CHAPTER 7

AGRICULTURE

Serge SCHMITZ*

*Professor, University of Liege, Faculty of Sciences, UR Spheres, Department of Geography, Liège, Belgium
E-mail: s.schmitz@uliege.be

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ABSTRACT

The development of agricultural practices has changed the local and global environment since the Neolithic Age. The influences of agricultural development in the last decades have been more important than ever and contributed largely to entering the Anthropocene, the suggested geological epoch marked by human beings and their activities. This chapter depicts most of the environmental impacts of agriculture from a global perspective and points out the main challenges concerning both agriculture and the food supply chain to mitigate damages to the environment. Geography, as a discipline, provides precious insights into interactions between agriculture and the environment, highlighting the different geographical scales of these interactions and the considerable diversity of situations worldwide.

Keywords: Agriculture, Anthropocene, Global Change, Food Supply Chain, Geographical Scales

1. Introduction

This chapter discusses the multiple forms of evidence of the impact of agricultural practices on local and global environments. It also questions food processing and diet around the world and conveys the calls for adaptation of food production and farming in order to both feed nine billion inhabitants in the coming decades and mitigate the destruction of our environment. While conventional agriculture causes damage to the environment, these recent transformations, in turn, affect agriculture in different ways depending on the location on Earth. If the Anthropocene is seen as the geological epoch when human beings become one of the more influential driving forces for environmental change (Crutzen, 2006), the natural sciences and humanities are called to work together (Palsson et al., 2013). Geography as a discipline is particularly relevant to contribute to multidisciplinary investigations on the Anthropocene because of geographers' long experience of analyzing, in a systemic way, the interactions between people and environments and their ability to reflect spatially and at different geographic scales. This chapter is divided into four sections. The first section presents the intimate links between several agricultural revolutions and the proposed onsets of the Anthropocene. The second describes the major impacts of agricultural development on the environment. The third underlines some of the adaptations suggested by researchers and NGOs to reduce environmental impacts. The fourth section reflects on the relevance of geographical thought and practices to support knowledge development and make recommendations.

2. Agriculture: a major driving force during the Anthropocene

Agriculture is one of the first driving forces that lead humanity to shape landscapes and drastically change the global environment. The first reason is that the number of human beings in the world increased at least tenfold thanks to the adoption of a new way of dwelling based on food production via agriculture instead of a hunter-gatherer lifestyle (Noin, 2005). The deforestation of vast parts of the continents started with agriculture. Therefore, some authors suggest that the Anthropocene began when humans started to cultivate plants and rear animals (Ruddiman & Thomson, 2001). The other dates (1850, 1950) proposed as the beginning of the Anthropocene (Crutzen & Stoermer, 2000; Smith & Zeder, 2013) also coincide with important changes in the way of food production. Around 1850, agriculture experienced important changes, including the development of mineral fertilizers and the reduction of fallows but also the development of commercial world agriculture for several food and fibre products (Bairoch, 1989). Considering the 1950s as the start of the Anthropocene corresponds to the period of the widespread mechanization of agriculture and the development of petroleumbased agriculture. In developing countries, this transformation of agriculture was called the "green" revolution, which increased agricultural production worldwide thanks to new technology-based practices. Technological innovations and scientific research developed new plant varieties and ways to fertilize and fight pests (Gliesmann, 2014). These technological changes created a gap between peasantry lifestyles and new industrial farm plants, resulting in marked disparities between regions worldwide (Schirmer, Schmitz & Schirmer-Nejfeld 1997). Considering both the amount of food produced and the impact on the local and global environment, world population development is intrinsically linked with agricultural progress. Therefore, the increasing impact of human beings on the Earth coincides with agricultural changes. However, it does not mean that agriculture is the only contributor to global change, but that its impact is significant besides, or in strong interaction with, other driving forces.

3. A complex of various impacts

Agriculture depends on the local, regional and global environment and, at the same time, affects and changes these environments. Anyone analyzing these effects faces a complex system wherein the driving forces, together with environmental changes and adaptations of farming activities, interplay and influence each other.

