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Environmental Impacts of Food and Agricultural Production: A Systematic Review

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Abstract

The systematic review focused on the environmental impacts of expansion of agriculture and food production which has been one of manmade largest impacts on the environment. Expansion of agriculture has transformed natural habitats and is one of the largest pressures for biodiversity: out of the 28,000 species assessed to be threatened with extinction on the International Union for Conservation of Nature (IUCN) Red List, agriculture is listed as the threat for 24,000 of them (85.71%). The exponential increase in population in recent decades has increased the agricultural land conversion practice to meet the demand for foods which has in turn increased the impacts on the environment. The environmental impacts of agriculture vary due to the wide range of agricultural practices employed all around the world. Consequently, the environmental impacts depend on the production practices and the agricultural system used by the farmers. There are two types of indicators of the environmental impacts of agriculture: effect-based and means-based. The environmental impacts of agriculture involve a range of factors from the soil, to the air, water, animal and soil varieties, plants, people, and the food itself. Some

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agricultural related environmental effects include climate change, deforestation, greenhouse gas and CO_2 emissions, genetic engineering, dead zones, irrigation problems, soil degradation, pollutants, and waste. Over 50% of the habitable land worldwide is used for agriculture. If pastures used for grazing are combined with land used to grow the crops for animal feed, livestock accounts for around 77% of global farming land. There are some measures to limit the negative impacts of agriculture and food production on the environment. Conservation tillage is an alternative method of tillage for farming that is more sustainable for soil and surrounding ecosystem. Sustainable agriculture employs the idea that agriculture should take place in a way such that we will continue to produce what is required without infringing on the capacity for future generations to do same.

Key words: Environment, Agriculture and Food Production, Environmental Impacts of Agriculture and Food Production, Pollution

1. INTRODUCTION

The environmental impacts of agriculture and food production are the effects different farming and food production practices have on the ecosystems, and how those effects can be directly or indirectly traced back to those practices. The environmental impacts of agriculture and food production vary based on the wide range of food and agricultural practices employed around the world. The environmental impacts depend on the production practices used by farmers. The connection between the farming system and emissions into the environment is indirect, as it also relies on other climate variables such as temperature and rainfall.

Two types of indicators of environmental impact include "effect-based", which is the impact farming methods have on emissions to the environment or on the farming system, and "means-based", which is based on the production methods of the farmer. A typical example of a means-based indicator is the quality of groundwater which is effected by the amounts of nitrogen applied to the soil. An indicator showing the loss of nitrate to the groundwater would be effect-based (van der Warf and Petit, 2002). Means-based evaluation looks at the farmers' agricultural practices, and the effect-based evaluation looks at actual effects of the agricultural system. For instance, the means-based analysis may consider pesticides and fertilization methods which farmers are using, while effect-based analysis may consider how much carbon dioxide (CO_2) is being emitted or what the soil nitrogen content is (van der Warf and Petit, 2002).

The environmental impact of agriculture usually vary depending on the region and geographical location, as well as the type of agriculture and food production methods in use (Chinaza *et al*., 2020; Awuchi and Igwe, 2017). Some specific environmental issues in many different regions around the world include Soil salinization, especially in Australia; Hedgerow removal in the UK; the phosphate mining in Nauru; Environmentalists attribute hypoxic zone in the Gulf of Mexico as usually encouraged by nitrogen fertilization of the algae bloom; the methane emissions from livestock in the New Zealand; among others.

Quantification of the food production and agro-environmental impacts is not often an exact science. The first reason is that there is extensive debate on their spatial extent, on the magnitude of current and long-term biophysical effects, and on the economic consequences of the impacts of agriculture. The literature is more concerned with land degradation, especially water erosion. The literature and media focus more on the impacts of environmental changes on agriculture and food production. Moreover, most of the assessments are usually of physical damage, though few attempts have been made to determine the economic costs of degradation as a proportion of agricultural Gross Domestic Product (GDP). The UN FAO estimates annual losses in agricultural GDP resulting from soil erosion for many African countries; which can be considerable. Unfortunately these cumulative estimates may be misleading, and the policy priorities for limiting the impacts based on physical damage might not reflect the true costs to the economy at large. The second reason is that the relative importance of different impacts can change with time, as the point sources of pollution can be increasingly brought under control and the non-point sources become major problem. Lastly, the offsite costs may be considerably greater than the onsite costs.

