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# CONTENTS

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RESEARCH ARTICLE

# Global impact of COVID-19 on the sustainability of livestock production

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**Abstract**
Global transmission of the 2019 coronavirus illness (COVID-19), caused by the coronavirus 2 strain associated with severe acute respiratory syndrome, has started (SARS-CoV-2). The pandemic has had far-reaching, devastating effects on human society, the natural world, and the environment on a global scale. The many links in the food production chain, particularly agriculture and cattle, are also badly impacted in terms of product sustainability and monetary losses. There has been a considerable drop in meat, milk, and egg production because of the global epidemic. National and international movement limitations enacted as part of public health sector control efforts have impacted the accessibility of inputs for livestock producers and farm outputs, veterinary services, farmworkers, and animal care businesses. As COVID-19 impacted the global livestock sector which is continuing, understanding and implementing sustainable approaches in livestock production is needed for both academia and industry. To respond to this need, this study carried out a systematic review of the existing literature on the impact of COVID-19 on the sustainability of livestock performance and welfare on a global scale. Significant consequences on livestock performance sustainability, worldwide animal welfare, and mitigation methods are discussed in this paper in light of the recent outbreak of COVID-19.

**Keywords:** Livestock production; COVID-19; Supply chain; Animal welfare; Sustainability

## Introduction

Worldwide anarchy in 2019 can be traced back to the pandemic Coronavirus epidemic that began that year. The disease has had such a terrible effect on people's health, economies, and social life all across the world that the World Health Organization (WHO) has declared it a pandemic (Zhou et al., 2020). A contributing element to the virus's virulence is the fact that COVID-19 was initially identified in zoo specimens (Tazerji et al., 2020). The virus destroyed all of the towns and ended life as it had been known before in a relatively short length of time. Although lockdown was an essential measure to halt the pandemic's spread, it had devastating unintended consequences for human and animal health and caused a financial disaster on a scale never previously witnessed. The inability of the populace to leave their homes has these results (Shehata et al., 2021).

COVID-19 has also had a significant negative impact on agricultural sectors worldwide (Rahman et al., 2021). This has had an obvious effect on the long-term viability of animal production systems, especially those that produce meat and milk, as well as supply chains, trade, and consumers' purchasing patterns (Bekuma, 2020). Global food insecurity is a big issue, especially because of the pandemic's effect on cattle production systems. The situation has worsened as a result of organizational shifts in animal care. As COVID-19 impacted the global livestock sector which is continuing, understanding and implementing sustainable approaches in livestock production is needed for both academia and industry. However, there is a research gap between COVID-19's impact on livestock production and the sustainability of livestock performance. To fill up this research gap, this study carried out a systematic review of the existing literature on the impact of COVID-19 on the sustainability of livestock performance and welfare on a global scale. The key concerns of this study are the long-term viability of livestock production and the impact that COVID-19 has had on the health and well-being of animals.

This review accumulates information from various organizational reports, cited observations, and scientific papers in order to illustrate how the outbreak of COVID-19 has affected livestock production all over the world, including the dairy, beef, and poultry industries, as well as their respective management systems. This kind of information and data might be helpful in making substantial efforts to improve the current situation and to assert learning for our future, with a particular emphasis on food security through sustainable livestock

production. Moreover, this study highlights COVID-19's effects on animal welfare and health which could be helpful to achieve sustainability of farming operations. Furthermore, this article provides recommendations for improved animal husbandry during the COVID-19 pandemic and the sustainability of livestock production.

**Methodology**

To provide a complete understanding of the sustainability of livestock performance and welfare on a global scale, this study conducted a systematic literature review to summarize the results and discussions on studies that cover the impact of COVID-19 on the sustainability of livestock production. A systematic review of the scientific literature leads to the selection of 44 documents published between 2020 to 2022. The documents were collected from Web of Science (WOS), Scopus, and Google Scholar databases. Figure 1 presents the development of criteria for document selection to conduct the review. This work presents an overview of the impact of COVID-19 on the sustainability of livestock performance and welfare on a global scale. To ensure the quality of the present study's findings, the development of a relevant agenda for future research, and provide appropriate recommendations for sustainable livestock production, this study included the research articles only from peer-reviewed journals. These papers were further analyzed to assess if the focus of their study was related to the present study's objective.