First, agriculture modifies the use of lands that were previously forests or natural areas. This phenomenon started with the Neolithic Age but experienced major momentum with the evolution of the world population. Nowadays, pasture and crop areas are reaching 50 billion hectares and cover 37% of the Earth's land surface (FAOSTAT, 2016), half of the habitable lands (Ritchie & Roser, 2020). The Wageningen University and Research Centre (2012) estimated that Agriculture is the direct driver for around 80% of deforestation worldwide. Yet, this expansion of farming lands is continuing in many countries for subsistence farming and, more importantly, for industrial farming, typically soy, palm oil and cattle ranching. During the last decade, 56,000 square kilometers of forest were converted annually to agricultural lands, mainly to pastures for livestock (FAO, 2016). We have, however, to note that, on the one hand, agricultural lands are also in high demand and converted to urban and industrial land uses and, on the other hand, reforestation of agricultural lands is happening in 88 countries, especially high-income regions such as Western Europe and North America.

The increase in agricultural land has serious consequences, including loss of biodiversity, the release of carbon, an increase in erosion, and changes in the water cycle. The destruction of millions of hectares of forest, in the past mainly in Asia and Europe, nowadays in South America and Africa, was accompanied by terrestrial and aquatic ecosystem destructions that have caused the extinction of thousands of plant and animal species each year. Moreover, by domesticating a small number of animals and selecting some cultivated plants that will feed and clothe humanity, agriculture reduces biodiversity (Diamond, 2002). Meadows and pastures represent 68% of the agricultural lands worldwide. Three kinds of cereal: wheat, maize and rice, and soybean, are the principal crops covering together 7 million square kilometers (more than twice the area of India). A third of these crops, more than 85% of maize, are destined for livestock (Dronne, 2019). Therefore, livestock production is pointed to as one of the major causes of the world's most pressing environmental problems (Steinfeld et al., 2006) because it occupies 26% of the terrestrial surface and represents 20% of the terrestrial animal biomass. By 2050, global demand for livestock should increase by 70%, increasing the negative effect on the environment (Thornton, 2010). Deforestation has negative impacts on the biosequestration of atmospheric carbon dioxide and is, therefore, a contributor to global warming. Around 10% of the greenhouse gases released into the atmosphere each year are caused by deforestation for agricultural purposes (Van der Werf et al., 2009). Moreover, deforestation reduces the atmospheric moisture and the content of water in the soil and groundwater. This results in a drier local climate, increasing soil erosion and land degradation, flooding and landslide events.

Secondly, agriculture is the largest user of water and an important polluter. Agriculture accounts for 70% of water abstractions worldwide, and so pollutes large amounts of water (Mateo-Sagasta et al., 2017). Farms release large quantities of pollutants into water bodies, including agrochemicals, organic matter, drug residues, sediments and saline drainage. These pollutants threaten aquatic ecosystems and human health (UNEP, 2016). The demand for water comes from cropping, livestock systems and aquaculture. The area equipped for irrigation has more than doubled since 1960, reaching 338 million hectares in 2017 (FAO STAT, 2019). The total number of livestock has more than tripled in the last decade, reaching, in 2018, 1.7 billion beef cattle, 25.7 billion poultry, and 2.2 billion sheep and goats (FAO STAT, 2019) (Figure 1). Aquaculture has grown more than 20-fold since the 1980s, particularly inland-fed aquaculture in Asia (FAO, 2016). These developments are unsustainable; both agriculture and a human diet that is increasingly oriented to animal proteins need to adapt rapidly to mitigate major problems concerning the world environment and the health of people around the world. Moreover, agricultural practices may interrupt the natural flow of water, causing, in many places, a rupture with the previous geosystems accompanied by regional climate changes, drought, land degradation and desertification. In addition, the use of water by industrial agriculture may have huge consequences for local people and lead to a transformation of their way of dwelling.