2. ENVIRONMENTAL IMPACTS

2.1 The negatives impacts of agriculture and food production on environment

2.1.1. Soil degradation

Soils hold the bulk of the global biodiversity, and healthy soils are vital for food production, agricultural activities, and adequate water supply. Soil degradation involves the decline in soil quality which can be caused by many factors, including agriculture. Common attributes of soil degradation can include compaction, pesticide contamination, salting, waterlogging, loss of fertility, alkalinity, salinity, changes in soil acidity, erosion (Awuchi and Igwe, 2017), and a decline in soil structure quality. Soil erosion occurs when there is wearing away of topsoil by wind, farming activities, or water. The high fertility of topsoil makes it valuable to farmers to grow crops, encouraging agricultural activities. Soil degradation also has huge impacts on biodegradation, which affects the microbial community and ecology of the soil and could alter nutrient cycling, control of pests and diseases, and the chemical transformation properties of the soil (National Estuarine Research Reserve System, 2015).

2.1.2. Irrigation

Irrigation can result in a number of problems. One of these problems is depletion of underground aquifers via overdrafting. Soil can be irrigated excessively and may result in water pollution. Over-irrigation can lead to deep drainage from rising water tables which can result in problems of irrigation salinity requiring water table control by some kind of subsurface land drainage. On the other hand, under irrigation of soil gives poor soil salinity control that leads to increased salinity of the soil with consequent accumulation of toxic salts on the surface of the soil in areas with high evaporation. It requires leaching to remove these toxic salts and a drainage method to carry the salts away (Chinaza *et al.*, 2020; Awuchi and Igwe, 2017). Irrigation with high-sodium (or saline) water can damage soil structure due to the alkaline soil formation.

2.1.3. Climate change contributions

Climate change and agriculture processes are interrelated, both take place on a global scale. Global warming is estimated to have significant impacts on the conditions affecting agriculture, including precipitation, glacial run-off, and temperature. These conditions determine the biosphere's carrying capacity to produce sufficient foods for both domesticated animals and the human population. Rising levels of carbon dioxide would also have both detrimental and beneficial effects on crop yields. The assessment of the effects of worldwide climate changes on agriculture may help to properly adapt farming to maximize agricultural and food productions. Although the net impacts of climate change on food and agricultural production remains uncertain, it is likely to shift suitable growing zones for distinct crops. The adjustment to this geographical shift involve considerable social impacts and costs economic.

Simultaneously, agriculture has been demonstrated to produce significant impacts on climate change, primarily by the production and release of greenhouse gases, including carbon dioxide, nitrous oxide, and methane. Additionally, agriculture that practices fertilization, tillage, and application of pesticides also releases phosphorus, ammonia, nitrate, and many other pesticides which affect the quality of air, soil, and water, as well as biodiversity (van der Warf and Petit, 2002; Chinaza *et al.*, 2020). Agriculture alters the Earth's land cover, which may change its ability to reflect or absorb light and heat, as a result contributing to radiative forcing. The land use change such as desertification and deforestation, together with the use of fossil fuels, are major anthropogenic sources of carbon dioxide (CO_2); agriculture is the major contributor to increasing concentrations of nitrous oxide and methane in the earth's atmosphere (UN Report on Climate Change, 2007).

Most of methane emissions result from use of livestock, especially ruminants such as pigs, cattle, etc. Other livestock, such as poultry, fish, etc., have a far lower impact. A number of solutions are being developed to counter emissions of ruminants. The strategies include the use of biogas from manure (Monteny *et al.,* 2006), immunization, rumen defaunation, genetic selection, diet modification, introduction of methanotrophic bacteria into the rumen (Parmar *et al.,* 2015), outcompetition of methanogenic archaea with acetogens, grazing management, among others (Boadi, 2004; Martin, C. *et al.* 2010; Eckard *et al.,* 2010). Certain changes in diet, such as with *Asparagopsis taxiformis*, allow a decrease of up to 99 percent in ruminant greenhouse gas emissions (Machado *et al.,* 2014). As a result of these negative impacts, and also for reasons of efficiency in farming, one estimate mentions a large decline of livestock, at least various animals (especially cattle), in some countries before 2030.

