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Carbon Footprint of Agricultural Production in Sudan

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Abstract

The increasing threat of climate change resulting from increased atmospheric carbon dioxide emissions has prompted a renewed global endeavor to counteract its detrimental impacts. This study addresses the detrimental effects of climate change and carbon dioxide emissions on Sudan's agricultural production. It is important to evaluate the effects of the environmental changes on Sudan's food security. Agricultural practices, including tillage, composting, irrigation, crop cultivation, animal husbandry, and equipment usage, emit large amounts of greenhouse gases, which have been linked to climate change, according to several studies. Moreover, energy input from fossil fuels, electricity, machinery, and livestock management accounts for a significant amount of agriculture's carbon emissions. Furthermore, there is a significant rise in carbon emissions owing to changes in land use, such as the burning of crop waste after harvest, deforestation, and the conversion of natural ecosystems to agricultural purposes. Based on these findings, we recommend Sudan promote and support the use of renewable energy sources in conjunction with agricultural practices that have the potential to reduce carbon emissions. Additionally, more investigations and studies on the relationship between Sudan's agricultural output and its carbon footprint in various locations are required.

Keywords: Agricultural Production, Carbon Footprint, Sudan

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INTRODUCTION

Climate change, the biggest challenge of the present era, is mostly caused by unbridled population expansion that is getting closer to an irreversible threshold and an unprecedented increase in the exploitation of natural resources. As greenhouse gas (GHG) emissions and population expansion accelerate, Earth's surface temperatures are predicted to rise by 1.6 to 5.8 °C by the end of the century (Prasad et al., 2017). It has been determined that human activity in natural agro-ecosystems is 95% likely to be the cause of the widespread climatic change that has been seen since the late 1800s. Consequently, reducing these greenhouse gas emissions into the environment is a significant effort that might be accomplished by having a thorough understanding of how human activity affects the carbon footprint (CF) (Ozlu et al., 2022). It is important to reduce GHG emissions in order to minimize the consequences of climate change. This may be achieved by having a thorough grasp of the CF phenomenon.

According to Gao et al. (2013), a "carbon footprint" is defined as "a measurement of the total GHG emissions caused directly or indirectly by an individual, an organization, or even a product, and is expressed as a carbon dioxide equivalent (CO_2eq)." The term has become extremely common and is now a worldwide concept. Thus, CF is the weight of carbon per person or activity expressed in kilograms or milligrams. Estimates of CF have been calculated using a variety of techniques, from straightforward web applications to intricate models, life-cycle analysis, and input-output-based systems (Gao et al., 2013). Therefore, using CF estimates to direct emission reductions and assess the danger of global warming may prove to be an effective strategy.

Due to population growth, there has been a rise in greenhouse gas emissions from the agriculture sector as food demand has increased. Increasing world population, changing climate conditions and economic activities are growing with each passing day makes it more important than water (Bağdatlı and Bellitürk, 2016b). There are changes in the water surface in the world due to global warming. This is the effect of evaporation in water resources and irregularity in the current precipitation regime due to climate change (Albut et al., 2018). Increasing or decreasing changes in climatic values affect living things negatively and cause a decrease in productivity, especially in agricultural production (İstanbulluoğlu et al., 2013).

The requirement for the industry to create a higher-quality and adequate food supply to provide for the growing worldwide population is one of the most significant challenges facing the global food and agriculture sector. At the same time, the general public, as well as governmental and non-governmental groups, closely monitor the primary environmental conditions within agricultural production and animal husbandry (Notarnicola et al., 2017). Agriculture-related operations, including tilling, plowing, manuring, irrigation, growing a range of crops, raising animals, and operating associated equipment, release a substantial quantity of GHGs, which are divided into three CF tiers and kept apart by fictitious borders. Energy input from fossil fuels, electricity, machinery, and livestock management accounts for a significant amount of agriculture's carbon emissions. In addition, changes in land use such as the conversion of natural ecosystems to agricultural uses, deforestation, and burning of crop residues after harvest all greatly increase carbon emissions (Ozlu et al., 2022).

