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Invited Review Article

Poultry and fishery industry: Environmental effect and its mitigation strategies

A. Verma Mukherjee[1*] and S. Haldar[1]

[1]Agrivet Research and Advisory Pvt Ltd, Lake Town, Kolkata- 700 089, West Bengal, India

Abstract

Increasing demand for animal-based food has led to sky-high production and domestication of livestock in the recent past. This increased rearing of livestock including poultry farming and aquaculture is the cause of wide range of environmental effects leading to climate change. According to estimates, the cattle sector is responsible for 18% of all worldwide greenhouse gas emissions. Chickens are estimated to emit 0.6 gigatonnes of carbon dioxide-equivalent, representing eight per cent of the livestock sector's emissions. The global aquaculture sector contributed 0.49 percent of anthropogenic greenhouse gas (GHG) emissions in 2017. About 7516 million tonnes of carbon dioxide (CO_2) are released into the atmosphere each year. Carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ammonia (NH_3) make up the majority of emissions associated with the livestock business. In the poultry industry, the increased usage of concentrate feed, especially grains and soybean meal, has contributed a lot to increase in agriculture activities and crop farming at the expense of forest land. Understanding the effects of aquaculture on the environment has recently been started. However, sustainable and responsible utilization of land, water, and feed resources in chicken and fish industry has been able to considerably minimize the consumption of water, farmland, electricity, greenhouse gases, and other vital resources. Continuously innovating and more research is still required to improve feed digestibility and animal genetic predispositions in order to maintain current production levels while lowering carbon footprint from the chicken and fish produces.

Key words: Aquaculture, Carbon footprint, Greenhouse gas, Livestock, Poultry

Highlights

- The environmental impact associated with livestock farming is staggering.
- Increased feed production leads to an increase in agriculture at the expense of forestland.
- Sustainability in livestock industry refers to responsible use of land, water, and feed resources.
- Developing sustainable and environmentally friendly practises is the only answer.
- With the aid of technological improvements limiting environmental effects is possible.

INTRODUCTION

Due to an increase in demand over the past 100 years, animal food production has increased (Steinfeld *et al.*, 2006). The livestock sector is the cause of a wide range of environmental effects. Different livestock production systems, types of animals, land use patterns, types of feed, enteric fermentation, manure management, slaughtering, processing, and storage contribute significantly to total greenhouse gas (GHG) emissions (Haldar *et al.*, 2022). Currently, the livestock sector emits an estimated 7.1 GT of CO_2-equivalent per year, representing 14.5% of human-induced GHG emissions (Crippa *et al.*, 2021). Carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ammonia (NH_3) make up the majority of emissions associated with the livestock business. Carbon dioxide is "naturally" released by domestic animals, and this gas significantly contributes to global warming. Over two-thirds of the world's agricultural land and one-third of its total land area are already used for livestock farming. The livestock sector has emerged as the primary driver of forest clearing and pasture conversion due to the rising demand for animal products and the limited availability of land. To fulfil the growing need for a cheap

*Corresponding Author, E mail: arpana@agrivet.in

and secure supply of meat and eggs, the poultry and aqua-industry has made enormous technical advancements over the past few decades. This article examines the environmental repercussions of the production of fish and poultry, evaluating these aspects from feed production to animal production and slaughter. It considers the consequences on all environmental media, including air, water, and land, at both local and global levels.

Livestock industry: The impacts of animal product consumption on environment

In order to meet the demand for meat and other animal products, animal farming has increased significantly worldwide. In 2020, for example, around 33.1 billion chickens were registered globally. This was approximately 130% more than in 2000 (Hötzel *et al.*, 2022). According to studies released in early 2013, around 70 billion animals were raised as domestic animals worldwide each year, with more than 6 million being slaughtered for food (Oppenlande, 2013) and roughly 56 billion mammals and birds being slain. Intensive livestock farming has negative consequences for the environment. It is characterized by high land and water consumption, pollutes soil and water, and contributes to climate change with its emissions.

