

Life Cycle-Based Analysis of Meat Production: Ecosystem Impacts

Michelle Zeyuan Ma, Hermann Heilmeyer

Abstract—Recently, meat production ecosystem impacts initiated many hot discussions and researchers, and it is a difficult implementation to reduce such impacts due to the demand of meat products. It calls for better management and control of ecosystem impacts from every aspects of meat production. This article analyzes the ecosystem impacts of meat production based on meat products life cycle. The analysis shows that considerable ecosystem impacts are caused by different meat production steps: initial establishment phase, animal raising, slaughterhouse processing, meat consumption, and wastes management. Based on this analysis, the impacts are summarized as: leading factor for biodiversity loss; water waste, land use waste and land degradation; greenhouse gases emissions; pollution to air, water, and soil; related major diseases. The article also provides a discussion on a solution-sustainable food system, which could help in reducing ecosystem impacts. The analysis method is based on the life cycle level, it provides a concept of the whole meat industry ecosystem impacts, and the analysis result could be useful to manage or control meat production ecosystem impacts from investor, producer and consumer sides.

Keywords—Eutrophication, life cycle based analysis, sustainable food, waste management.

I. INTRODUCTION

FOOD is a basic necessity for our lives, but the industrialized food production supply chain caused many environmental problems, especially meat-based food products. Nowadays, meat-based food products are in a hot discussion because of their environmental or ecosystem impacts. American doctor and author John A. McDougall said "*We Are Eating Our Planet to Death*", based on his experiences in healing people with meat eating related problems and his knowledge in meat related environmental problems [1].

We are eating all kinds of meat without knowing where they come from due to the over processed steps, additives and coloring materials added to the food, and the food industry is controlling our health and our ecosystems more than ourselves. It is an urgent task to feed an increasing population with sustainable food systems and at the same time to reduce ecosystem impacts. Scientists have started scientific studies on environmental impacts from our food industry. In 2006, the UN FAO report "Livestock's Long Shadow" was published, it

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aimed to raise both technical and public attention to the major impacts of the animal raising industry on environments. FAO senior officer Dr. Henning Steinfeld highlighted that the meat industry is

"one of the most significant contributors to today's most serious environmental problems" and "urgent action is required to remedy the situation" [2].

"US Population "Meatless Monday" = 0.6% GHG savings" [3].

As the report, "Livestock's long shadow" [4] stated, world livestock sector generates more greenhouse gases as measured in CO₂ equivalent – 18% – than the total transport sector. It was emphasized that livestock-related agriculture is also a major source of land and water degradation.

In "Livestock's Long Shadow" [5], it was pointed out that livestock has several major impacts on our environment.

1. Climate Change. Animal raising causes 18% greenhouse gases that measured in term of CO₂ effect; 65% human related greenhouse gas nitrous oxide emission; 37% human induced methane; and 64% percent of the ammonia emissions (which contributes to acid rain and acidification of ecosystems)
2. Land degradation. Grazing farmland occupies 26% ice-free terrestrial surface of the Earth; 73% of range-lands or grazing areas are downgraded to dry areas by overgrazing (desertification).
3. Water shortage and waste. A total of 8% of global water used by man is for irrigation to grow animal feeding crop.
4. Water Pollution. Water eutrophication, coastal dead zone, antibodies, hormones etc.
5. Deforestation. Livestock raising is a key reason of deforestation, 70% Amazon deforested land is used for pasture now.
6. Loss of Biodiversity. Livestock raising is the leading factor of Biodiversity Loss due to its deforestation, pollution and climate change reasons.

Producing meat products consumes much more water, arable land, feeding crops, and chemicals than producing any other food products. Added to the direct environmental problems from cattle raising, meat production and consumption causes big problems to our human ecosystems, such as energy consumption and human health impacts.

"The World Health Organization has determined that dietary factors account for at least 30% of all cancers in Western countries and up to 20% in developing countries" [6].

And with the waste management from meat production life cycle, there are post impacts from fertilizer usage, antibiotics,

artificial chemicals and heavy metal residuals, as well as all kinds of pollution.