Sudan possesses abundant natural and human resources. Despite having a plenty of natural resources, the nation is categorized as least developed, low-income, and food-deficient. In 2013, the population of Sudan was estimated to be 36.2 million. About 80% of the workforce is employed in agriculture, which is the primary economic sector and accounts for 27% of the GDP. Sorghum, millet, wheat, maize, rice, sesame, groundnuts, sunflowers, cotton, and tomatoes are among the primary agricultural resources. Irrigated agricultural schemes and rain-fed farming are the two primary crop methods. The main agricultural products exported are cattle, cotton, sesame, and Arabic gum. Wheat is farmed for home consumption, while grain sorghum serves as the main food crop (Hussein et al., 2022). Rainfall is the primary factor in Sudanese agriculture and commerce; poor rainfall is a sign of climate change, which is predicted to have a detrimental impact on the nation's agricultural output and trade. The main goal of this review is to examine the carbon footprint of agricultural production in Sudan. Potential steps to reduce greenhouse gas emissions from Sudan's agriculture sector will be discussed, as well as measures that may help reduce greenhouse gas emissions from the agricultural sector in Sudan.

The main characteristics of agriculture in Sudan:

Agriculture in Sudan is organized into two primary farming systems. The major system is rainfed (both automated and traditional), accounting for more than 90% of all farmed land (21.2 million hectares in 2018), while the secondary system is irrigated. The sector is further split into three primary subsectors: crops, livestock, and forestry/fisheries, which contributed 39, 60, and 1% of agricultural GDP, respectively, in 2015/16 (Hussein et al., 2022). The Sudan's land cover atlas divides the country's entire land area (188 million hectares) into 83 separate classes, which are then aggregated into seven major classes (FAO, 2012). Agricultural is mostly done on territory classified as 'agricultural in terrestrial and aquatic/regularly flooded land', which covers 23.7 million hectares and accounts for 12.6% of the country's land area. The bulk of this land cover type is found in the rainfed states of Northern Kordofan (20%), El Gadarif (15%), Southern Darfur (9%), White Nile (9%), and Southern Kordofan (8%) (Siddig et al., 2020). the rain-fed mechanized, traditional rain-fed, irrigated, and livestock sectors comprise Sudan's primary agricultural industries. Out of the approximately 84 million hectares that may be arable, around 2 million hectares are used for irrigated agriculture. Government projects accounted for around 93% of the irrigated land; private owners owned the remaining 7%. About 6 million hectares are covered by the rain-fed mechanized system in the states of Southern Kordofan, Blue Nile, Upper Nile, Sinnar, and Gedaref. Mechanized farms often span more than 420 hectares. In this industry, land preparation, sowing, and the majority of threshing are carried out by machines; nevertheless, seasonal laborers perform manual weeding, harvesting, and part of the threshing on these farms (Elsheikh et al., 2022a).

Prior to separation, Sudan had an estimated 86 million hectares of cultivable arable land. Post-secession, that figure has been reduced by at least 35%. However, less than 20% is used for three primary farming sub-sectors: irrigated, semi-mechanized rainfed, and agro-pastoral traditional rainfed. The agricultural sector plays a significant role in ensuring food security by improving food production and creating job opportunities in rural areas. The irrigated subsector in this sector was projected to be one million hectares. Its key schemes are Gezira, Rahad, New Halfa, and Suki. The sub-sector accounts for an average of 21% of the overall agricultural output value, including 100% of wheat and 25% of sorghum produced in the country. It contributes less to sorghum production than the rain-fed sub-sector, but it is more stable. During droughts, it is critical to satisfy consumption requirements. The Semi-Mechanized Rainfed Sector: This sector was encouraged in the mid-1940s in the Gadarif area and is located in Blue Nile, Sennar, Kosti, Renk, and Dilling, with an area of roughly 6 million hectares. The two primary crops produced by this sector are sorghum and sesame (Figure 1). This sector is constrained by a variety of challenges, including low yields, high production costs, a lack of formal finance, and inadequate infrastructure. This is in addition to the lack of machinery services for small farmers, limited access to marketing services, and questionable land title, with the traditional rain-fed sector dominating (Mohamed, 2010). Of the four main crops grown, sorghum, sesame, and groundnut yields are typically highest in the areas of the Blue and White Niles. The Darfur area is the primary location for millet cultivation, and there the production is at its maximum. Although Kordofan is the location where sesame is mostly farmed, crop yields are quite poor there. Additionally, the lowest peanut and sorghum yields are seen in Kordofan.