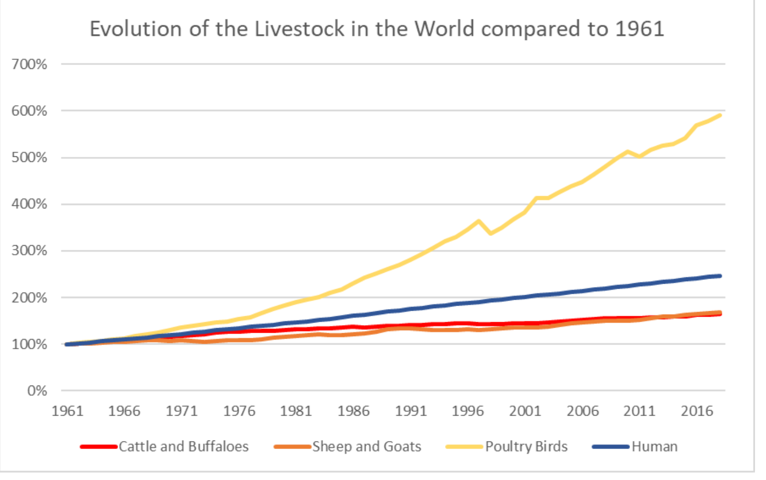

Figure 1: The evolution of livestock in the world (FAO STAT, 2019)

Thirdly, agriculture directly influences soil erosion and so may shape geomorphological processes. Depending on practices, e.g., the size of the parcels, the tillage method including the orientation and the depth of the furrows, the soil cover, the plantation of trees and hedges, and cultivation on steep slopes, soil erosion may vary, but the erosion of agricultural lands far exceeds the replacement by soil production (Montgomery, 2007; Vanwalleghem et al., 2017). In recently deforested tropical soils, monoculture planting exhausts the thin layer of nutrients (Tyrrell, 2014). The use of mechanization in modern times, allowing deeper plowing, significantly increases water and wind erosion, and the overuse of pesticides and chemical fertilizers destroys organisms that bind the soil. The impact of the loss of arable soils on the Earth is also one of the most challenging issues. On average, soil erosion in conventional agriculture is around 1 mm of soil per year. This is 10 to 100 times higher than natural erosion levels and 15 to 20 times more than the rate of soil formation (Balesdent, Dambrine & Fardeau, 2015). Beyond the loss of fertile land, soil erosion affects water quality, increasing turbidity and the eutrophication of water bodies, which disturb natural life. Moreover, the degradation of soils reduces their capacity to serve as a carbon sink and to hold water, thereby increasing flood events.

Fourthly, the use of chemical fertilizers and pesticides is another environmental concern relating to agricultural practices because it is a significant source of soil, water and air pollution. Pesticides and herbicides are used to combat pests that disrupt agricultural production, but they are also toxic for soil organisms and animals, including bees and other pollinator insects, thus threatening food supplies and ecosystem services (Vanbergen, 2013).

Fertilizers are additional sources of nutrients for plants. Based usually on nitrogen, phosphorus or potassium, they increase plant growth and yield. Nevertheless, an important share of these elements are in excess and are not used by the crops, and finally pollute soil and water. These inputs can have a considerable impact on both animal and human life. At the farm stage, overuse of chemical fertilizers and animal husbandry are the largest sources of agricultural emissions (Sun, Yun & Yu, 2017).

Finally, as mentioned above, the livestock sector is developing quickly and contributes significantly to global human-induced greenhouse gas emissions. Livestock supply chains emitted an estimated total of 8.1 gigatonnes of CO2 equivalent in 2010. Methane (CH4) represents about 50 percent of the total (Mottet et al., 2018). Projections also suggest a 60% increase in ammonia and methane emissions from livestock, especially beef and dairy cattle, which contribute 62% of the livestock emission (Figure 2). More than 2 gigatonnes of CO2 equivalent are due to the methane produced by the enteric fermentation of ruminant animals (FAO STAT, 2019). Nonetheless, farming could also have a positive role to play. By 2030, the amount of carbon locked up in cropland soils, as soil organic matter from crop residues and manure, could rise by 50 percent if better management practices are introduced (Zomer et al., 2017). This appealing prospect requires, however, further development of scientific analyses, measurement tools, and protocols (Paustian et al., 2016).