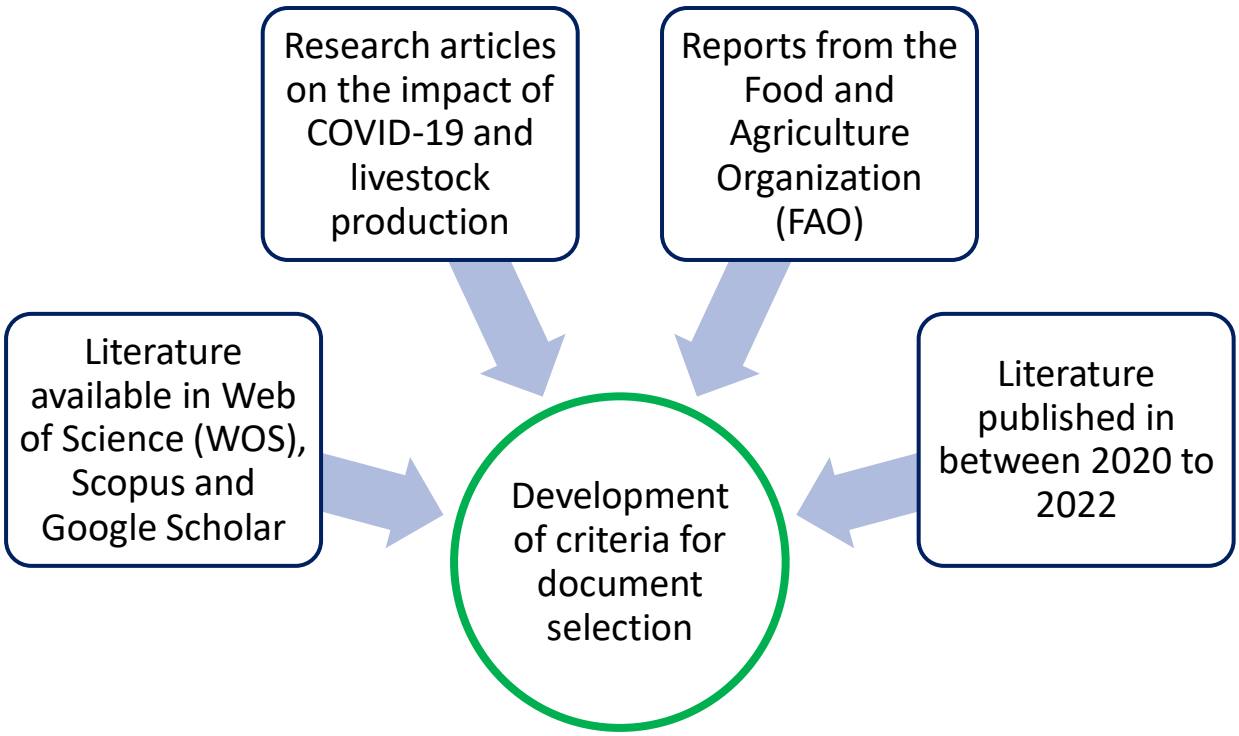


**Figure 1.** The development of criteria for document selection

**COVID-19's impact on livestock production**

Economy, food distribution networks, and people's standard of living are only few of the many spheres of influence that are intricately linked to livestock production systems (FAO, 2020a). The COVID-19 pandemic has had a devastating effect on the whole animal-rearing industry,

including its processing, transportation, sales, and consumer behavior (FAO, 2020b). Processing facility closures, travel restrictions, and quarantine/isolation practices all contributed to a scarcity of workers and/or the elimination of some jobs in the food supply chain. Hence, many countries' agricultural systems are under danger (FAO, 2020b). Backlogs have developed in the majority of Austria's animal production systems due to the labor issue. Eighty percent of Austria's meat processing industry workers are immigrants from Eastern European countries (Hashem et al., 2020). Between 60%-70% of Chinese dairy farms reported a lack of workers in February 2020. (Qingbin et al., 2020). In addition to other essential imported feed and feed ingredients, such as soybeans, wheat, and corn, a number of countries have said that they do not possess this commodity (Rahimi et al., 2022).

Developing countries have also suffered as a result of their reliance on international trade (Galanakis, 2020; Raihan, 2023a). Due to trade and movement limitations, several countries experienced a lack of veterinary services, production tools, vaccines, disinfectants, feed additives, and medications on the farm level (FAO, 2020b). The animals' health and well-being suffered as a result of this (Hashem et al., 2021). The global market for animals and animal products has also suffered severe harm as a result of the closure of a large number of retailers and restaurants, the implementation of a stringent lockdown, and the restriction of transit options. Twelve to fifteen percent less milk and cheese were consumed in the US (Gibbens, 2020). Sales of meat, eggs, and milk all dropped drastically in the United States, Southeast Asia, the Middle East, and Latin America during the COVID-19 pandemic (Galanakis, 2020). The lack of farmland has also contributed to an increase in the price of animal feed around the world (FAO, 2021a). The impact of COVID-19 on the long-term viability of cattle production systems is shown in Figure 2.