II. ECOSYSTEM IMPACTS OF MEAT-BASED FOOD PRODUCTS

"The meat derived from cattle is known as beef, meat derived from pigs as pork and from chickens as poultry. Pork is the most widely eaten meat in the world accounting for over 36% of the world meat intake. It is followed by poultry and beef with about 35% and 22%, respectively" [7].

To understand how meat products affect our ecosystem and biodiversity, we need first to understand the meat products producing life cycle. It is composed of several phases, which we can break down further to make the analysis easier and clearer.

A. Meat Products Life Cycle

There is a term for this cycle that is "Cradle to Grave", which accurately describes our meat-based food producing process (Fig. 1). With growing consumption demand for meat

products, the profits of producing meat and raising animals are increasing, modern animal farms and factories are booming with more investment from individual investors and government sectors. This phase includes activities to cut down rain-forest or grassland for livestock farms or factories.

After the initial investment, farmland and animal factories are set up; animals are raised by modern factories instead of grazing on farms. Their lifespan, growing speed and even how their meat should be, fat or lean, are all controlled by a business plan and target consumers' requirements instead of the natural path of animal growth.

Meat starts at the slaughterhouse, and then preservationist, processing, packaging, transportation and marketing are processes that happen before consumption. Finally, waste management is implemented to solve meat product waste and reduce its environmental impacts. The last step of the complete meat production life cycle is the environment and landscape recovery process after an animal factory is closed, the ecosystem should revert to a natural and sustainable status.

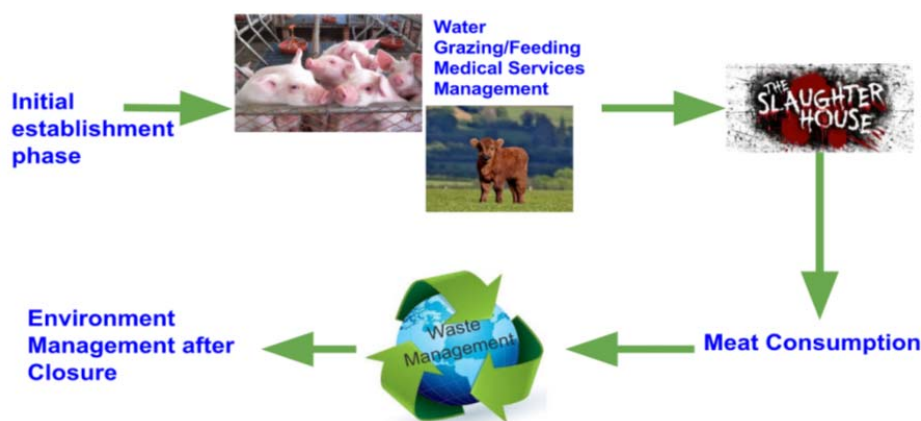


Fig. 1 Meat Production Life Cycle

B. Initial Establishment Phase

Global pasture land use is the main reason for deforestation,

"Since the 1960s, the cattle herd of the Amazon Basin has increased from 5 million to more than 70-80 million heads. Around 15% of the Amazon forest has been replaced and around 80% of the deforested areas have been covered by pastures (approximately 900 000 km²)" [8].

The major ecosystem impacts of initial phase include:

1. Deforestation during pasture land or factory initialization.
2. Arable land loss and land waste when grains are grown to feed animals instead of feeding a hungry population.
3. Biodiversity loss is another indirect impact from deforestation, which is caused by reclamation of animal farm land.

C. Animal Raising Phase

After the factory or farm is set up, it runs daily management in feeding animals, medical services, living wastes management, and other operational processes. Because of the

limitation of land use and great demand for meat products, and as most of the investors want to get a return on investment as fast as possible, the meat products life cycle has been dramatically accelerated and has broken natural and traditional animal raising culture. For example, for beef products, nearly all beef cows are fed in feedlots instead of pasture grazing, and the average lifespan of a beef cow is around 14 months, which is when they are considered ready as meat for consumption. Thus, animal raising is more like an industrialized practice through intensive animal raising than an agricultural process based on biological principles.

