44	0.07	16.2	24.3	4.0
Onion, dry	54500	0.60	0.90	0.15	32.7	49.1	8.2
Total					683	1024	171

4.2 Emissions of GHGs Associated with Rice Import and Consumption

Rice is not cultivated locally, it is rather imported from remote sources including Egypt, the USA, Pakistan, India, and other South Asian states, which implies that a large portion of its carbon footprint is attributed to transportation. Rice has gradually become a main constituent of Jordanians' daily meals and it's an important ingredient of the national dish (Mansaf) that is cooked and served in social gatherings and celebrations including wedding and funeral banquets. The carbon footprint of rice is reported by Werner et al. (2014) to be 3.74 kg per kilogram of rice. When multiplying this value by the Jordanians' rice consumption in 2017 (194 kt), the answer is 726 kilotons of CO2 equivalent, which is about 39% of the total emissions from vegetables and fruits that appear in Table 1. This finding places an important and ethical responsibility on governmental authorities, community leaders, religious preachers, and social activists to work toward changing the habits of offering vast rice quantities in wedding and funeral banquets that end up being dumped in domestic landfills for more production of methane and other greenhouse gases.

4.3 Emissions of GHGs Associated with Animal-Derived Food

Jordan enjoys mild weather throughout the year with a small annual and diurnal temperature means, which offers excellent conditions for growing chicken and other poultry species. This encouraged the investment in growing chicken for their meat and eggs, which then became the main source of protein for most Jordanians. however, beef and lamb meat markets depend mainly on imported rather than growing local livestock because of the low precipitation that is required to support and maintain natural grazing thereby forcing livestock owners to rely on expensive fodder to feed their animals, which puts extra cost on local meat production. Seafood is relatively new to Jordanians' diet due to a lack of local sources. Historically, total fish consumption in Jordan reached an all-time high of 47.8 kt in 2013 and an all-time low of 1.07 kt in 1961 (FAOSTAT, 2022).

Jordanians' consumption of meat, milk, eggs, and vegetable oil reported by FAOSTAT are available up to the year 2013. Therefore, we assumed that the 2013 per capita of these products remained the same until the year 2019 (the same year for vegetables and fruits reported by the Department of Statistics). This assumption is 90% valid as can be seen from the time series plots for these food items illustrated on the FAOSTAT webpage. This implies that the calculated carbon dioxide equivalent of GHGs generated from animal products and vegetable oil presented in this paper (Table 2) is about 80%-90% accurate.

Table 2. Carbon Dioxide Equivalent of Greenhouse Gases Emanated from Meat products and vegetable oil.

Meat	2013 Total Meat Consumption (kt) (FAOSTAT, 2022)	2013 Per Capita Meat Consumption (kg)	Estimated 2019 Total Meat Consumption (kt)	CO2 Footprint (kg) (Werner et al., 2014)	2019 CO2 Equivalent (kt)
Poultry	239	28.1	284.0	6.9	1959.5
Beef	52.9	6.2	62.9	68.8	4324.6
Lamb And Goat	39.1	4.6	46.5	39.2	1821.2
Fish	47.8	5.6	56.8	5.4	306.7
Eggs	49.1	5.8	58.3	4.9	285.9
Milk	280.4	33.0	333.2	1.9	633.0
Veg. Oil	151	17.8	179.4	3.2	574.2
Total					9905.1

4.4 Reducing Greenhouse Gases Emanated from Food Systems

Table 3 summarizes the findings of the previous sections. As can be readily learned from the table, it is evident that the food systems in Jordan generated more than more than 12.5 million tons. The 12.5 million ton makes up about 47% of the total Jordanian greenhouse gases emanated nationwide which is 26.5 million kt of carbon dioxide equivalent (World Data Atlas, 2022). There was a lot of carbon dioxide equivalent released by the food systems, but it's important to remember that people need food to survive.