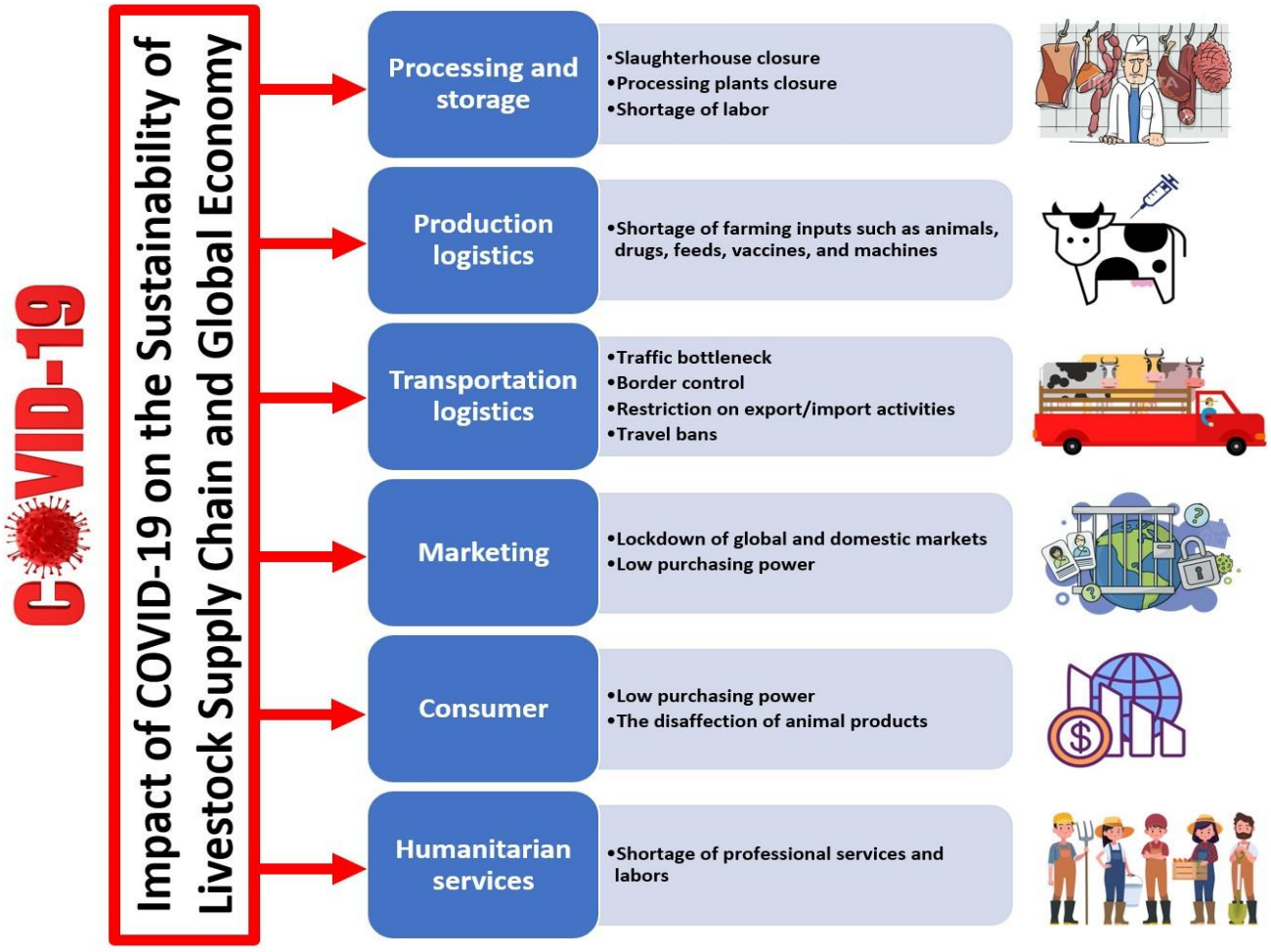


**Figure 2.** COVID-19 pandemic's effect on the sustainability of the livestock supply chain and the worldwide economy
**Source:** Adapted from FAO (2020b)

**COVID-19's impact on animal products**

This pandemic has generated significant secondary health concerns (for both humans and animals) and economic loss, despite the fact that social isolation and lockdown are necessary to limit and delay the spread of the virus (Shehata et al., 2021). This article explores how factors like lockdowns, isolation, panic, and employee illness affect livestock productivity.

**Meat**

Some specialists speculated at the outset of the pandemic that SARS-CoV-2 could be spread from humans in China to pangolins (WHO, 2021). The rising global population has resulted in a higher demand for meat and other foods (Raihan et al., 2021; Raihan et al., 2022a; Raihan and Said, 2022; Raihan, 2023b). The great bulk of the meat that is consumed by humans comes from livestock raised in intensive farming operations. The main components of worldwide animal production, imports, and meat exports are broken down into thousand tonnes of carcass weight equivalent and presented in Table 1 for the years 2019 and 2020 (before and during the COVID-19 pandemic). Since the beginning of the pandemic in 2019, there has been a decline in bovine meat output as well as decreases in imports and exports, whereas pig meat has shown the opposite trend (FAO, 2021b). In countries with a low income and a food deficit, production, imports, and exports of meat have all fallen. On the other hand, in developed countries, the output of meat has climbed while imports and exports of meat have decreased. In general, the findings indicate that the influence of COVID-19 on the production, imports, and exports of meat differs according to the kind of meat, with poultry meat being unaffected in comparison to other types of animal meat. In addition, the stages of development that countries are now in have a direct bearing on how output, imports, and exports shift through time.

**Table 1.** The livestock production, imports, and exports of meat (measured in thousand tons of carcass weight equivalent) worldwide before and after the COVID-19 pandemic

| Meat classifications | Production | | Imports | | Exports | |
|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 |
| Poultry | 131,562 | 133,266 | 12,451 | 12,501 | 14,241 | 14,226 |
| Pigs | 110,095 | 109,200 | 9,101 | 11,574 | 9,553 | 11,889 |
| Bovine | 72,410 | 71,408 | 10,627 | 10,650 | 11,335 | 11,193 |
| Ovine | 16,214 | 16,276 | 1,045 | 977 | 1,049 | 981 |
| Worldwide production of meat | 337,209 | 337,182 | 33,630 | 35,999 | 36,611 | 38,694 |
| Low-income nations with food deficits | 27,272 | 26,558 | 2,452 | 2,134 | 1,741 | 1,579 |
| Less developed nations | 14,448 | 14,570 | 1,483 | 1,393 | 56 | 50 |

Source: FAO (2021b)

Although there are no statistics available about the effects of the COVID-19 pandemic on the production of small ruminants, there has been claimed to be a short-term economic impact of COVID-19 on the small ruminant flocks in Spain. When compared to the pricing in March 2020, milk prices for dairy goat flocks experienced a decline of approximately 4.5 cents per liter in April 2020. On the other hand, the cost of one month's supply of sheep milk remained practically unchanged throughout this time period, with some sources indicating a rise of more than 6 cents per liter in comparison to the previous year. In addition, the worldwide data collected from 2,750 Spanish flocks revealed a decrease in the price of lamb ranging from 16.8 to 26.9%. This information was obtained. In a similar fashion, the prices of goat kid meat fell by 12.5% per kilogram. (Vidaurreta et al., 2020).