2.1.4. Wastes

Plasticulture is a practice involving the use of plastic mulch in agriculture. Some farmers use sheets of plastic as mulch to cover 50 to 70% of the soil and allow the use of drip irrigation systems to have a better control over the soil nutrients and moisture. Rain is not needed in this system. Farms that use plasticulture are often built to encourage fastest runoff of rains. Using pesticides with plasticulture allows the pesticides to be transported easily in the surface runoff towards the wetlands or tidal creeks. Runoff from pesticide and chemicals in the plastic may cause serious deformations and even death in shellfish as the runoff carries the pesticide and chemicals towards the oceans (Kidd, 1999–2000).

Along with the increased runoff which results from plasticulture, there is also problem of increased amount of wastes from the plastic mulch itself (Chinaza and Chibueze, 2019a; Chinaza and Chibueze, 2019b). The plastic mulch usage for strawberries, vegetables, and other orchard and row crops surpasses 110 million pounds per annum in the US. Most plastic ends up in landfill, though there are other options for disposal such as by disking mulches into the soil, on-site storage, on-site burying, reuse, incineration, and recycling. Recycling and incineration options are complicated by the range of the types of plastics used and by geographic dispersal of the plastics. Plastics contain dyes and stabilizers, as well as heavy metals, which limit the number of products which are recyclable. Research is continually being done with more focus on creating photodegradable or biodegradable mulches. While there has been an inconsequential success, there is also problem of the duration it takes the plastic to degrade, as several biodegradable products take a very long time to completely break down (Hemphill, 1993).

2.1.5. Deforestation

According to the UN Framework Convention on Climate Change (UNFCCC), agriculture is the overwhelming direct cause of deforestation. Subsistence farming contributes 48% of deforestation; commercial agriculture contributes 32%; logging 14%; while fuel wood removals make up 5% (UNFCCC, 2007). Deforestation involves the large scale clearing of the Earth's forests, often worldwide, and resulting in several land damages. One of the major causes of deforestation is land clearing for crops or pasture. Norman Myers, a British environmentalist , stated that 5% of deforestation is caused by cattle ranching, over-heavy logging causes 19%, 22% caused by the growing palm oil plantations, and 54% caused by slash-and-burn farming (Hance, 2008).

Deforestation results in habitat loss for millions of both plant and animal species. Deforestation is also a driver of climate change, as trees act as carbon sink: i.e., they absorb carbon dioxide (CO_2), an unwanted and undesirable greenhouse gas in the environment, out of the atmosphere. Removing the trees releases CO_2 into the atmosphere, leaving behind smaller number of trees to absorb the increasing amounts of carbon dioxide (CO_2) in the air. In this manner, deforestation intensifies climate change. In general, when trees are removed from the forests, the affected soils tend to dry out as there is no longer shade to protect them from sun, and there are insufficient trees to assist in water cycle through returning water vapor (moisture) back to the environment. Without trees, the landscapes that were formerly forests can potentially turn into barren deserts. Tree removal also causes extreme temperature fluctuations.

In 2000, the UN Food and Agriculture Organization (UN FAO) stated that the role of population dynamics in local setting might vary from being decisive to negligible, and deforestation may result from a combination of stagnating economic and population pressure, social and technological conditions (Alain, 2000).