Table 3. Summary of CO2 equivalent associated with producing, importing, consuming, and wasting food in Jordan in 2019.

Food	2019 CO2 Equivalent (kt)
Meat	8105
Fish	307
Eggs	286
Milk	633
Veg. Oil	574
Vegetables and Fruits	1878
Rice	726
Total	12509

The quantity of greenhouse gas emissions brought on by the production of food that is never consumed is harder to comprehend. Some food that Jordanians produce, or import is wasted by shops, eateries, and customers, or it spoils or spills throughout the supply chain. Therefore, local authorities and stockholders are invited to work toward minimizing food losses and waste to prevent producing unnecessary greenhouse gases. The Paris Agreement mandates signatory nations to update or resubmit their Nationally Determined Contributions plans (NDCs) every five years. Therefore, Jordanian authorities and legislators should seize this opportunity to adopt more ambitious initiatives and measures to reduce greenhouse gas emissions from food systems by reducing food losses and waste, improving food transport and distribution methods, and controlling methane emissions from livestock whether imported or raised locally.

Fruit and vegetable waste (FVW) are produced in enormous amounts in markets and are an annoyance in municipal landfills. When dumped in domestic landfills, anaerobic microbes decompose food and other organic waste into biogas, composed mainly of methane and carbon dioxide. A field survey on Ma'an found that a large constituent of

domestic solid waste in this southern Jordanian governorate is food remains and organics (Jaradant and Al-Khashman, 2013), making it a major source of methane, the potent greenhouse gas (Tavakoli, 2017). The municipality of Irbid thought of turning the FVW into compost to prevent methane production and provide local farmers with chemical-free fertilizers and soil conditioners. Adopting similar initiatives and practices by other municipalities throughout Jordan is vital to reducing national emissions of greenhouse gases from wasted fruit and vegetables.

5. Summary and Conclusions

Food systems involve major sources of carbon dioxide, nitrous oxide, and methane including agricultural practices, food packaging, and refrigeration, hauling of food products from sources to end users, and disposing of food losses and waste. This implies that any plan that aims to cut emissions of greenhouse gases shall control emissions from food systems locally, regionally, and globally. This necessitates national quantification of greenhouse gasses emanating from food systems to plan carbon cuts accordingly.

This paper presents the main estimates of the food system's contribution to the national budget of greenhouse gases. Main vegetables and fruit produced in Jordan include Citrus Fruit, Dates, Olives, Wheat (Bread), Lentils, Chick-Peas, Potatoes, Tomatoes, Squash, Eggplants, Cucumbers, Cabbages, Cauliflower, Sweet (Bell) Peppers, and Onion. Transportation and distribution of food products, including air and sea shipping of meat products are the main emitters of greenhouse gases, therefore national initiatives to reduce the contribution of food systems to national emission inventory of greenhouse gases have to adopt restrictive regulations and innovative practices to reduce food imports. Reducing the total distances traveled by trucks that transport vegetables and fruit from producers to consumers could significantly cut GHGs emissions from food transport. Food losses and waste are among the unnecessary components that contribute a large portion of the national greenhouse gases. Rice is particularly important in this aspect because rice paddies are the main sources of methane production. In addition, all rice consumed or wasted in Jordan is imported from remote sources, thus generating tons of transport-emitted carbon dioxide. Therefore, Jordanian authorities and community activists are invited to advocate food conservation and minimize food waste in large gatherings such as wedding feasts and other celebrations. Healthier vegetarian diets are among the good food habits that would help Jordanians reduce the food system's contribution to the national emission inventory of greenhouse gases.

The paper offers several actions that can be nationally adopted to cut off greenhouse gases emanating from food systems. The actions include reducing land-use change and conversion of natural habitats, reducing food loss and waste, improving food transport and distribution means, reducing methane emissions from livestock, and shifting to healthier and more sustainable diets with a higher proportion of plant-based than animal-based foods.

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