The Carbon Implications of China's Food and Agriculture Industry

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Introduction

As the planet has been called to action in the fight against climate change, curbing carbon dioxide (CO_2) emissions has been identified by the Intergovernmental Panel on Climate Change (IPCC) as a key to future success (IPCC, 2018). Since 2004, China has had the largest national carbon footprint in the world and in 2017 produced 28.3 percent of global CO_2 emissions (China Power, 2018). Emissions have continued to rise as a result of increasing levels of consumption caused by population growth, rapid urbanization and a higher standard of living (Zhang, Liu & Gao, 2014). By 2030, if not sooner, China is aiming to have reached peak carbon production, facing more domestic and international pressure (Dong, Hua & Yu, 2018). In the context of the food and agricultural industry, CO_2 emissions result at all stages of the supply chain, especially as a result of waste, and certain diets are more carbon intensive (Song, Li, Semakula & Zhang, 2015). Waste and loss of food continue to be a growing concern because of their environmental implications, such as emissions, and the implications for food security (Piesse, 2017). Globally, food waste accounts for approximately eight percent of total greenhouse gas emissions (GHGs) and occurs at the highest scale in industrialized Asia (Frischmann, 2018; FAO, 2011). The impact of specific foods is determined by the carbon footprint of different agricultural products, which is calculated using a Life Cycle Assessment (LCA) (FAO, 2011). A product's carbon footprint considers GHGs that result from the production and successive phases and is expressed as a CO_2 equivalent (FAO, 2011). Throughout agricultural production, the release and sequestration of CO_2 is greatly influenced by the methods employed, including inputs, machinery, soil and what is being grown (Zhang, Shen, Zhang, Li & Zhang, 2017; FAO, 2011). Consecutive phases, such as "processing, transportation, preparation [and] waste disposal" are also considered within an LCA and the total CO_2 equivalent of the food being produced (FAO, 2011). China aspires to reduce their emissions associated with the food and agriculture sector by 18 percent as part of their 13th Five Year Plan (2016-2020) (Tong et al., 2016). Public education is also going to play an important role in GHG reduction, helping individuals understand how their habits related to food, particularly consumption and waste, are adding to the problem. The objective of this paper is to facilitate the understanding of the carbon footprint of China's food and agricultural sector and its greatest contributors. This is essential for developing strategies to mitigate China's CO_2 emissions.

Food Carbon Footprint

The food industry in China has experienced rapid growth, producing and consuming more food than anywhere else in the world, which is not surprising considering China is also the most populous country in the world (Lin & Lei, 2015). Economic development and government investment in the food and agricultural industry have driven this growth and also the subsequent emissions intensity (Chen, Cheng & Song, 2018). The carbon footprint of food has to consider all of the inputs required throughout the food lifecycle, such as energy required for production, processing and distribution (FAO, 2011). Correlated with ongoing growth and inputs in the food and agricultural sector, CO_2 levels have experienced an increase from approximately 18.46 million tonnes in 1986, to 39.25 million tonnes in 2010, averaging to a 3.6 percent growth rate each year (Lin & Lei, 2015). The industrialization of the agricultural sector has largely been responsible for the increase in emissions, as indicated through the growth of mechanization and factory processing, both of which require more energy and therefore produce more emissions (Lin & Lei, 2015). Furthermore, some machinery remains inefficient but is highly depended on—some harvesting machinery leaves up to ten percent of crops in the field after crop collection (Piesse, 2017).

The carbon footprint of crops in China have gained more attention as efforts to increase and improve sustainable agriculture are being pursued (Yang et al., 2019). A study of the factors influencing the carbon footprint of rice, wheat and maize was conducted in production regions across the country and considered all carbon release and sequestration throughout the lifecycle (Zhang et al., 2017). Zhang et al. (2017) observed that practices and methods of production varied both across and within the regions being studied, but rice consistently had the highest carbon footprint, followed by wheat and then maize. At the production level, carbon rates were determined as an average of the emissions resulting from nitrogen fertilizer, straw burning, fossil fuel use for mechanization, methane conversion, electricity for irrigation and "upstream production and transport of agricultural inputs" (Zhang et al., 2017, p.3). The factor most contributing to the high carbon footprint of rice was CH_4 conversion, which accounted for 45 percent of paddy field emissions (Zhang et al., 2017). As for wheat, the electricity required for irrigation was the greatest contributor to carbon emissions, totalling 37 percent. Further studies about carbohydrate rich foods indicated that 39 percent of carbon emissions from 17,110 individuals living in Chinese households were produced by rice, wheat, legumes and cereals (Yang et al., 2019). Spatial geography also needs to be considered because when total carbon emissions are compared per capita based on consumption, urban areas produce three to four times more than rural areas, particularly because of food processing (Zhang, Liu & Gao, 2014). Research by Yiu and Campos (2013) determined that an urban community of 10,000 people and 8ha of workable agricultural land could be 40 percent self-sufficient and the waste produced could be used as organic inputs, resulting in net zero waste. Addressing carbon footprint reduction needs to happen at all levels of the food supply chain through sustainable agricultural solutions.