2.1.6. Pollutants

The use of synthetic pesticides, such as Kelthane, confidor, Malathion, and Rogor, is the most widespread method of pest control in agriculture. Pesticides could leach through the soil and move into the groundwater, and can also linger in food products, resulting in death in humans and wildlife (EPA, 2011). A range of agricultural chemicals are used in agriculture and food production, and some end up becoming pollutants through use, ignorance, or misuse (OMAFRA, 2018; Chinaza and Chibueze, 2019a; Chinaza and Chibueze, 2019b). The erosion of topsoil, which may contain chemicals such as pesticides and herbicides, can be carried from farms to other places (OMAFRA, 2018). Pesticides and herbicides can be found in groundwater and streams. A typical example of herbicide is 'atrazine' used to control weeds growing among crops. This herbicide have the ability to disrupt endocrine production which can result in reproductive problems in amphibians, fish, and mammals that are exposed. Pollutants from agriculture and food production have a huge effect on the quality of water. Agricultural NPS (Nonpoint Source) solution impacts rivers, lakes, estuaries, groundwater, and wetlands. Agricultural NPS can result from poorly managed animal feeding operations, plowing, fertilizer, overgrazing, and excessive, improper, or badly timed pesticides usage. Pollutants from farming include nutrients, pathogens, sediments, pesticides, salts, and metals (US EPA, 2015). Animal agriculture can as well cause pollutants to enter into the environment. Bacteria, pathogens, and other microorganisms in manure can find their way into groundwater and streams if grazing, storage of manure in lagoons and application of manure to fields is improperly managed.

Additional and specific problems which may arise with release of pollutants from agriculture include; Pesticide drift (air pollution *spray drift*, soil contamination); Pesticide residue in foods; Pesticides, especially organochloride based pesticides; Bioremediation; Pesticide toxicity to bees; Dead zones caused by fertilizers runoff.

2.2. Land use

Around 50% of the world's habitable land is currently used for agriculture. In human history, most land in the world was wilderness: grasslands, shrubbery, and forests dominated its landscapes. This has dramatically changed within the last few centuries: wild habitats are squeezed out by converting them into agricultural lands. Back in 1000 years ago, it is estimated that less than 4% (4 million square kilometers) of the world's non-barren and ice-free land area was used for farming (Hannah and Max, 2020). About 10% of the world is covered with glaciers, and a further 19% remains barren land – deserts, beaches, sand dunes, dry salt flats, and exposed rocks (Hannah and Max, 2020). This leaves what we referred to as “habitable land”. Around 50% of the world’s habitable land is presently used for agriculture; 37% for forests; 11% as grasslands and shrubs; 1% as freshwater coverage; and then the remaining 1% is built-up urban area which includes towns, villages, roads, cities, and other human infrastructure.

There is high distribution inequality of land use between crops and livestock for human consumption. If pastures used for grazing are combined with land used to cultivate crops for animal feed, livestock alone accounts for 77% of the global farming land. While livestock alone takes up most of the global agricultural land, it produces 18% of the global calories and 37% of the total protein (Poore and Nemecek, 2018).

Agricultural expansions have been among the largest impacts of humans on the environment (ecosystem). Agricultural expansion has transformed habitats and is among the greatest pressures for biodiversity: according to the IUCN Red List, of the 28,000 species considered to be threatened with extinction, agriculture is listed as threat for 24,000 of them (Hannah and Max, 2020). These impacts can be reduced, both through technology advances and through dietary changes, by substituting meat with plant-based alternatives; although the latter can lead to chronic deficiency of some nutrients such as vitamin B_{12}, which can also be avoided by consuming fortified foods. In recent decades, crop yields have significantly increased, meaning a lot of land have been spared from agricultural production: worldwide, to produce the same quantity of crops as in 1961, only 30% of the farmland is needed (Hannah and Max, 2020).

2.3. Greenhouse gas emissions and CO_2

Food production accounts for 25% to 26% (1/4) of the global greenhouse gas emissions (Hannah and Max, 2020). When it comes to dealing with climate change, the focus is often on clean energy solutions (deployment of renewable or nuclear energy); cleaner production; transition to low-carbon transport; and improvements in energy efficiency. Undeniably, energy, whether in form of heat, transport, electricity, or industrial processes, are responsible for the majority (76%) of the greenhouse gas emissions (IPCC, 2014). However, the global food system, which covers production, processing, and distribution is also a significant contributor to emissions.