The problems caused by intensive animal raising include: food products wasted in animal feeding; water pollution and waste; chemical, antibiotics and hormones that are applied to animals, greenhouse gases emission, etc. "According to a WWF study, it requires 120,000 to 200,000 liters of water to produce 1 kg beef" [9]. And indirectly, around 70% of global fresh water is used to grow grains for feeding of animal. As well, "17 billion pounds of fertilizer a year are used to grow animal feed. Producing fertilizer requires significant amounts

of energy. Spreading fertilizer generates nitrous oxide, a potent greenhouse gas. Contaminated runoff pollutes surface and groundwater" [10].

Lots of foods are grown for animal feeding. Take the example of beef cows, they are fed by forage for around 6 months after they are born, and then go to an intensive fattening operation which is called "Concentrated Animal Feeding Operations", the beef cows eat more than 20 pounds of grains to gain three pounds daily. According to ecologists at Cornell University, "The US could feed 800 million people with the grain that livestock eat" [11].

At the same time,

"Animals in confined feeding operations produce a massive 500 million tons of manure a year, more than three times the total of all human waste." [12].

Animals are also fed with several hormones, and sick animals are treated clinically by antibiotics to reduce disease infection. Tetracycline, penicillin, and streptomycin are common additives in feed for livestock and poultry; "70% of all antibiotics used in the United States are fed to livestock" [13]. Furthermore, "167 million pounds of pesticide a year are used to grow animal feed. That km² takes significant amounts of energy, and using pesticides contaminates air, water, soil and wildlife resources." [14]. Generally, pesticides are transferred from grass, forage or grains to animal's bodies. Some pesticides and antibiotics are soluble in fat [15], and fat-soluble pesticides residues are stored in animals' tissues and eggs, and then transferred to the next generation and finally to human tissues and organs through meat consumption [16]. Meat products are becoming a media that transfer antibiotics, pesticides and hormones into human's body [17]. And this is a major factor to modern diseases, such as obesity, cancer, puberty [18], [19], as well as swine flu, bird flu, etc.

As pesticides, antibiotics and hormones can cause many health problems and illnesses; this increases the burden of our society economically and physically. Use of pesticides leads to contamination of groundwater, and bacteria from "Concentrated Animal Feeding Operations" is threatening drinking water resources. This contamination has caused some widespread outbreaks of illness, such as diarrhea, gastrointestinal illnesses, skin illnesses, etc. Besides the livestock sector, the fishery sector is worse than ever before in its history in using hormones and antibiotics, it shortens animal's maturity time and lifespan, transfers toxic chemicals to fishes and then to human bodies, where the transferred hormone causes several kinds of cancers [20], [21].

Finally, those wastes from animal factories, and those chemical materials introduced by pesticides, antibiotics, and hormones become waste residuals in our environments, and cause further pollution to soil, air, water body and wildlife.

"More than 34,000 miles of rivers and 216,000 acres of lakes and reservoirs in the US have been degraded by waste from confined feeding operations" [22]. "A 2007, the US Geological Survey found that pesticides contaminated 90% of all agricultural streams tested. Nearly 10% of them had concentrations considered unsafe for human health" [23].

Besides the above problems, the most serious environmental problem of this phase probably is the greenhouse gases emissions.

"The greenhouse gases from feedlots come from the digestive processes of cattle and sheep (enteric fermentation), manure and fuels burned for transportation and by farm equipment. Manure, which is stored in large lagoons or spread as fertilizer on fields, releases both nitrous oxide and methane, whose warming potential is 300 times greater and 25 times greater, respectively, than carbon dioxide's. Manure is the fastest growing major source of methane in the US, up 60% from 1990 to 2008" [24]. "In 2012, agriculture-related emissions were around 70 million tons of CO₂ equivalent—about 7.5% of the year's total greenhouse gas emissions. This means that after industry, which made up 84%, agriculture was the second largest emitter in Germany" [25].