Food Loss and Waste

An analysis of China's urban solid waste observed an increase in waste being produced, with the highest contributor being food waste (Xioa, Bai & Ouyang, 2007). Food loss and waste remain a significant barrier in China's ability to be food self-sufficient because it equates to wasting 24 percent of freshwater, 23 of land used for agriculture and 23 percent of fertilizer throughout the country (Song et al., 2015). The negative impacts of this waste are exacerbated by the fact that availability of water and land have become scarce (Song et al., 2015). Environmentally, waste from the food sector is also associated with increased GHG emissions and therefore contributes to the food-carbon footprint. On its own, food waste is estimated to reach 17 to 18 million tonnes in China annually, and consideration for food loss increases that estimate to 35 million tonnes each year (Piesse, 2017). Waste occurs at all levels of the food supply chain, but is highest during the consumption phase, especially now that the restaurant and catering sector is growing rapidly (Song et al., 2015). Approximately 19 percent of food waste results from this sector, compared to five percent at homes and in canteens, and only two percent during transportation (Piesse, 2017). Also, waste that occurs further down the supply chain has a higher carbon contribution, since the wasted agricultural inputs used in the earlier phases has to be considered (FAO, 2011; Piesse, 2017).

How waste is dealt with also impacts the amount of carbon that is emitted and there needs to be more recycling and reuse options implemented throughout China. The use of landfill and incineration in Beijing to manage waste results in both an increased level of GHG production and higher food-carbon footprints (Xioa, Bai & Ouyang, 2007). Alternatives such as using organic waste as feed, fertilizer or energy, through the processes of sterilization, composting and anaerobic digestion can collectively reduce the food being landfilled or incinerated (Li et al., 2016). This will also help extend the life of landfills, which is important during this time of rapid urbanization and declining access to land. A model of reuse has other environmental benefits too, in addition to economic and social implications. Reducing landfill GHGs and lessening the resource intensity of production will actively reduce food-carbon footprints throughout the country (Li et al., 2016). Lessening food waste and loss can occur through top down approaches, such as government food sorting policies at time of disposal or bottom up approaches like backyard composting. Regardless of the method, carbon reduction at the consumer level will be important in future initiatives as waste during that phase continues to increase.

Household Consumption

Consumption patterns greatly influence food-carbon, especially when the entire lifecycle of a product is considered. Within Hong Kong, 23 percent of household's ecological footprint was attributed to consumption activities related to the food sector (Yiu & Campos, 2013). However, at the household level, food consumption is largely dependent on socio-demographic factors such as income, education level, age and occupation (Luo, Ouyang & Frostick, 2008). A study in Beijing determined that food carbon consumption was mainly driven by the amount of grain consumed, but that age and consumption by men were also factors that created significant differentiation at the household level (Luo, Ouyang & Frostick, 2008). Income was expected to significantly impact carbon footprint but was found only to be true in the context of high-income families consuming food outside the home more frequently than low income families (Luo, Ouyang & Frostick, 2008). Food outside the home has been linked to higher amounts of waste being produced, and consequently higher $C0_2$ emissions. A separate study of Beijing households by Luo et al. (2005) determined that per capita food-carbon consumption experienced a decrease between 1979 and 1999, but a total increase has occurred as a result of population growth. Again, this draws the role of urbanization and growth into question and how feeding such a populous country will impact the carbon associated with the food supply chain.

The growing meat industry is also significantly influencing the agricultural carbon footprint of China's diet (Luo et al., 2005). Meat production, and therefore consumption, requires increasing energy and land amounts to meet demands, resulting in carbon emissions and environmental degradation (Luo, Ouyang & Frostick, 2008). In a study of Chinese households, animal-based foods only made up 15 percent of food consumption based on weight but contributed 34 percent of the total food-carbon footprint (Song et al., 2015). This is largely due to the energy and inputs required previous to the consumption phase along the food supply chain. Although reducing meat consumption is one approach to limiting the carbon footprint, this might only have a small impact if meat is replaced by other carbon-intensive foods (Yang et al., 2019). China's "meatification" has become an area of increasing research, but further understanding about what alternatives exist and their carbon footprint in contrast to meat will be needed to promote sustainable solutions.

Solutions

Education will need to play a large role in the future to help Chinese society understand how food is contributing to carbon emissions and the ways that they can consume more sustainably. Since carbon footprint calculated using the LCA approach considers everything from production to consumption or disposal, each phase and their carbon production need to be considered in the process of implementing solutions. Throughout production, there are many ways that China can continue to optimize practices that result in lower carbon footprint foods. Within the grain sector, the over-application of fertilizers, use of electricity for irrigation and energy for straw burning all negatively impact the LCA used to determine the food-carbon of wheat, maize and rice (Zhang et al., 2017). Additionally, improving harvesting technology or using more labour-intensive approaches that result in thorough crop collection will reduce food loss and therefore GHG emissions (Piesse, 2017). Decreasing energy usage throughout the food supply chain- particularly the industrialized approaches to agriculture, such as urban manufacturing during processing, can positively contribute to less CO_2 emissions associated with the industry (Lin & Lei, 2015).

