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Carbon Footprint of Wheat and Maize: A Greek Case Study

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RESEARCH ARTICLE

Abstract
Wheat and maize are two of the most dominant crops of considerable importance in human nutrition. At the same time, agriculture is responsible for about 1/3 of anthropogenic greenhouse gas emissions. The aim of this study is to estimate the carbon footprint of the two aforementioned important crops in the region of Larissa, Greece. Under this context, the emitted CO_{2eq}- per kg of product, the corresponding emissions per hectare and per g of harvested plant protein were estimated. The carbon footprint was measured using the CoolFarm Tool (Cool Farm Alliance). Data were collected through questionnaires and interviews with local farmers. According to the results, the carbon footprint per hectare in maize (2,979 kg CO_{2eq}^{-} ha^{-1}) is significantly higher compared to wheat (1,090 kg CO_{2eq}^{-} ha^{-1}). In contrast, the differences in the footprints per kilogram of product and per g of harvested protein were insignificant. Tillage was found to be the main factor increasing CO_{2eq}- emissions in both crops. In this research work we demonstrated that tillage regimes are crucial for mitigating agricultural related GHG emissions.

Keywords: carbon footprint; maize; wheat

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INTRODUCTION

The ever - rising global population leads to a notable increase in food demand. Cereals are inseparable part of human nutrition. Amongst the different cultivated cereals around the world, wheat and maize are two of the most prominent ones (Acevedo et al., 2020). Indicatively nearly half of the global plant – based caloric intake, and nearly 70 % of the respective plant – based protein intake derive from wheat, maize and rice (Erenstein et al., 2022). The need to increase cereal production could lead to a corresponding increase in agriculture - related Green House Gases emissions. However, this raise concerns as agriculture has been estimated to produce nearly 1/3 of the anthropogenic GHG emissions (Jaiswal & Agrawal, 2020). As a result, several researchers and policy makers worldwide, are focusing on optimizing agricultural practices in order to reduce the carbon footprint of staple crops (World Bank, 2023). Essentially, an urgent need has arisen for the adoption of sustainable agricultural management practices to mitigate the environmental footprint of agriculture. The objective of the present study was to estimate the carbon footprint of two major crops (wheat and maize) in the area of Larisa, Greece. Besides the emitted CO_{2eq}^{-} per kg of product, the respective emissions per ha and per g of harvested plant protein were also estimated.

MATERIALS AND METHODS

The estimation of the carbon footprint was carried out via the utilization of the Cool Farm Tool (CoolFarm Alliance). Data were collected by questionaries. The questionnaires were distributed and completed by ten (10) wheat and ten (10) maize farmers. The questionnaires were organized in five different input stages (Groups). In particular, the five Groups were:

- **Group 1** contained information regarding the cultivation area and the yields. Data on crop residues management were also collected in Group 1.
- **Group 2** regarded soil characteristics such as soil texture (clay, silty, sandy, etc.), soil organic matter, soil moisture.
- **Group 3** included fertilization and pesticides inputs. Information regarding these inputs included the type of fertilizer used, its application dose. For the plant protection inputs, farmers provided information regarding the dose and the method of the pesticide application. The direct energy use, i.e., the type and the amount of fuel (liters) used throughout the cropping season was provided in Group 4.
- **Group 4** Fuel consumption was estimated separately for different agricultural machineries (plowing, harrowing, sowing, harvesting, etc.).
- **Group 5** included water use, i.e. how many irrigations per season, water source and irrigation method. In the present research, Group 5 was completed only by maize producers.

The experimental data were subjected to statistical analysis according to the split-plot design. The statistical analysis was performed with SigmaPlot 12 statistical software (Systat Software Inc., San Jose, CA, USA). The differences between means were compared using Tukey's test. All comparisons were made at the 5% level of significance.

RESULTS AND DISCUSSIONS

Regarding the environmental footprint of these crops, maize had three times the environmental footprint per hectare (Figure 1). However, this difference does not translate at national level due to the difference in cultivated acreage. Case in point, in 2020, about 115,000 ha of maize and 355,000 ha of wheat were harvested in Greece, therefore their difference was negligible (FAOSTAT, 2023). Similarly, the difference in emissions per kg of product and per gram of plant protein was insignificant. However, the total emissions from these two crops are noteworthy as in 2020 they amounted to about 700,000 tonnes CO_{2eq^-} (FAOSTAT, 2023).