Summary of Biodiversity and Ecosystem Impacts:

1. CO₂, Methane, and Nitrous Dioxide emissions contribute to global warming: equivalent to 18% of global CO₂ emission.
2. Animals' manure causes waste pollution to soil, air, and water.
3. Residual and impacts from pesticides, antibiotics, hormones, and other chemicals that are introduced to ecosystems when raising cattle affect human health and well-being; possible biodiversity variation is caused by using above chemical materials.
4. Large amounts of water are used to raise cattle for meat products consumption despite the world water shortage situation.
5. Overgrazing by cattle causes desertification of farmland and degradation of soils. Nearly 33% of arable land globally is used to produce livestock feeding grains, which causes tremendous losses in world food production.

D. Slaughterhouse Processing

Most people take it for granted that meat comes from the supermarket; however, consumers have the right to know where their food comes from, and meat production should start from animal farming; an animal becomes meat in the slaughterhouse, until then, they are intensively fattened up until their legs can no longer sustain their weight. Meat production starts from the slaughterhouse, where meat is produced through several steps: animals are killed by machines; their bodies are separated, the flesh are processed as meat, other parts are made into by-products through biochemical treatment and post processing; followed by packaging, storage and transportation.

There are two main wastes released during slaughterhouse processing, the first are the useless and inedible solid waste from animal's body, like unused bones and hair, another waste is the waste water that results from slaughterhouse activities that contains several kinds of pollutants such as blood, manure, and cleaning chemicals, which will later cause pollution to ecosystems [26].

Beside the waste mentioned above, slaughterhouse

consumes much energy to run all the machines, equipment and the power used for cooling, storage, packaging and transporting live and dead animals in and out.

"It's estimated that electricity consumption accounts for five percent of beef related emissions, 13 percent of pork related emissions and 24 percent of chicken related emissions." [27].

There are big concerns related with slaughterhouse introduced bacteria problems; those bacteria and virus are easily transferred to residents nearby and to consumers. Since the last century there have been several major global-scale infections of bird flu and swine flu, which originated from animal raising area or factories [28]. People in close contact with animals are more likely to get infected.

In a slaughterhouse, once the animals are dead, ptomaines are generated within several minutes, and even with the many post processes that are implemented, the ptomaine cannot be destroyed completely, and this can cause cancer and tumors from long-term consumption of contaminated meat products. If the sanitary conditions and processes are not strictly controlled, the slaughterhouse could be a place that introduces many viruses that are harmful to consumers' health and the environment.

Summary of Biodiversity and Ecosystem Impacts:

1. Water, soil pollution caused by slaughterhouse waste water released.
2. Water wasted in cleaning and operating slaughterhouse.
3. Further pollution to the environment is caused by solid wastes released from slaughterhouses, such as chemicals, useless animal parts, packaging, storage, and cleaning materials.
4. Energy used in slaughterhouse operations increases the environmental burden of greenhouse gases emissions and other pollution.
5. Waste residues for landfill cause pollution to ecosystems, soil contamination, and biodiversity variation and landscape impacts.

E. Meat Consumption

Meat consumption involves many interrelated works from other sectors in the society, such as transportation, energy, health, chemical industry and food industry, etc.

"What we eat not only affects our own health, but also the environment. Food is at the heart of many environmental issues – it's a significant contributor to climate change and responsible for 60% global biodiversity loss" [29].

Meat products post processing can introduce many artificial chemicals such as pesticides and fertilizer residues, artificial hormones, antibiotics residues, preservatives, colorants, flavorings, and food supplements, which are the most common materials or toxins in our daily consumed meat products. Pesticides and fertilizer residues can stay in the feeding plants and then be transferred to animals that eat them, and since those chemicals may be soluble in animal fats, they are transferred to meat consumers. Antibiotics and hormones that are used in animal's body can be transferred to meat

consumers as well [30]. Added up, the artificial chemicals introduced during the meat products post processes, mean that our food is now beyond the meaning of real food.

"As a result, food producers use any of 14,000 laboratory-made additives to make our food to appear fresher, more attractive or last longer on the shelf" [31].