**Eggs**

Currently, there is no proof that eggs or other poultry products can transmit SARS-CoV-2 to humans (Suárez-Garca et al., 2020). In contrast to the 2006 avian flu pandemic, which only affected a tiny portion of the chicken processing business, COVID-19 has had far-reaching consequences for the whole industry (Das and Samanta, 2021). Market closures and restrictions on egg sales were direct results of the COVID-19 epidemic. Because they couldn't sell their eggs to nearby supermarkets or eateries, farmers took a major financial hit (Hafez et al., 2021). Restrictions on farmer travel, disruptions in the food supply chain, and containment efforts conducted during the COVID-19 pandemic led to a drop in the value of global egg imports and exports in 2020 compared to 2019.

**Processed food**

Eating ill animals or foods that have been contaminated by other foods, diseased food handlers, or contaminated food contact materials is one way that SARS-CoV-2 could potentially be disseminated. Another way is by the consumption of foods that have been contaminated by other foods (Oakenfull and Wilson, 2020). The Centers for

Disease Control and Prevention (CDC) have so far pinpointed processed foods, packaging, and handlers as potential vectors for the spread of SARS-CoV-2 (FAO, 2021c). Depending on the surface, the virus can live for a few hours up to a few days (Van Doremalen et al., 2020). The Centers for Disease Control and Prevention (CDC) advises washing and sanitizing a variety of surfaces to reduce the risk of spreading germs (Seymour et al., 2020). At present time, there is no proof that the SARS-CoV-2 virus can be spread through eating contaminated food. Considering how crucial food is to our life, we can't rule out the potential that it could also serve as a vector for the spread of disease (Duda-Chodak et al., 2020).

**Effects of COVID-19 on the economy of animal production**

The spread of COVID-19 has had far-reaching consequences for the world economy, especially in the areas of animal production and trade in related goods. Hence, global economic growth has slowed from 2.9% to 2.4%. Rates are expected to drop to 1.5% if the outbreak continues (Hussain et al., 2020). Likewise, individuals who depend on agriculture (about 60% of the global population) have suffered as a direct result of the COVID-19 pandemic (Lenzen et al., 2020). The results of COVID-19 on the world economy are shown in Figure 2.

**Effects on the dairy industry's economy**

The dairy industry around the world has felt the effects of COVID-19. Even though milk production has decreased because of the epidemic, the daily demand for milk is increasing. As a result, there was a significant chasm between demand and potential supply. Producers of dairy products in the United States lost millions of dollars when they had to dump 4 million gallons of fresh milk in the trash during the first week of April 2020 because they couldn't get it to market (Newman and Bunge, 2020). Canadian dairy farmers were forced to give up producing fresh milk because of a shortage of markets, the inability to safely store their product at home, and a dearth of processing plants (Weersink et al., 2020). As a result of the market closure caused by the COVID-19 outbreak, dairy farmers in Bangladesh were severely impacted financially (Zabir et al., 2020). Milk prices have dropped drastically during COVID-19 as well. As a result of COVID-19, fresh milk in Bangladesh has been dumped, costing the country 67 million dollars (Begum et al., 2020).

Nepal has also lost $17 million in dairy product sales (Poudel et al., 2020). As a direct result of the COVID-19 epidemic, Pakistan experienced a drop in revenue equivalent to 57.3 billion liters worth of milk and other dairy products (such as yogurt, butter, and ghee, amongst others) (Ghafar et al., 2020). Indian milk sales have dropped by 50 percent, while milk consumption has dropped by 25 percent to 30 percent (Bajwa, 2020). The Chinese dairy industry has suffered economically due to problems with production and transportation, a shortage of inputs, and an increase in input prices. Milk from approximately 6.25 percent of farms was not accepted by processors, and 27.34 percent of farmers were unable to sell their whole milk production due to a lack of buyers. Moreover, 12.50% of farms had to throw out some milk because of the sickness epidemic (Qingbin et al., 2020). Losses in economic output for the dairy industry can be traced back to the global spread of the COVID-19 pandemic, as seen in Figure 3.