The livestock sector requires a significant amount of natural resources and is responsible for about 14.5% of total anthropogenic greenhouse gas emissions (FAO, USA, 2010). CO_2, N_2O, CH_4 and NH_3 make up the majority of emissions associated with the livestock business (Leytem *et al.*, 2011; Russell *et al.*, 2014). Domestic animals "naturally" release CO_2, which significantly contributes to global warming. Over two-thirds of the world's agricultural land and one-third of its total land area are already used for livestock farming (Ilea, 2009). The livestock sector has emerged as the primary driver of forest clearing and pasture conversion due to the rising demand for animal products and the limited availability of land. The consumption of natural resources, extinction of plants and animals, water soils, and global warming are all significantly impacted by the meat business on a large scale (Steinfeld *et al.*, 2006).

Poultry farming in India: Poultry farms refer to breeding, hatcheries, layer and broiler farms. Raising domesticated birds for food production, such as chickens, turkeys, ducks, and geese, is known as poultry farming. The most prevalent and common domesticated poultry species is the chicken, while other species, including duck and geese, make up a very minor fraction of

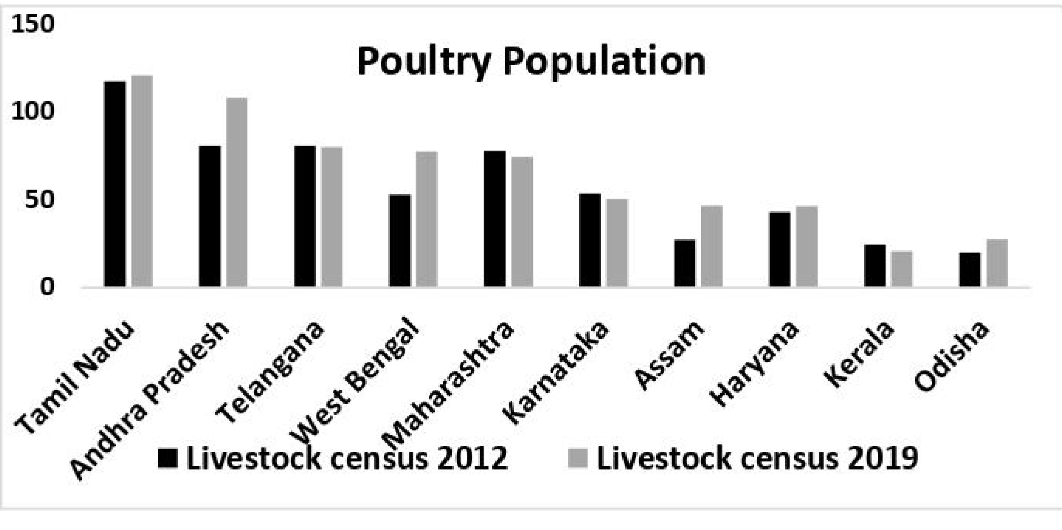

Fig. 1. Poultry population of major states of India in 2012 and 2019. (20th Livestock Census)

activities. India's poultry farming industry has grown dramatically over the year and becoming a thriving sector of the agricultural economy. As per the 20th Livestock Census, the total poultry in the country was 851.81 million in 2019, which is an increase of 16.8% over the previous Census. The total backyard poultry in the country was 317.07 million in 2019, an increase of 45.8% over the last Census and the total commercial poultry in the country was 534.74 million in 2019, an increase of 4.5% over the previous Census. Tamil Nadu, Andhra Pradesh, Telangana, and West Bengal are the top states with poultry farms, followed by Maharashtra, Karnataka, Assam, Haryana, Kerala, and Odisha.

General impacts of poultry farming on local environment: Feed production, energy use, and manure management are the three main causes of the environmental effects connected with chicken farms. According to Rodić *et al.* (2011) and Maheshwari (2013), poultry facilities are a source of stench and attract flies, mice, and other pests that cause annoyance in the neighbourhood and spread diseases. The odour emissions from poultry farms affect local residents because of a number of contributing factors, including NH_3, volatile organic compounds (VOCs), and hydrogen sulphide (H_2S) (Maheshwari, 2013). In regions where manure is stored, poor manure management typically leads to the contamination of soil and water with nutrients, pathogens, and heavy metals. People who reside close to poultry operations are also concerned about fly infestations.