And bacteria and viruses can be transferred from cattle to the environment through contact media, air and meat consumption, which causes difficult or fatal diseases to human consumers,

"there has been a concern about a connection between cows infected with bovine spongiform encephalopathy ("Mad Cow Disease") and Creutzfeldt-Jakob Disease, a 100% fatal human brain disease" [32].

Besides the health problems introduced by prions, viruses and bacteria by meat products, meat consumption is the major factor for global obesity. According to WHO,

"39% of adults aged 18 years and over were overweight in 2014, and 13% were obese", while "41 million children under the age of 5 were overweight or obese in 2014" [33].

There are more diseases related to meat consumption directly and indirectly, and this leads to great economic losses every year, especially in developed countries where meat consumption is highest.

Through meat products consumption, the chemicals introduced from the producing place are transferred to the meat consumption place. Food security and contamination issues are becoming an international problem through meat imports and exports. It also creates other political, diplomatic, economic, environmental and global health problems.

Since the 1960s, meat consumption kept increasing through modernized animal raising technologies and economic development. Fig. 2 shows global meat production trends from 1961 to 2006. The figure shows that during the last 45 years, pork production tripled, beef has production doubled, and poultry production has increased six-fold. The soaring rise in meat production has lead to increased consumption of natural resources and environmental problems, as well as new health issues and diseases.

Global production of meat

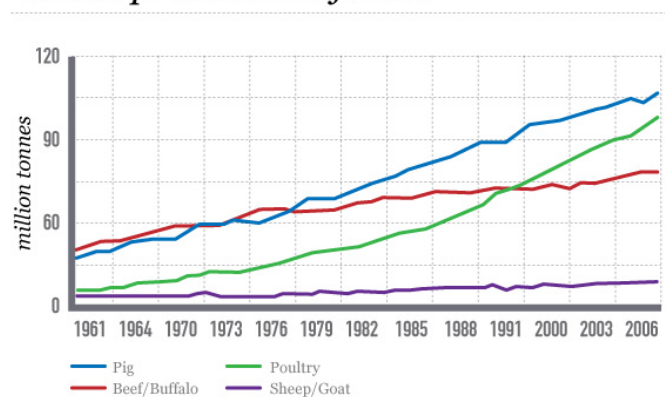


Fig. 2 Global production of meat [34]

A recent research published by British Medical Journal concluded:

"The results show increased risks of all-cause mortality and death due to nine different causes associated with both processed and unprocessed red meat, accounted for, in part, by heme iron and nitrate/nitrite from processed meat" [35].

And the related research results show that meat consumption is the key reason that causes several major diseases, such as diabetes, cancer, infections, stroke, kidney diseases, heart diseases, respiratory tract, liver disease, and etc.

Summary of Biodiversity and Ecosystem Impacts:

1. Greenhouse gases emission caused by energy consumption in food cooking, post-processing, packaging, storage, and transportation systems contribute to global warming.
2. Artificial chemicals, bacteria and virus introduced into ecosystems cause pollution to air, soil, water; biodiversity variation; human ecosystem health problems.
3. Antibiotics, hormones, and other artificial chemicals can be transferred from meat products to meat consumers, which will impact our ecosystems.

F. Meat Products Waste Management

After meat products consumption, the waste management is another big job. In many countries, the meat products waste that is not edible and cannot be used as by-products is handled by waste management companies. But in some developing countries, due to their environmental implementation limitations, some meat products wastes are not well managed; wastes are dumped without any post biochemical or physical processing, and thus, cause air, soil, water pollution; and even health hazards to residents nearby.

In a common waste management process, the solid wastes and liquid wastes from meat products consumption are processed with composting or anaerobic treatment. Through composting, the wastes change into fertilizer and can be reused in agriculture in an eco-friendly cycle. With anaerobic treatment, the degradable part can be used as fertilizer or landfill, the liquid part enters the water way and enrich the water body, and leads to algae and fish living space risks, finally pollutes the water body and endangers water ecosystems [36].