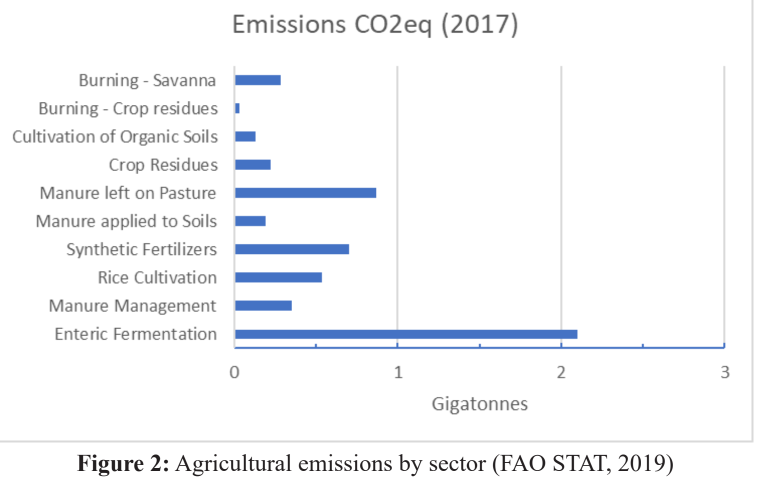

Figure 2: Agricultural emissions by sector (FAO STAT, 2019)

As listed in this section, agriculture's environmental impacts are multiple and unsustainable. Nonetheless, as humanity, we should also consider the numerous services agriculture delivers and how it has intimately shaped our civilisations. Henceforth, there is an urgent need to reconsider, globally and locally, how we will produce and consume agricultural products in order to both adequately feed an increasing population and preserve a liveable environment. Furthermore, besides the agricultural impact, we must also acknowledge that the whole food processing chain should be reformed because transport, storage and waste contribute strongly to increasing the environmental debt.

4. A necessary adaptation

Acknowledging that we are in a new epoch marked by the prevalence of anthropic driving forces raises questions, especially around the future of agriculture and so of humanity. The world's population will continue to increase for at least another 50 years (UN DESA, 2019). Instead of clearing new agricultural lands, experts underline the necessity to use existing fields better and reshape food processing and consumption (Godfray et al., 2010). Furthermore, over the following decades, many environmental problems linked to agriculture will remain severe and require attention to develop more sustainable ways of producing food. Depending on experts' backgrounds and values, two opposite visions coexist.

The first perspective trusts that technology can enhance yields via more precise agriculture-based practices, inter alia, on selecting crops and creating genetically modified crops (GM). Experts have calculated the theoretical optimum of yield and want to close the yield gap (Mueller et al., 2012).

These experts claim that sustainable intensification is possible. This agriculture would produce more calories with less land and water. Agricultural productivity has doubled over the past 50 years thanks to chemical fertilizers and pesticides, the selection of plants and animals, irrigation systems and mechanical technologies. If Western Europe and Northern Europe have achieved their high-input potential crop calorie production, and North America, South America, South-East Asia and Oceania have reached 60% of their potential production, massive efforts are possible in Africa and Eastern Europe (Pradhan et al., 2015). The actors who believe their technology will feed the planet support this perspective. Presently, these actors are also those who will gain from an economic point of view and maintain their control of the agricultural trade market.

The second perspective claims that agroecological farming should be the solution to enhanced yields and find a better equilibrium between the environment, social structures and economic activity (Eldridge, 2018). It requires a paradigm change and gives prominence to traditional local knowledge (Bernard & Lux, 2017) and farming imitating nature. The aim is to transform food systems through a holistic approach. The agroecological approaches include poly-cropping, integrated crop and livestock systems, endogenous crop preferences, and agroforestry. These practices present several advantages in maintaining soil fertility thanks to rotation and manuring, better water use and carbon sequestration in the soil (Gliessman, 2014). However, there is a lack of comprehensive studies to demonstrate that agroecology can feed the world population (Bernard & Lux, 2017). Moreover, agroecology faces the barrier of being management- and knowledge-intensive (Paarlberg, 2018).