Another issue of environmental concern is water pollution near poultry houses. There have been allegations that pesticides are used to manage pests and predators, such as parasites and disease vectors, pollute groundwater and surface water. Poor disposal of poultry carcasses can make water quality worse, especially in areas that are prone to flooding or have a low water table (Maheshwari, 2013). The primary environmental issue caused by slaughterhouse operations is the discharge of wastewater into the environment. Like many other food-processing activities, the need for hygiene and quality control in meat processing leads to high water usage and, as a result, high levels of wastewater generation, which has high levels of biochemical and chemical oxygen demand (BOD and COD) due to the presence of organic materials like blood, fat, flesh, and excreta (Harris *et al.*, 2018). Aquatic life may then become less active or possibly die as a result of this. Salmonella and Campylobacter bacteria as well as leftovers from cleaning and disinfection agents like chlorine, may be present in the water. In addition, process wastewater may contain high levels of nitrogen and phosphorus which may cause eutrophication of the affected water bodies.

Impacts of poultry farming on the global environment: The effects of poultry production on the environment can have an impact on a global scale. Increased usage of concentrate feed, especially grains and soybean meal, has contributed to the outstanding performance of the chicken industry over the past three decades. According to OECD/FAO estimates, by 2025, chicken meat will outpace beef, lamb, and pork in terms of production and consumption. This estimate was mostly based on the availability and cost of chicken meat as a low-fat source of protein (King *et al.*, 2017). However, this increased feed production has led to an increase in agriculture at the expense of forest land (deforestation). Regarding poultry farming activity, the potential impact on environmental factors refers to ammonia emissions into the air, nitrogen and phosphorus leaks from manure into the soil, groundwater and surface water (Mitroi *et al.*, 2021).

Mitigation strategies: Mitigation, in relation to climate change, is any practice that reduces the net amount of GHGs released into the atmosphere. To make a balance between demand and supply, specific mitigation strategies with multidisciplinary approaches on livestock production systems, animal nutrition, shelter and manure management, disease surveillance and health care need to be addressed (Haldar *et al.*, 2022). Thornton and Herrero (2014) suggest that three dimensions of sustainability (economic, environmental, and social) need to be considered before recommending suitable mitigation opportunities. Improving production efficiency will increase the output of meat, milk, and eggs per unit of input, thereby reducing GHG emissions per unit of product produced (Smith, 2014). Proper manure management will reduce GHG emissions and has the added benefit of protecting air and water quality. Manure management techniques have a significant impact on the size of environmental impacts. Numerous methods and management techniques can be used to control the aforementioned environmental effects. The anaerobic digestion of manure slurries prior to application to soils is one of the promising practices for mitigating GHG emissions from manure (Yang *et al.*, 2019). Odour and flies can be controlled by minimizing the surface of manure in contact with air, frequent collection of litter (once a week in dry seasons and twice a week in rainy seasons) and closed storage (bags or closed sheds). Also, keeping manure in closed structures or bags prevents the spread of water- and food-borne diseases (Burkholder *et al.*, 2007; Scallan *et al.*, 2011). Vermicomposting is a bio-ecologically effective, economically sustainable and eco-friendly waste management technology that can help to reduce environmental impacts and associated health risks (Mahaly *et al.*, 2018; Raza *et al.*, 2021). Vermicomposts are good sources of bio-fertilizer and earthworms are an excellent source of protein for fishes and monogastric animals (Hussain and Abbasi, 2018; Kopec *et al.*, 2018). Alternative strategies for using the manure material could be used for the generation of electricity. This reduces the emission of GHGs from the manure and also reduces the emissions of GHGs associated with fossil fuel combustion (Stiles, 2017).

A contingency plan should be in place for disposing of large numbers of dead birds in the event of disease outbreaks (Delgado *et al.*, 2010). Additionally, consideration should be given to impacts on the physical environment; for example, burial pits should be at least 3 metres above the maximum groundwater table. Dead-bird management and disposal must also comply with legally accepted practises, including rendering, composing, incineration, and burial (Mustafa *et al.*, 2018). Installing energy-efficient lighting, such as LED lamps, along with efficient heating and cooling systems, will lessen GHG emissions and reduce energy bills (Smith, 2014).