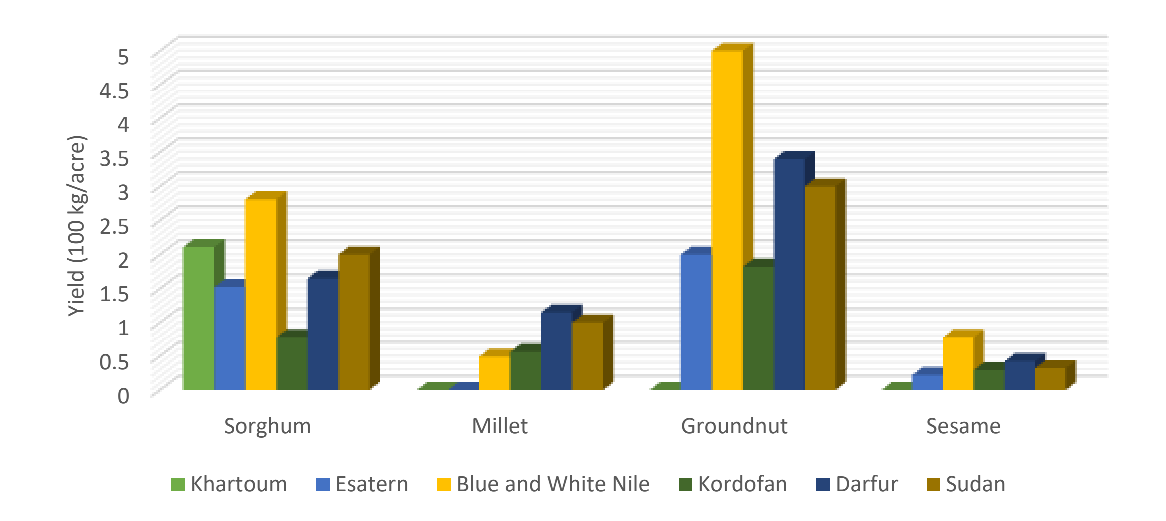

Figure 1. Yield of the Four Major Cultivated Crops in Sudan (in Relevant Growing Regions), 2014/15 (Ali et al., 2020).

States that produce more sorghum also often have lower rates of poverty; however, the opposite is true for millet. The reason for the positive trend observed in sorghum and the negative trend shown in millet is because sorghum is cultivated more widely than millet, which is mostly farmed in Kordofan and Darfur. Sesame, groundnuts, and sorghum produce more when planted on irrigated soil out of the four major crops farmed in Sudan. Significant productivity increases for the next three crops result in yield increases of about 50% (Ali et al., 2020). In Sudan, summer is the primary wet season, lasting from May to October. The amount of precipitation varies depending on the region, with the extreme north receiving less than 50 mm and the extreme south receiving more than 600 mm autumn is typified by notable fluctuations in its distribution, timing, and location. Previous research demonstrated how the economics and prosperity of the nations that make up the Greater Horn of Africa and their citizens are being undermined by climate change (Nasreldin & Elsheikh, 2022). Over the past four decades, there has been a nationwide decline in summer rainfall of 15 to 20 percent, accompanied by an increase in temperatures. The average maximum temperature in central and eastern Sudan rose to 38 C, with notable increases being seen in the minimum and maximum temperatures of winter and autumn (Hussein et al., 2022).

Carbon Footprint of Agricultural Production in Sudan:

Climate change is referred to as changes in the weather and atmospheric air that last for millennia, which can occur naturally or as a result of human activity. These climate changes might have a detrimental impact on agricultural productivity (Elsheikh et al., 2022b; Bağdatlı and Arıkan, 2020). According to Bağdatlı and Can (2019), global climate change has had a negative influence on the atmosphere by increasing carbon dioxide levels. Global warming causes climate change by emitting industrial gases like methane, nitrogen oxides, carbon dioxide, and ozone into the atmosphere, increasing global temperatures (Bağdatlı and Belliturk, 2016a; Bağdatlı and Arslan, 2020; Bağdatlı and Can, 2020).

The agricultural sector has presently advocated for the use of biological or biodynamic growth methods rather than chemical sources containing organic active components. Using chemical fertilizers in agriculture has been demonstrated to increase GHG emissions, notably N_2O, thereby adding to the exacerbated climate change difficulties. Furthermore, agricultural activities need a substantial quantity of energy owing to equipment procedures. As a result, increasing energy efficiency and minimizing CF associated with agricultural production are critical requirements. GHG emissions are from soils and originated from biological processes that are susceptible to soil conditions (Ozlu et al., 2018).