Summary of Biodiversity and Ecosystem Impacts:

1. Dumped solid wastes cause pollution in air, water, and soil, and introduce bacteria, chemicals to ecosystems that bring health hazards.
2. Wasted water treatment cause soil and water body pollution, and endanger to health of water body, aquatic organisms, groundwater, and environment around.
3. Artificial chemicals used in food preservation, processing and addition introduced into ecosystems, lead to enriched water, biodiversity variation, mass death of fishes and water plants.

III. DISCUSSIONS OF SOLUTIONS

G. Ecosystem Recovery

In addition to the responsibilities in waste management of different meat producing phases, the government, community, investors, and animal factories should take responsibilities to handle environmental problems after the closure of animal farms or factories.

This step should be included in the meat production life cycle ideally. But in actuality, the ecosystem cannot be recovered if the ecosystem impacts are irreversible. We are facing the task to search for an alternative food system to reduce ecosystem impacts, and make a transition to a sustainable food system, and at the same time, to feed the world population.

H. Sustainable Food is the Solution

IV. THE VOICE OF EXPERTS, SCIENTISTS, AND LEADERS:

Since 2006, the UN FAO published data that with regard to livestock's contribution to GHG emissions, most government and public organizations have increased their consciousness of meatless solution to curb global warming and their own environmental problems.

"If you're serious about protecting the environment, the most important thing that you can do is stop eating meat, eggs and dairy foods" [37].

The German Environment Ministry published a new rule that meat and fish will no longer be served at their official functions [38].

V. PUBLIC HEALTH CALLS

Addition to the concern for the environmental aspects of meat production and consumption, most people become vegetarian or vegan due to health concerns or food safety considerations; meat products introduce fertilizers, pesticides, hormones, antibiotics, preservatives and other artificial chemicals in food supply chain, and human consumers intake these chemicals through meat consumption. It was scientifically shown that meat products are a killer to human health; it can cause varieties of cancer, heart disease, obesity, high blood pressure, diabetes, swine flu and bird flu. "*Sustainable and healthy diets will require a move towards a mostly plant-based diet*" [39].

VI. CURB THE GLOBAL WARMING

As the FAO reported, the meat products supply chain contributes to 18% of the planet's greenhouse gas CO₂ emissions; 65% human related greenhouse gas nitrous oxide emissions, 37% human generated methane; and 64% percent of the ammonia (which contributes to acid rain and acidification of ecosystems) [40]. The food industry contributes GHG more than the total GHG from the transportation sector, and is the number one factor for global warming and climate change. Our diet is affecting our environment, our fate, and future generations. Efforts to reduce the harmful effects of this industry include "*Meatless*

Monday" in the US, in which the benefits are promoted as: "If all US Americans practiced Meatless Mondays, we would reduce the US national GHG emissions by 0.6%" [41]. Our diet style can be a good solution to curb global warming, without any policy and government meetings.

VII. REDUCE WORLD HUNGER

Meat products production is the main reason of food waste; 21 pounds of feeding grains can produce only 3 pounds of cattle meat, which accounts for the lowest land use efficiency among food products. If the feeding grains were used as human food products, it could reduce world hunger population immediately. "Cutting Back on Meat Consumption Could Help End Hunger by 2030" [42].

VIII. SAVE THE NATURAL RESOURCES

As the analysis from above sections confirms, meat products consume more natural resources, such as water, energy, arable land, etc. To save our limited natural resources, a sustainable food system is one of the best solutions. Encouraging people to eat sustainable foods, such as "plant-based food", "fresh and local produced food", can lead to more sustainable food consumption, and thus create a promising sustainable food supply chain in the near future.

IX. CONCLUSION

We can make the conclusion from the above analysis and discussions that meat production has a huge impact on our ecosystems.

1. Leading factor for Biodiversity Loss;
2. Water waste, land use waste and land degradation;
3. Greenhouse gases emissions;
4. Pollution to air, water, and soil;
5. Leading factors that cause main major diseases.

The sustainable food system can feed the world population at the same time mitigate ecosystem impacts from meat-based food production.

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