Sustainability: How is the chicken industry minimizing its environmental impact?: Chickens are the most efficient converters of feed into meat of all land-based livestock species due to several key factors like traditional breeding, nutritious feed tailored to each stage of a chicken’s life, better living conditions through climate-controlled barns and new technology, and protection from extreme temperatures, predators and disease, up-to-date biosecurity practices and veterinary oversight (Hume *et al.*, 2011). Because of all of these reasons, chicken consumes less feed and water to reach market weight, reducing its environmental impact.

In addition to that, to promote a healthier earth, the chicken industries are dedicated to environmentally sound and sustainable chicken production methods. Sustainability in the chicken industry refers to using land, water, and feed resources responsibly (Steinfeld *et al.*, 2006). The chicken industry has been able to considerably minimize the consumption of water, farmland, electricity, GHGs, and other vital resources by continuously innovating and guaranteeing the highest possible bird health. In fact, producing the same amount of chicken today as in 1965 has 50% less impact on the environment (NCC, 2020).

In comparison to almost all other animal agriculture industries, the production of

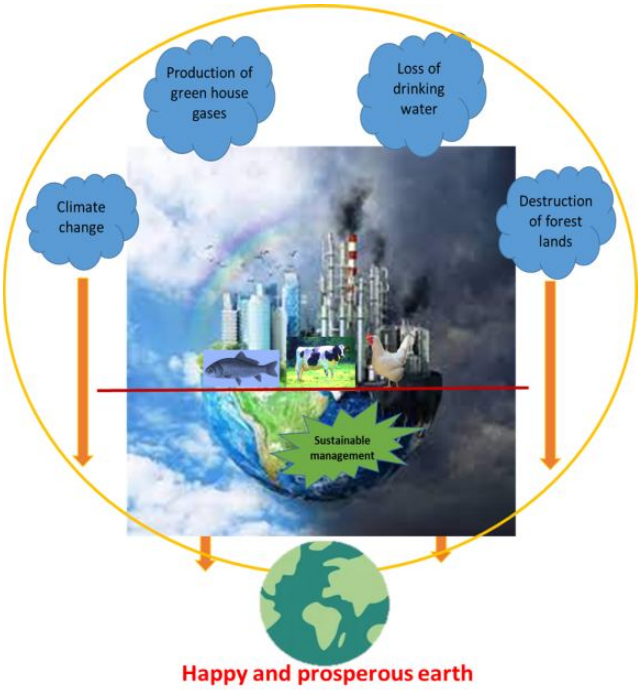

Fig. 2. Sustainable management strategies in poultry and aqua-industry for a happier earth

chickens has a smaller environmental impact (da Silva *et al*., 2014). To ensure that we leave the planet in better condition than when we found it, the chicken industry is constantly improving and developing sustainable and environmentally friendly practises. With the aid of technological improvements and enhanced animal husbandry techniques, this industry has achieved considerable progress in limiting environmental effects (Nkukwana, 2018). In addition to feed driving the cost of production of poultry, carbon footprint of live poultry production is also known to be highly related to feed. New feeding strategies are being planned to reduce these effects on the global climate. In a recent study based in Brazil, it was observed that the feed carbon footprint contributed to more than 90% of total carbon emissions/kg live weight (Blanvillain rivera *et al*., 2022). In this study, it was revealed that using poultry fat rather than soya oil allowed to reduce carbon footprint by 9% when maintaining fat level at 2% of feed diet. This was possible because the carbon emission factor of poultry fat is almost four times lower than that of soy oil. It was observed in this study that providing poultry diets devoid of animal by-products led to a 28% rise in broiler carbon emissions. The usage of soy oil and the rise in the use of soybean meal as a substitute for animal meal were the main causes of the increase in carbon emissions. Overall, the study shows that choosing a feeding plan is a key factor in intensive live broiler production systems' carbon emissions, and ingredient reassessment and sustainable planning can lower the emissions in a more effective way.