There are four important elements to consider when quantifying food GHG emissions:

a) Crop production is responsible for 27% of food emissions, of which 21% of the food's emissions comes from the crop production meant for direct human consumption, and the remaining 6% comes from the animal feed production. They are direct emissions resulting from agricultural production. This includes the methane emissions from rice production; carbon dioxide from agricultural machinery; and release of nitrous oxide from the application of fertilizers and manure (Hannah and Max, 2020).
b) Livestock and fisheries account for 31% of the emissions from food. Livestock (animals raised for eggs, meat, dairy, and seafood production) contribute to environmental emissions in many ways (Hannah and Max, 2020). Ruminant livestock – mostly cattle – for instance, produce methane during their digestive processes (during a process referred to as 'enteric fermentation'). Pasture management, manure management, and fuel consumptions from fishing vessels fall into this category. The 31% of emissions relates to the on-farm production emissions alone: it excludes the land use change or the supply chain emissions from production of crops for animal forage: these figures are added separately in other categories.
c) Supply chains are responsible for 18% of the emissions from food. Food processing (converting farm produce from the farm to final products), transporting, packaging, and retail all require resource and energy inputs. Many assume that consumption of local is key to low-carbon diet, nonetheless, transport emissions are usually very small percentage of total emissions from food (only 6% worldwide) (Hannah and Max, 2020). Whilst supply chain emissions may appear high, at 18% (Hannah and Max, 2020), it's important for reducing food emissions through preventing food wastes. Food waste emissions are bulky: one-quarter (1/4) of emissions (3.3 billion

tons of CO_2eq) from production of food ends up as wastes either from consumers or supply chain losses or both. Durable packaging, food processing, and refrigeration can all help in preventing food wastes. For example, wastes from processed fruits and vegetables is about 14% lesser than fresh, and 8% lesser for seafood (Gustavsson *et al*., 2013).

d) Land use is responsible for 24% of emissions from food. Twofold as several emissions result from the land use for livestock (16%) as for the crops for human consumption (8%) (Hannah and Max, 2020). Expansion of agriculture leads to the conversion of grasslands, forests, and other carbon sinks into pasture or cropland resulting in the emissions of carbon dioxide. Land use here refers to the sum of land use change, organic soil cultivation (the plowing and overturning of soils), and savannah burning.

Reducing the emissions from food production is one of our greatest challenges in next decades. Unlike several aspects of energy production where likely opportunities for scaling up low-carbon energy (nuclear or renewable energy) are available, the ways which we can decarbonize agriculture are either unclear or less clear. Inputs such as fertilizers are required to meet the growing demands for food, and cattle can't be stopped from producing methane. A menu of solutions will be needed: food waste reduction; changes to diets; technologies which make low-carbon food alternatives affordable and scalable; efficiency improvements in agriculture; among others.

Whether food travels through air or sea makes a difference. Transporting foods through air emits roughly 50 times as much GHG as transporting the same quantity by sea (Hannah and Max, 2020). More specifically, 0.023 kg of CO_2eq (carbon dioxide-equivalents) per ton-kilometer by sea, versus 1.13 kg CO_2eq by air. The emission factors for different transport modes can be seen in Table 1. For foods transported by sea, the transportation doesn't really contribute much to the carbon footprint. As most of our foods are transported by sea, the transport emissions account for only 6% of the average carbon footprint of foods (Hannah and Max, 2020). But for those foods which travel by air, the travel distance does have a huge impact. Where we can, air-freighted goods should be avoided.

Table 1: Emission factors for freight by transport mode (kilograms of CO_2eq per tonne-kilometer) (Poore and Nemecek, 2018; Hannah and Max, 2020)

Transport mode	Ambient transport (kg CO_2eq per tonne-kilometer)	Temperature-controlled transport (kg CO_2eq per tonne-kilometer)
Air Transport	1.13	1.13
Rail Transport	0.05	0.06
Road Transport	0.2	0.2 to 0.66
Sea / Inland Water Transport	0.01	0.02

2.4. Genetic engineering

Genetically engineered crops are planted in the fields much like the regular crops, where they directly interact with the organisms that feed on crops and indirectly interact with the other organisms in the food chain. Pollen from the plants can distributed all over the environment just like any other crop. Such distribution has resulted in concerns over the effects of genetically modified crops on the environment. Some potential effects are pesticide resistance, greenhouse gas emissions, and gene flow/genetic pollution.