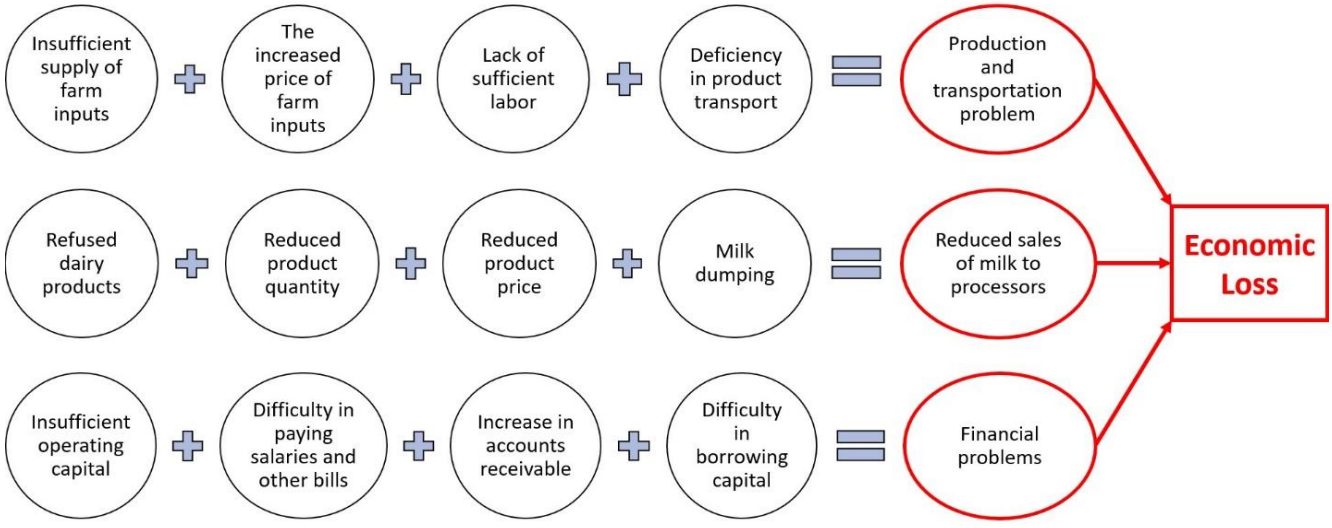


**Figure 3.** The major causes of the economic losses in the dairy industry as a consequence of the COVID-19 pandemic
**Source:** Adapted from FAO (2020b)

The major causes of the economic losses in the dairy industry due to the COVID-19 pandemic consists of production and transportation problems; reduced sales of milk to processors; and financial problems. Insufficient supply of farm inputs, the increased price of farm inputs, lack of sufficient labor, and deficiency in product transport, all lead to production and transportation problem. Moreover, reduced sales of milk to processors are caused by refused dairy products, reduced product quality, reduced product price, and milk dumping. Furthermore, the financial problems in the dairy industry created because of the COVID-19 pandemic are insufficient operating capital, difficulty in paying salaries and other bills, an increase in accounts receivable, and difficulty in borrowing capital.

**Effects on the economy of the meat industry**

COVID-19 has had an effect on the beef industry all over the world as a result of restrictions placed on imports and exports, a fall in the market, and issues in the processing business (Ijaz et al., 2021). The output of beef in the world is projected to decrease by 1.7%, falling from 338.9 million tons in 2019 to 333 million tons in 2020. (FAO, 2020a). The United States' 2020 pork output forecast is down 8.9 million tons, or 8 percent, from 2019's projections. Beef production decreased by 1% in 2020, compared to 2019 (72.6 mmt) (FAO, 2020a). There will be a 7% drop in market pork sales compared to 2019 because 10 million pigs will be removed from the supply chain of pig markets between April and September 2020, causing an economic catastrophe (loss of 2 billion pounds of pork) (Ijaz et al., 2021). Because of farm and slaughterhouse closures in the United States, beef production dropped by 25% and 43%, respectively (Hashem et al., 2020). U.S. economic losses from the beef business are estimated at $13.6 billion (Peel et al., 2020). The price of ovine meat fell by 8.6 percent during the COVID-19 pandemic, and the prices of other types of meat followed suit (poultry > hog > beef) (Pal and Kerorsa, 2020).

**Effects on the poultry industry's economy**

Chicken producers felt the effects of the COVID-19 pandemic, in part because of emergency pandemic marketing measures (Sattar et al., 2021). By the end of April 2020, it is anticipated that COVID-19 will have caused record losses for India's poultry business in the amount of 370 million United States dollars. (Biswal et al., 2020). There have been observations of comparable tendencies in other South Asian nations, such as Bangladesh and Pakistan. The catastrophic economic crisis that has gripped China has also had a detrimental influence on the export of chicken and other items derived from poultry in that country. Turkey temporarily restricted Chinese poultry imports (Pan et al., 2020). The majority of countries have instituted bans or quotas on some animal imports, including chicken and poultry products. This includes the United States, India, and Russia (Pan et al., 2020).

In addition, six million Bangladeshis have direct or indirect connections to the poultry industry (Hamid et al., 2016). The commercial poultry industry in Bangladesh is growing about 15% annually (Mahmud, 2020). Not only that, but a great deal of the nation's economy relies on the industry (Hamid et al., 2016). Nonetheless, chicken farms experienced significant financial losses as a result of the COVID-19 pandemic. Around $1 billion in lost revenue has been incurred by the Bangladeshi government as a direct result of the COVID-19 outbreak, which has caused a 35% drop in commercial output of day-old chicks, eggs, and meat (BPICC, 2020). In addition, the industry has lost almost 29% per farm egg (production cost of $0.07 versus selling price of $0.046 to $0.065), even though the price per farm egg was between $0.08 and $0.09 before the epidemic. Chicken producers lost 32-40% of their original investment since they could only sell broiler meat for $0.77-$0.80 per kilogram, despite spending $1.17-1.18 per kilogram on manufacturing (Mahmud, 2020).