How is the chicken industry limiting resource and energy use?: All food productions, including meat, seafood, fruits, and vegetables, produce GHGs. The chicken industry is committed to minimizing the negative effects on the environment brought on by the usage of resources and waste products from poultry production that fuel global warming (Nkukwana, 2018). The environmental effect of producing 1000 kg of live chicken has decreased by half since 1965. Today 75% lesser resources are needed to produce the same amount of chicken as was in 1965 (Putman *et al*., 2017). Modern technology and better animal husbandry techniques have made these developments possible. Efficiency and localization have a direct impact on lowering GHG emissions. Chicken production takes place very close to home; localized production at the hatchery, farm, and processing facility cuts down on expenses, emissions, and travel time (National Chicken Council blog, accessed in 2022).

Most chicken farms today use LED illumination, which can reduce energy consumption by 80–85 percent when compared to incandescent light bulbs (Barros *et al*., 2020). The majority of modern poultry houses are automated to adjust the temperature and ventilation to keep the chickens in the best possible circumstances while using less gas and power.

Responsible use of poultry litter and manure: A sustainable nutrient loop

Poultry litter consists of a mixture of chicken excrement, feed that has been spilled, feathers, and bedding material of the houses. The poultry litter may be used as fertilizer, animal feed, fuel source etc. (Bolan *et al*., 2010; Dalólio *et al*., 2017). However, before poultry litter is used as animal feed, it must be properly processed. Materials such as feathers and plastic must be removed before use. Also, bacteria such as salmonella may also be present in the poultry litter which must be properly removed through processing before using it as animal feed to avoid harm to the animals consuming it. In fact, the litter from chickens is not a waste. Rather, it is a very important agricultural input resource. Poultry litter is gathered and stored by farmers for use as an organic crop fertilizer. It's a closed, sustainable nutrient loop where plants feed by the chickens, and chickens fertilize the plants (Dalólio *et al*., 2017). Poultry manure contains all 11 of the essential plant nutrients that are used by plants. These include iron (Fe), boron (B), calcium (Ca), magnesium (Mg), manganese (Mn), copper (Cu), zinc (Zn), phosphorus (P), potassium (K), sulphur (S), and molybdenum (Mo). Animal feed, supplements, pharmaceuticals, and water use are the sources of plant nutrients. All or part of the plant needs may be met by using poultry manure as fertilizer for trees or crops (Sangodoyin *et al*., 2003). Chicken manure is an important raw material in mushroom compost and for the composter, as it is the biggest source of nitrogen. In addition, it is full of decomposable carbohydrates and numerous interesting minerals for compost nutrition (Pokhrel, 2016). Poultry manure also contains many bacteria and other microorganisms with a beneficial effect on the composting process (Nauanova *et al*., 2020).