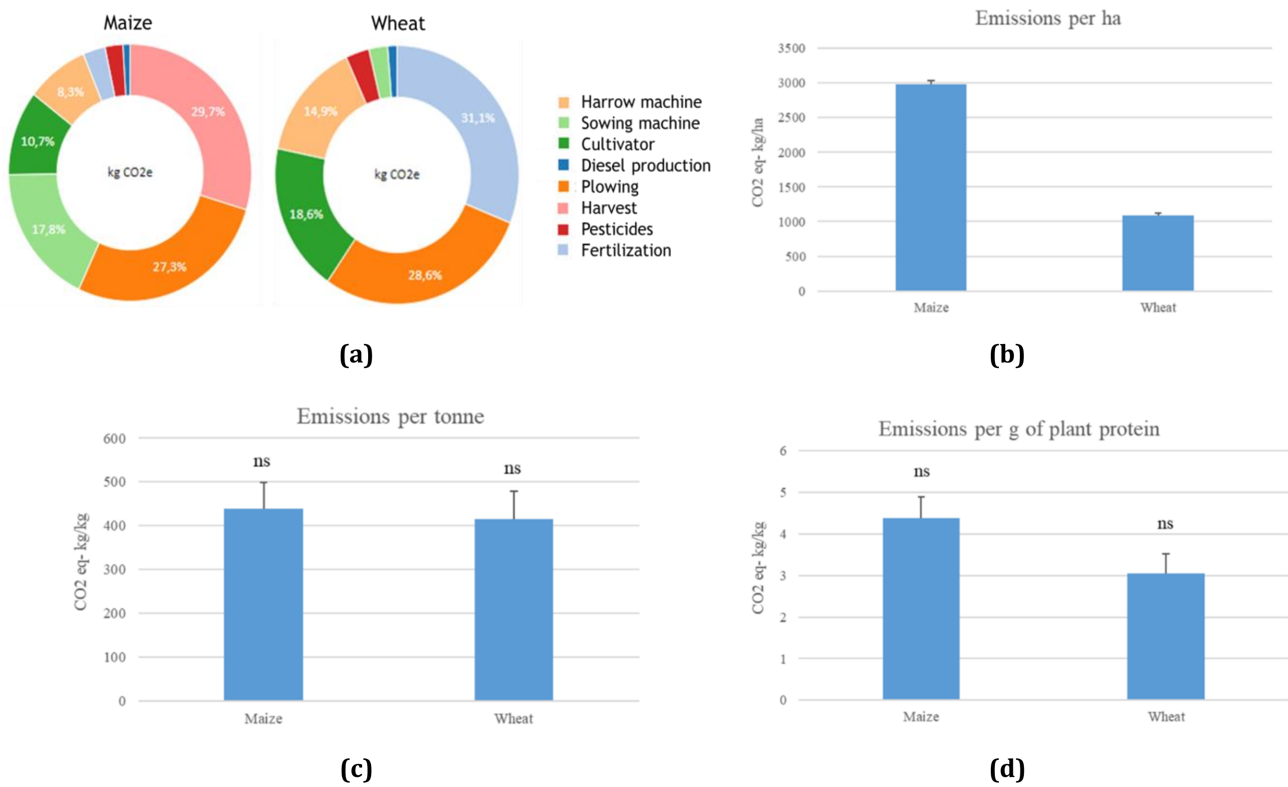

Figure 1. (a) CO_{2eq-} emissions (%) per source; (b)CO_{2eq-} emissions (kg) per hectare; (c) CO_{2eq-} emissions (kg) per ton of product; (d) CO_{2eq-} emissions (kg) per g of plant protein.

According to our results, the use of machinery and the application of fertilization are the two main factors that elevate the GHGs emissions in wheat and maize (Figure 1). This finding is in accordance with the available literature

(Chataut et al., 2023). In a study by Chataut et al. (2023), the authors concluded that the adoption of optimized tillage, fertilization, and irrigation regimes can significantly reduce CO_{2eq}- emissions. Holka and Bieńkowski (2020) estimated that in maize no-till systems can reduce GHGs emissions per ha by 20%. Similarly, Kumar et al. (2021) observed that increasing N fertilization rates in maize can elevate the CO_2 emissions per hectare in maize by more than 3 times-fold. In wheat, proper nutrient management and fertilization, as well as no-till production can reduce the emissions by more than 20% (Syp et al., 2015; Pu et al., 2022).

Achieving and maintaining food security requires food stability, a term that is intertwined with agricultural sustainability (Mavroeidis et al., 2022). Sustainability presupposes the reduction of GHGs emissions (ESDN, 2020). Assuming that the European Green Deal's emissions target is adopted vertically across all member states, the total CO_{2eq}- values of these two crops (based on 1990 acreage data and the indicative values of this study) should be reduced from 1,624,000 tons to 730,800 (FAOSTAT, 2023) by 2030. Therefore, the findings of the present study are encouraging yet further GHGs reduction is needed. Crop rotations, the adoption of conservation till, the reduction of pesticide use and synthetic fertilizer applications could significantly reduce the emissions in both wheat and maize (Chataut et al., 2023).

CONCLUSIONS

According to the findings of the present research, the average carbon footprint per hectare for maize is significantly higher from that of wheat. Emissions per hectare in the case of maize were almost three times higher than those of wheat. However, no statistically significant differences were observed between the two crops when calculating the carbon footprint per tonne of product. The activities that greatly increase the carbon footprint in maize cultivation are tillage, while in wheat cultivation it is tillage and fertilization. Tillage or reduced tillage seem to be strategies that would reduce the respective carbon footprint.

Author Contributions: I.K. and D.B. Conceived and designed the analysis; A.M and P.S. Collected the data; I.R. Contributed data or analysis tools; A.T. Performed the analysis; A.T. and D.B. Wrote the paper.

Conflicts of Interest

The authors declare that they do not have any conflict of interest.

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