**COVID-19's effects on animal welfare and health**

Global animal health and wellbeing have suffered as a result of the COVID-19 limits on farming and veterinary services. Quarantine measures taken in response to the COVID-19 pandemic may also make it more difficult to conduct regular zoonotic disease surveillance. Furthermore, because of these movement restrictions, efforts to monitor and control wild animals and diseases including foot-and-mouth disease, African swine fever, and exotic transboundary diseases have been put on hold (lumpy skin disease, pox virus diseases, Japanese encephalitis, and Rift Valley fever). The global spread of the COVID-19 pandemic had a terrible impact on the well-being of animals. In addition, global warming and climate change has negative consequences on human and animal health (Raihan et al., 2022b; Raihan et al., 2022c; Isfat and Raihan, 2022; Raihan, 2023c). Animals are more likely to contract various diseases due to their prolonged confinement on farms. As a corollary, the global economic crisis and associated restrictions on human mobility and procedures have had a major impact on the health of animals, as have the suspension of farming activities and veterinary services (Hashem et al., 2021; Raihan, 2023d; Raihan et al., 2023a; Raihan et al., 2023b). Because farmers have less access to animals (particularly cattle, sheep, and goats) and animal products, they are forced to kill or induce abortions in order to control animal populations and prevent overproduction. Pig farmers are aborting sows and killing them inhumanely by methods including suffocation, burning, and shutting off air since consumer demand has dropped and the marketing mechanism has been disrupted (Jones, 2020).

The effects of COVID-19 on animal healthcare on farms, in communities, and around the world are already apparent, and they are not good news. As a result, many national and international organizations have had to put off or postpone important activities, initiatives, and projects until they can secure more money. Several animal and zoonotic disease prevention, control, and eradication efforts have stalled as a result (FAO, 2020a). The following effects on animal health and welfare (Deeh et al., 2020) were noted as a worldwide result of the COVID-19 pandemic:

**Farming activities**

One of the drawbacks of COVID-19 is that it makes it difficult to keep up with normal animal health tasks like disease diagnosis, routine immunization, and effective treatment of sick animals. Prolonged durations of animal lodging on farms lead to stress, immunosuppression, growing stocking density, and multifactorial diseases as a result of decreased movement, higher mortality, lower productivity, and diminishing economic benefits. Animal producers were unable to get advice, therefore their animals didn't get veterinary care, because of a shortage of veterinarians and the frequency with which they could see them. The lack and erratic supply of inputs such animal feed additives led to an increase in illnesses as a result of import and export restrictions (vitamins, minerals, antibiotics, and others). For instance, the COVID-19 epidemic has caused a kink in the supply chain for animal pharmaceuticals traveling between China (home to multiple pharmaceutical firms) and the United States (Hashem et al., 2021). Figure 4 shows how the spread of COVID-19 threatens the viability of farms.

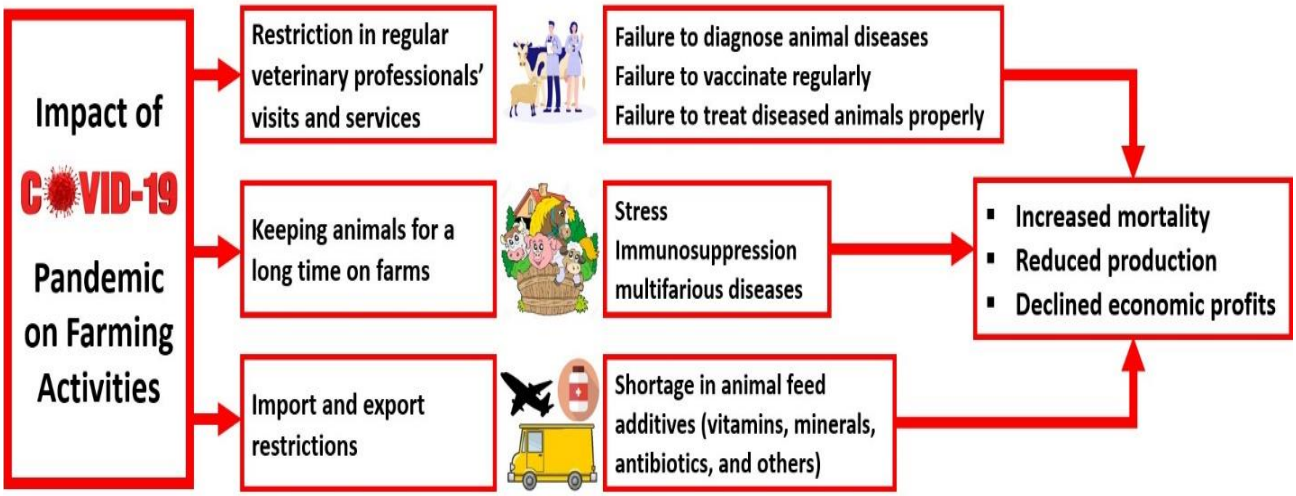


**Figure 4.** The effect of the COVID-19 outbreaks on the sustainability of farming operations

**Lab operations and veterinary services**

It was challenging to import laboratory agents and equipment due to import/export restrictions. Because of the social lockdown, veterinary experts in the lab were unable to conduct their jobs because they couldn't get to work. Issues with transporting samples from animal farms to labs and a lack of personal protective equipment (PPE) were also factors. Often there were no on-call veterinarians or open laboratories. Lack of safety precautions, PPE, sample collection gear, laboratory agents, and PCR materials also contributed to an increase in the transmission of animal diseases.