Studying the mechanisms in the complex and dynamic soil system, as well as their intercorrelation with climate change challenges, is vital given the critical direct and indirect effective components in agricultural GHG emissions (Ozlu et al., 2022). Food production is a major concern that might be affected by climatic fluctuations (Bağdatlı et al., 2023; Elsheikh et al., 2023). For example, rising sea levels due to climate change can devastate forests, which are essential sources of food in many locations (Afreen et al., 2022). Precipitation and rainfall provide water for many activities such as survival, agriculture, migration, and urbanization (Bağdatlı and Arslan, 2019; Bağdatlı and Ballı, 2020). Land degradation is a significant cause of climate change due to GHG emissions and lower rates of carbon absorption in soil (Tione et al., 2022). Due to their direct effects on soil and terrestrial biota, land degradation processes have a significant impact on the exchange of CO2 with the atmosphere (Ackerl et al., 2023). Illegal logging, poor forest management, and the conversion of primary land to unmanaged forests all contributed to greenhouse gas emissions and would have further impacts on the local climate, such as changes in albedo (Kim et al., 2021).

According to reports (Praveen and Sharma 2019; Tongwane and Moeletsi 2018) on greenhouse gas emissions in a few selected Sub-Saharan Africa (SSA) countries, emissions of greenhouse gases other than CO_2 from the production of food crops have increased from the 5.82 Gt CO_2eq/yr trend in 2018 to an estimated 6.95 Gt CO_2eq/yr by 2030. Crop production activities have expanded and will continue to raise the concentration of anthropogenic GHG emissions in SSA due to the centrality of food in human life (Ackerl et al., 2023). Agriculture has a variety of detrimental effects on the environment in addition to contributing to different anthropogenic greenhouse gas emissions in SSA (Borrelli et al. 2020). Fertilizers high in nitrogen have the potential to contaminate water bodies and endanger aquatic ecosystems by way of surface runoff. Similarly, a loss of biodiversity would result from the use of pesticides, herbicides, and excessive tillage (Outhwaite et al. 2022). However, ongoing soil exploitation from agricultural farming may result in erosion and compaction, rendering the land unusable for future generations and eventually impacting local climate change (Borrelli et al. 2020).

Moreover, Crippa et al. (2021) reported that the latter phases of urban agricultural food production, such as propagation, processing, consumption, disposal, digestion, and water reuse, also contribute to the detrimental environmental effects of GHGs on climate. This makes for around half of the total GHG emissions in SSA that are linked to the food industry (Tongwane and Moeletsi 2018). Approximately 30% of the overall carbon footprint of SSA cities is thought to be attributed to food production through community farms and family gardens (Ebhota and Tabakov 2021).

Deforestation (for fuel wood and agricultural expansion) is the primary cause of climate change in Ethiopia, Sudan, Chad, and Niger, according to Abbass et al. (2022) and Tongwane and Moeletsi (2018). Similarly, by continuously upsetting the topsoil, heavy tillage is a customary land-use strategy in Mali, Guinea, and Mauritania that greatly contributes to climate change (Tongwane and Moeletsi 2018). By causing soil erosion and the breakdown of organic matter in the soil, these activities raise emissions of CO_2 and CH_4 (Ngarava et al., 2023). Consequently, the concentration of greenhouse gases in the atmosphere has been impacted by forestry and woodland management, leading to climate change (Robinson 2020).

Sudan has been classified as being at danger from the effects of climate change on agriculture. The diminishing agricultural productivity in Sudan is concerning and a significant problem. Sudan's economic performance, particularly in agriculture, is heavily influenced by weather conditions, with rainfall being the most important climatic variable. Summer rainfall patterns across the country have decreased by 15 to 20% over the previous 40 years, but temperatures have risen. The model scenario simulations demonstrated that the impact of the falling rainfall and increasing temperature trend will result in significant losses to market supply, deteriorating the country's external sector and foodsecurity status. (Hussein et al., 2022).