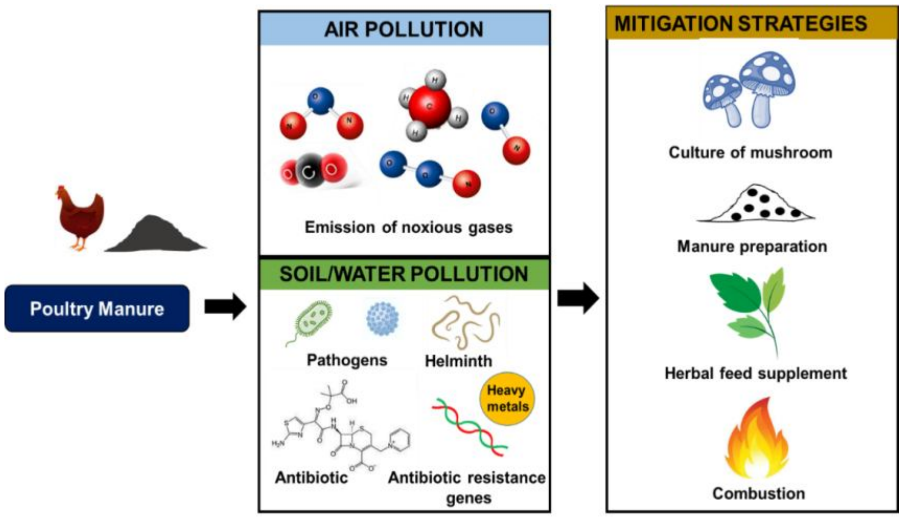

Fig. 3. Poultry manure management to reduce environmental impact of poultry

Environmental impacts of aquaculture: By boosting food availability and accessibility, global aquaculture both directly and indirectly plays a significant role in ensuring food security (MacLeod *et al*., 2020). The effects of aquaculture on the environment are only now starting to be understood. Through feed waste, fish excretion, faeces production, and respiration, a very high percentage of the organic carbon and nutrients input as feed is lost into the environment in all aquaculture systems (MacLeod *et al*., 2020). In many nations, especially with limited carrying capacity of water, the high pollution loading has raised serious environmental concerns (Cole *et al*., 2009; Robb *et al*., 2017). Environmental issues have also been brought up by the usage of chemicals (such as therapeutics, vitamins, colours, and antifoulants) as well as the introduction of infections and new genetic strains (Robb *et al*., 2017).

Many aquaculture species, especially salmon, need wild fish as fish meal and fish oil for their sustenance. What this means is that most of the time, it takes more than a kilogram of wild fish to create a kilogram of farmed fish (Kaushik and Troell, 2010). Even if the fish farming industry has recently become more feed-efficient, the overfishing of forage fish around the world is endangering marine food webs. Forage fish now make up around 20% of the global catch, the most majority of which is used as feed for aquaculture.

The farming of marine fish, crustaceans and even bivalves produce waste in the form of faecal matter and unused feed. These largely nitrogen-based wastes can cause oxygen depletion in coastal environments and a net loss of marine productivity in certain coastal areas. Additionally, the use of antibiotics, antifoulants, and pesticides are all problems that aquaculture can introduce into the marine environment (Chen, 1991).

Shrimp farming has drawn the most criticism because shrimp are raised in tropical and subtropical ponds and impoundments which are frequently located inside the boundaries of coastal mangrove forests. Hundreds of thousands of acres of mangrove forests have been destroyed, which are essential ecosystems for the growth of wild fish and the defence of the coast against storm surges (Paprocki and Cons, 2014). Mangrove cutting has decreased recently in some areas, most notably in Thailand, where it is now prohibited, but new issues continue to emerge (Goldberg, 2020).

Lowering the environmental impacts of aqua farming: Maintaining stocking densities (and, thus, pollutant loadings) substantially below the carrying capacity of the water body is one practical technique to reduce the environmental impact of fish farming (Hammer *et al*., 2022). The maximum stocking density at which water quality might be sustainably maintained may be calculated using computer simulation and hydraulic models. Improved feed formulation and integrated culture can also dramatically lower pollution loading and environmental consequences (Ahmed and Turchini, 2021). Mitigation and adaptation may help us to deal with climate change as effectively and efficiently as possible (Zolnikov, 2019). A mix of new and established technologies and techniques, such as electrification, hydrogen production, sustainable bio-based feedstocks, product substitution, and carbon capture, use, and storage, can be used to reduce GHG emissions with a particular focus on CO_2 emissions (Environmental Protection Agency, 2016). Producers and other stakeholders in aquaculture may be able to significantly reduce the consequences of climate change by making the necessary changes to their production practises focused at reducing GHG emissions. This specifically entails utilizing eco-friendly procedures and technology, including solar electricity, appropriate feeding procedures, and sustainable wastewater management (Maulu *et al*., 2021).

Conclusions

Both poultry farming and aquaculture continue to significantly expand its production, making them one of the fastest-growing food production sectors globally. However, the sustainability of these sectors is at stake due to the predicted effects of climate change that are not only a future but also a present reality. The production of poultry in intensive systems, aqua farming and their effects on the environment have been the main issues of discussion. This review has shown how it's important to look beyond individual farms in order to understand how the industry affects the environment. Even though numerous studies have shown that the production of poultry has a lower environmental impact than that of other livestock, more research is still required to improve feed digestibility and animal genetic predispositions in order to maintain current production levels while lowering its carbon footprint. Likewise, in aquaculture, improved feed formulation and integrated culture can lower pollution loading in the aqua-system and its environmental consequences.

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Author's contribution: AVM: Compiled and wrote the manuscript; SH: Edited the first draft of the manuscript.

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