**Local animal health efforts**

The COVID-19 pandemic has caused considerable economic disruption, which has had a substantial impact on a variety of approaches to the prevention and treatment of disease in animals. Mobility restrictions hampered efforts to vaccinate, diagnose, and treat many different types of animals and animal diseases. The lockdown impeded the Papua New Guinea National Agricultural Quarantine and Inspection Authority's (NAQIA) ability to visit affected areas, despite the agency's use of stringent control measures to battle COVID-19 (FAO, 2020a).

**Animal health activities worldwide during COVID-19**

Famous multinational organizations have delayed or canceled their global animal health initiatives due to a lack of financial and logistical assistance. As a corollary, trade and transportation barriers have impeded global animal health initiatives.

**Recommendations for improved animal husbandry during the COVID-19 pandemic**

In order to effectively deal with the COVID-19 pandemic, animal husbandry techniques must be improved both during and after the outbreak. Protecting the well-being of those who care for animals is a top priority. This includes giving out vaccines when it's safe to do so, encouraging people to eat healthier, and decreasing stress levels. Despite this, public confidence in immunization is low because of worries about the safety of the current COVID-19 vaccines. Many people believe untrue statements about the COVID-19 vaccine, such as the following: the vaccine is ineffective and causes severe side effects; vaccine material can integrate into human chromosomes; fetal tissue is used in the vaccine's development; and the vaccine contains a microchip or nano-transducer (Shehata et al., 2021). Achieving high rates of immunization among workers while alleviating their anxiety is strongly encouraged. Helping the public understand the need of vaccinations, setting realistic expectations, and using motivational tactics to dispel misinformation about them is a key responsibility of health professionals (Verger et al., 2021).

A wide variety of animals, both domestic and wild, have been found to have spontaneously contracted SARS-CoV-2 infections. All of these animals are included in this category: canines, felines, minks, ferrets, lions, tigers, pumas, snow leopards, and gorillas. Despite the fact that poultry and cattle are resistant to the virus and only moderately vulnerable to it, respectively, these animals may nevertheless impede the progression of the virus and its ability to propagate (Shehata et al., 2022). Therefore, it is absolutely necessary to utilize the One Health approach. Furthermore, climate change adaptation and mitigation strategies (Begum et al., 2020; Ali et al., 2022; Raihan, 2023e; Raihan et al., 2023c) should be taken for the sustainable development in the the livestock sector. It has been suggested that a number of actions be taken in order to guarantee the production of livestock for the long term: (i) the strict hygienic processing of animal products during marketing and handling; (ii) the improvement of social distance and hand washing hygiene practices in production facilities; (iii) the strict regulations of animal farms regarding biosecurity, isolation, care, visitors, and animal workers; and (iv) the improvement of animal housing and hygiene.

**Conclusion**

This study presents an overview of the global impact of COVID-19 on the sustainability of livestock performance and welfare. The systematic literature review method was used to conduct this study which includes 44 documents published between 2020 to 2022. The fulfillment of the nutritional requirements of human beings is significantly aided by the production of meat from livestock and poultry. They are absolutely necessary for the achievement of global food security, the Sustainable Development Goals, as well as the economic prosperity and GDP of many agricultural countries. A significant amount of damage has been done to human civilization as well as to ecosystems and the economy as a result of the COVID-19 pandemic. The findings of this study revealed that the impact of the pandemic has threatened the sustainability of businesses related to livestock and poultry, which has led to workers in those industries losing their jobs. In light of the effects of the ongoing pandemic and the knowledge gained from it, it is time to rethink the strategies currently in place for the control of pandemics and infectious diseases in animals, particularly those involving significant zoonotic infectious agents.

The findings of this study suggest that progressive methods of animal husbandry and agricultural production, which take into account the welfare of animals, should be implemented. In order to identify newly emerging diseases and pandemics, the authors of this study suggest placing a greater emphasis on coordinated efforts directed toward developing a disease surveillance and monitoring system based on the One Health approach. It is absolutely necessary to have a robust network on all three levels (local, national, and international) in order to be adequately prepared to stop any further pandemic outbreaks. This study could be useful for making major efforts to improve the existing situation and acquiring knowledge for the future, with a focus on food security through sustainable livestock farming. In addition, this study reveals COVID-19's impacts on animal welfare and health, which could aid in achieving sustainability in farming activities. In addition, this article provides ideas for enhanced animal husbandry and sustainable livestock production during the COVID-19 pandemic.