In fact, the food system globally produces enough food calories to feed everyone and more (Cassidy et al., 2013). However, some uses of agricultural production divert calories to produce first-generation biofuels (Ciervo & Schmitz, 2017) or other industrial products (9% of these calories). Moreover, another 36% are used for animal feed (less than 10% of which is recovered in the form of animal-based food calories), leaving only 55% to be eaten directly by humans. Another sticky problem is that one-third, 1,300 million tonnes per year, of the food produced is wasted both along the supply chain and at the household level (Gustavson et al., 2011). Food waste is spatially diverse, considering both the volume and the processes and could benefit from a geographical analysis. While North America, Europe and Oceania waste 300 kilogrammes of food yearly per habitant, South and South East Asia waste 125 kilogrammes (Gustavson et al., 2011). In developing countries, losses are mainly attributable to the poor market, conservation and transportation facilities. Moreover, this lack of market and transportation infrastructures increases the cost of the inputs for the peasants and adds important transportation costs to enter the national or international market. In developed countries, pre-retail losses are much lower, but food wastes at the retail, food service and home stages are important and ethically questionable. Because of the low food price in these markets, consumers and retailers pay less attention to food waste and want fresh and good-looking products. They also buy more and sometimes eat more than they need. These issues of reducing food waste are as important as the increase in yields and should be at the top of the research agenda concerning food processing and its impact on the environment. This also requires changes in how food is produced, stored, processed, distributed, and consumed.

The increasing demand for meat linked to the population's growth and the world's adoption of a Western diet is also unsustainable. Because of the loss of food when transforming vegetable proteins to animal proteins that could be estimated as twofold for eggs and twenty-fold for beef (Shepon et al., 2018), a change of the dietary pattern is urgently recommended by substituting some meat with plant-based alternatives. All the more so, food is a strong lever to optimize human health and environmental sustainability on Earth (Willett et al., 2019).

5. A multiscalar issue

The recognition of being in this new epoch, the Anthropocene, should require a new governance system because the Earth has become a subject to be cherished if we want human beings to survive into the coming centuries (Gemenne & Rankovic, 2019). This is especially the case with agriculture, which influences vital elements such as water, food, air, soil, and climate but also directly and indirectly, affects our health. It is no more just a question to be dealt with at the levels of towns or states, but in the epoch of the Anthropocene, the choices, including the agricultural strategies, will also affect globally the climate, the aquatic and terrestrial ecosystems and the populations of the Earth. Behind the use of the notion of Anthropocene, which tends to embark the whole of humanity on the same vessel, we should recognize that, from geographical and historical perspectives, people around the world do not have the same responsibility concerning environmental damages (Vanwambeke, 2019) and will not be affected in the same way. Moreover, the notion of Anthropocene places, once more, the human being at the center of the universe, considering nature as a contextual decor, as if humans could control nature (Stengers, 2015).

Geography as a discipline should be a key player in gathering information worldwide to understand how the different scales are interlinked and underline the particularities of ecosystems and anthroposystems on the different continents (Barcus et al., 2022). Because the discipline has developed expertise in questioning the interdependence between people and the environment for more than a century, geography should help to understand the diversity of situations around the world and sort out the different driving forces that affect local, regional and world environments. If the idea of an Earth system science has an appeal, the analysis at this level risks neglecting spatial and social inequalities. The daily life and the perspectives of peasants and farmers worldwide are diverse. They must compete with other economic activities that covet the same resources and adapt their agricultural practices to biophysical, socio-economic and political constraints. For instance, global warming is not expected to affect the different regions of the Earth similarly; while temperate regions would benefit from an increase in crop production, other places would suffer from climatic changes, including low-lying land that rising sea level and salinisation will threaten. On the other hand, increasing carbon dioxide (CO_2) levels can directly stimulate plant growth. Recommendations about agricultural practices should pay attention to the diversity of the biophysical and socio-economic constraints around the world and try to take into account the multiple interactions in a systemic way.

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