Mohamed (2020) evaluated the impact of energy consumption, economic expansion, and agricultural growth on Sudan's emissions of nitrous oxide (N_2O) and methane (CH_4). In terms of economic growth, agricultural expansion, and energy consumption, the study has demonstrated a long-term equilibrium connection for both CH_4 and N_2O. The findings imply that agricultural operations have produced more emissions of CH_4 and N_2O than overall economic activity, and that an important contribution to economic expansion has come from activities producing N_2O emissions specifically (Mohamed, 2020). According to the most recent available emissions statistics, Sudan was responsible for 0.24% of the world's greenhouse gas emissions in 2020. This translated into 107 million metric tons of CO2 equivalent, or MtCO2e. By -0.1%, these emissions were less than those of 2019. Agriculture is the sector in Sudan that contributes the most emissions. In 2020, this equated to 76.6 million metric tons of CO2 equivalent (Figure 2) (Boyle, 2024). Therefore, in order to promote a low-carbon economy and sustainable growth, Sudan should implement more energy-efficient policies and increase the use of renewable energy sources.

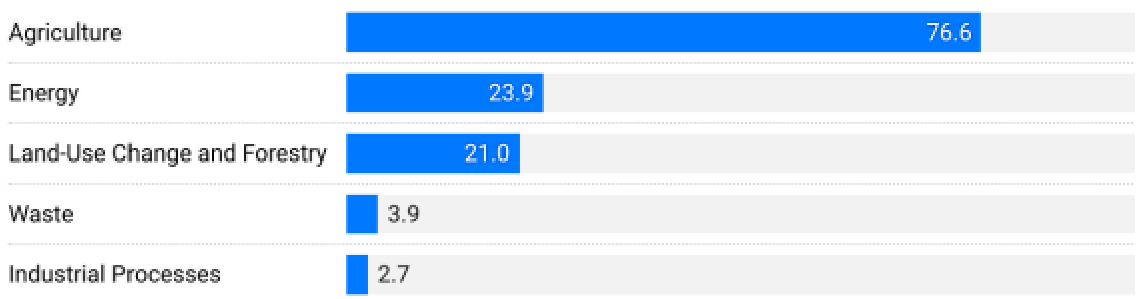

Figure 2. GHG Emissions (million metric tons) by Sector in the Sudan (Boyle, 2024).

Over the previous three decades, Sudan's average annual temperature has risen by more than 1°C and in certain areas, by up to 2°C. The estimated model temperature changes in Sudan areas are somewhat consistent with a 3-4.5°C increase over the next three decades, with the lower (upper) end corresponding to a mitigation (business-as-usual) scenario (Eltahir et al., 2019). Temperature changes alone may have a major impact on agricultural productivity and output. It is widely documented in the literature that most crop yields follow a 'bell curve' as a function of temperature (Hatfield et al., 2011). Sudan's agricultural sector is facing significant challenges. Among these are low crop yield, water scarcity owing to poor maintenance, insufficient and late application of fertilizers and pesticides, diminishing efficiency of farm machinery services, insufficient policy interventions, limited financial resources, and low farm gate pricing. As a result, the agricultural industry requires large-scale, phased investment.

Shortening of the growing season, increased water stress, and an increase in the frequency of disease, pest, and weed outbreaks are some of the ways that climate change is predicted to affect agricultural activities in SSA. The two most extreme environmental effects of climate change on agricultural production systems are thought to be heat and water stress. Furthermore, livestock and the production of food crops such wheat, rice, soybeans, maize, sugar cane, millet, and sorghum are expected to be impacted by the distortions in the carbon cycle (Robinson 2020). Adaptations to climate change heavily rely on lowering agricultural GHG emissions, including carbon dioxide, nitrous oxide, and methane.

Sustainable agricultural practices create positive impacts in combating climate change by reducing carbon footprint. As a result, sustainable agriculture minimizes agricultural carbon footprint through the use of renewable resources and energy efficiency in the agricultural production chain (Unlukal and Erguven, 2024).

CONCLUSION

Due to the growing threat of climate change brought about by rising atmospheric carbon dioxide emissions, there is a reinvigorated worldwide effort underway to mitigate its negative effects. The carbon footprint of agricultural production in Sudan is reviewed in this study, which highlights the substantial effect that agricultural activities have on carbon emissions in Sudan's agricultural sector. We evaluated a variety of greenhouse gases released by the energy used in agriculture, their consequences for climate change, and several ways to adapt to them. We have also looked at knowledge gaps that need to be filled with additional study. Energy input from fossil fuels, electricity, machinery, and livestock is responsible for a significant amount of agriculture's carbon emissions. The development and use of innovative techniques to accommodate Sudan's regional variety while considering climate change adaptation would be necessary for policies aimed at boosting agricultural production. More thorough research is required to control climate change since we have discovered that agriculture negatively affects the consequences of climate change in Sudan.

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