2.5. Sustainable agriculture and food production

Sustainable agriculture is a knowledge that agriculture have to occur in such a way that we can continue the production of what is needed without infringing on ability of future generations to do same. The exponential increase in population in current decades has led to increased agricultural land conversion practice to meet the growing demand for food, and in turn has increased the impacts on the environment. Agriculture can have negative impacts on biodiversity as well. Organic farming, a multidimensional sustainable agriculture set of practices, can have a lesser effect on the environment at small scale. In most instances, organic farming results in a lower yield of production per unit area (Seufert *et al.,* 2012). As a result, the widespread adoption of the organic agriculture will require the clearing of additional land and the extraction of water resources to meet the same production level. A European meta-analysis reported that organic farms inclined to having higher content of soil organic matter and lower nutrient losses (nitrous oxide emissions, ammonia emissions, and nitrogen leaching) per unit field area, but higher nitrogen leaching, ammonia emissions, and nitrous oxide emissions per unit of product (Tuomisto *et al.,* 2012). Many believed that conventional farming systems result in less rich biodiversity than the organic systems. Organic farming has demonstrated to have an average 30% more species richness than the conventional farming. Organic systems on the average also have 50% higher organisms. This data has some concerns because there were many results that showed negative effect when in an organic farming system (Bengtsson *et al.,* 2005). Oppositions to organic agriculture believe that these negatives are concerns with the organic farming system. What began as small scale, environmentally mindful practice has now turn into just as industrialized as the conventional agriculture. This industrialization can result in the issues such as deforestation and climate change.

2.6. Conservation tillage

Conservation tillage, an alternative tillage method for farming, is more sustainable for both the soil and the surrounding environment. Conservation tillage is done by allowing residue of the previous harvest's crops remain in soil before the tilling for next crop. Conservation tillage improves many things including moisture retention by the soil, and reduce erosion. Some disadvantages include; more expensive equipment is required for the process; more pesticides re required; the positive effects take a very long time to become noticeable. The barriers to conservation tillage policy include farmers are unwilling to change their farming methods, and will protest any more expensive, and time consuming tillage method than the conventional one they use (Holland, 2004).

3. CONCLUSION

Agricultural expansion and increase in food production have been among the humanity's leading impacts on the environment. Agricultural expansion has transformed habitats and is among the greatest pressures for biodiversity: among the 28,000 species on the IUCN Red List estimated to be threatened with extinction, agriculture alone is listed as threat for 24,000 (i.e. roughly 85.71%). Recently, the exponential increase in population has increased the practice of agricultural land conversion and food production to meet the growing global food demand which in turn has increased the impacts on the ecosystem. The environmental impacts of agriculture and food production vary based on the wide variety of agricultural practices and production processes employed worldwide. In agriculture, the environmental impacts depend on the production practice of the farming system used by the farmers. There are two kinds of indicators of environmental impact: effect-based, which is the effect that farming methods have on farming system or on the emissions to the environment, and means-based, which is based on farmer's production methods. The environmental impacts of agriculture and food production involve many factors from the soil, to the air, water, animal and soil varieties, plants, people, and the foods themselves. Some of the environmental issues which are related to agriculture include climate change, greenhouse gas and CO_2 emissions, deforestation, dead zones, irrigation problems, pollutants, genetic engineering, soil degradation, and waste. The environmental impact of agriculture and food production can vary depending on the region and the type of food and agricultural production methods being used. Over 50% of the habitable land worldwide is used for agriculture. There is also highly unequal land use distribution between crops and livestock for human consumption. A combination of pastures used for animal grazing with land used to grow the crops for animal feeds, livestock accounts for 77% of farming land worldwide. While livestock takes up most of the global agricultural land, it produces 37% of world's total protein and 18% of the calories. There are some measures required to limit the negative impacts of agriculture and food production on the environment. Conservation tillage, an alternative tillage method for farming, is more sustainable for both the soil and the surrounding environment. Sustainable agriculture is a knowledge that agriculture have to occur in such a way that we can continue the production of what is needed without infringing on ability of future generations to do same.

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