At the city scale, urban planning and management can be used to create infrastructure that reduces the food-carbon footprint associated with the transportation and storage phase (Si & Scott, 2016). Cities that are highly dependent on imports, which need extensive transportation, will have less capacity to create a sustainable food supply chain, negatively influencing their food-carbon consumption (Yiu & Campos, 2013). In contrast, a balance of production and consumption at the local scale could be used to achieve higher self-sufficiency, leading to reduced food needs and waste through a cyclical approach (Yiu & Campos, 2013). Furthermore, overall food waste reduction is important for eliminating carbon associated with the consumption phase of the food supply chain (Song et al., 2015). More initiatives, such as diversion programs, fees for waste disposal or limitations on quantity of disposal per household could all be used in urban areas to deter throwing food away (Xiao, Bai & Ouyang, 2007). The government has also used campaigning, like Empty Your Plate in 2013 Beijing, ending banquets hosted for government officials and abolishing minimum order fees at restaurants that encourage people to order more but pay less (Piesse, 2017).

Food choices greatly contribute to an individual's carbon footprint in the food and agricultural industry, so increasing consumption of low-carbon foods would have beneficial environmental and health implications (Yang et al., 2019). Currently, rice, flour and wheat flour are three of the foods responsible for the greatest carbon emissions per day, per capita for carbohydrate-rich foods in the Chinese diet (Yang et al., 2019). Overall reduction of these foods or replacing them with foods such as potato and sweet potato have been suggested, although research about options from other food groups should be given further attention in the future (Yang et al., 2019). The recommendations made by Yang et al. (2019), such as optimizing sweet potato within the Chinese diet, are a basis of the weight and nutritional content of the food in contrast to the ration of carbon dioxide they produce. Limiting meat consumption to reduce the industry's land and energy requirements will also lessen the CO_2 that is prevalent in the production, processing, distribution and consumption of animal products. Healthy and environmentally aware diets are interconnected in a way that promotes sustainable food and agriculture within China.

Recommendations

Reducing the carbon footprint of the food system and transitioning to a more sustainable agricultural model will need to be a priority for China to achieve the climate change goals they have agreed to at the international level (Si & Scott, 2016). Understanding how carbon is being produced throughout the industry and each phase in a product's lifecycle is important for implementing effective solutions. Particular focus should be given to the ways the industrialization of agriculture is negatively influencing CO_2 levels, such as through increased fertilizer application and mechanization. Additionally, shortening the food supply chain and creating new innovations to reduce the carbon associated with food processing- especially in urban settings- should continue to be studied and considered in future policy (Zhang, Liu & Gao, 2014).

Awareness about how food, especially those perceived to be household staples, impacts GHG emissions needs to be spread to all locations and demographics of people. More consumer education will also be important for helping individuals understand how they can reduce their food waste and therefore their food-carbon footprint (Song et al., 2015). Food that cannot be consumed should be disposed of through methods like composting or anaerobic digesters, the by-products of which can be used for agricultural inputs such as fertilizer and energy (Frischmann, 2018). Furthermore, knowing how specific foods, like meat and grains that are carbohydrate-rich, can influence carbon footprint will also help determine what sustainable consumption looks like in China's future households. A sustainable approach to China's food and agricultural sector will positively contribute to reducing GHG emissions, specifically the carbon footprint of the industry.

From an academic perspective, future studies about the carbon footprint of China's food industry should strive to standardize the approach used to calculate emissions. The current LCA considers varying factors throughout the literature, which Zhang et al. (2017) acknowledge in their research. Contextually, different components of the production cycle are chosen by researchers, and it was not until 2017 that sequestration of carbon was used in the net carbon footprint calculations of grain (Zhang et al., 2017). Currently, comparing literature that uses the LCA approach to determine food carbon footprints must be done with caution since there is no standardization within the included components.

Conclusion

For China to reduce the carbon emissions produced throughout the food and agricultural sector, solutions related to food carbon footprint, food loss and waste, and household consumption need to be implemented. Realizing how the current standards of production- such as through industrialized approaches- contribute to the carbon footprint of foods is essential for adopting more sustainable practices (Zhang et al., 2017). Addressing all components of the LCA, even though it is inconsistent throughout the literature, is also needed to understand the role of processing and consumption. At the consumption phase, food loss and waste contribute most heavily to carbon production and are further influenced by the method of disposal (Song et al., 2015). Utilizing a cyclical approach, like composting food waste to be used for fertilizer, produces less carbon than landfilling or incineration (Xiao, Bai & Ouyang, 2007). Within

Chinese households, further education is needed to explain the ways carbon footprint is heavily influenced by diet, particularly when large quantities of rice and meat are consumed (Luo, Ouyang & Frostick, 2008; Luo et al., 2005). Furthermore, enabling urban areas to localize production and reduce the quantity of imported foods will have positive environmental and health implications (Yiu & Campos, 2013). In future developments, the food and agricultural sector in China will have to consider the role of education and the policies of the government in supporting a more sustainable system. Achieving an 18 percent reduction in emissions throughout China's food industry, a goal set in the 13th Five Year Plan, will require continued, collaborative efforts that address food carbon footprints, food waste and loss and household consumption habits.

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