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RESEARCH ARTICLE

# Investigating the nexus between energy consumption, industrialization, urbanization, economic growth, and Carbon dioxide emission: Panel data analysis from the Belt and Road Initiative countries

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**Abstract**
An increase in urbanization rises the use of energy in urban areas which leads to high carbon dioxide discharge and worsen environmental quality. Industrialization and economic growth are also linked with environmental quality and thus need to investigate the effect of these factors on environmental quality. This study uses panel data from 1976 to 2019 and investigate the nexus between urbanization, industrialization, economic growth, energy consumption and carbon dioxide emissions in the belt and road initiative countries using static and dynamic panel models. The findings reveals that the effect of urbanization, energy consumption, industrialization and economic growth on carbon dioxide emission is positive and it reduce environmental quality however, international trade significantly reduce carbon dioxide emission. This study further confirms the existence of a U-shape link between urbanization and carbon dioxide while the square term of economic growth doesn't validate the Environmental Kuznets curve hypothesis. The findings of this study have considerable policy suggestions regarding carbon emission mitigation in term of urbanization, energy use, industrialization and economic growth.

**Keywords:** Urbanization; Carbon dioxide emission; Nonlinear relationship; Environmental Kuznets Curve

## Introduction

Same as other factors, urbanization also affects environmental quality where some studies in the prevailing literature indicate that a rise in long term economic growth rises environmental quality while a rise in urban population increases environmental degradation Adem, Solomon et al. (2020). An increase in urbanization rise the use of energy in urban areas which leads to high carbon dioxide discharge and worsen environmental quality Khoshnevis Yazdi and Golestani Dariani (2019). A study confirms the statement that urbanization level raises carbon dioxide emission and worsens the quality of the environment Sadorsky (2014) while opposite findings are also obtained that low density of population makes inefficient public transfer and infrastructure and thus carbon emission reduces Chen, Colombo et al. (2008). Likewise, the lowest carbon footprint in urban areas has been indicated by Muñoz, Zwick et al. (2020) while on the other hand, urbanization in an economy The use of energy and carbon dioxide enhance economic growth while on the other hand, energy consumption has been considered concerning scale effect and the driving factor of development with the use of energy from environmentally friendly Zhang, Wang et al. (2020). Urbanization has been considered that effect carbon emission positively and unreasonably Poumanyvong and Kaneko (2010). Urbanization above the unity level effects the income groups carbon emission differently Martínez-Zarzoso and Maruotti (2011). On the other hand, the nexus between urbanization and carbon emission is found U-shaped Kong, Wang et al. (2021). Urbanization effect national carbon dioxide emission in variables ways in different regions Jorgenson, Auerbach et al. (2014). Uncontrol urbanization level leads to environmental degradation and other related problems such as air pollution, waste disposal and land insecurity Ikumapayi (2020). Newly industrialized countries produce high carbon emission due to high amount of energy use Khoshnevis Yazdi and Golestani Dariani (2019). Countries are increasing production in order to rise economic growth to enhance living standard.
degrade environmental quality Kahouli, Miled et al. (2022). High level or industrialization and a rapid increase in

urbanization have effected the urban building which results a major effect on energy consumption Gierałtowska, Asyngier et al. (2022). Urbanization has different independent effects on energy consumption independently Shao, Chen et al. (2019). Urbanization convert traditional energy consumption to modern types and thus rise intensity of energy which reduce pollution such as pollution purification and urban transportation Martínez-Zarzoso and Maruotti (2011). Several studies indicates that the environmental Kuznets curve in this context is valid. According to this phenomenon, urbanization rise carbon dioxide emission with a rise in urban land and decrease when there is further rise in urban land at the highest level of urbanization Li, Wang et al. (2016); Sadik-Zada and Gatto (2021). Complex mechanism has been debated by which the effect of urbanization on carbon emission has positively or negatively shown Zhou, Wang et al. (2019);Yao, Zhu et al. (2021). Beside urbanization, most of other activities such as industrialization and production in countries are increased in order to rise economic growth while increase in these activities increase energy demand and rise carbon dioxide emission.

The belt and road countries are mostly developing and emerging countries. These countries need to increase industrialization and production to rise economic growth while industrialization and production need high amount of energy. Thus, a rise in energy consumption and economic growth leads to high carbon emission discharge. The rapid industrialization in the countries is also observed as urbanization also linked with economic growth and thus its effect carbon emission. In this study, we believe that the specific characteristics of the belt and road countries, the effect of urbanization, energy consumption, economic growth and industrialization on carbon dioxide can be different as a regional difference. Several previous studies have conducted studies on the effect of urbanization on carbon dioxide emission however industrialization, energy consumption and economic growth has not been considered while this study considered these closely related factors. The nonlinear association between urbanization and carbon dioxide emission has not been considered in such kind of investigation. This study tests both the nonlinear association between carbon emission and urbanization as well testing for the environmental Kuznets curve by introducing the square term of economic growth per capita. Considering the belt and road countries data and its specific characteristics and economic level, this study investigates the effect of urbanization, energy consumption, industrialization and economic growth on carbon dioxide emission from 1976 to 2019 using dynamic panel models. The findings reveals that the effect of urbanization, energy consumption, industrialization and economic growth on carbon dioxide emission is positive and it reduce environmental quality however, international trade significantly reduce carbon dioxide emission. This study further confirms the existence of a U-shape link between urbanization and carbon dioxide while the square term of economic growth doesn't validate the Environmental Kuznets curve hypothesis.

The rest of the paper is structure as follows; literature review is presented in part 2, section 3 is composed of variables and method used, part 4 present results and discussions while the part 5 conclude the study findings and give policy implications.

**Literature review**

Large number of studies have been examined the nexus between different factors with environmental quality proxy by carbon dioxide emission such as economic growth, energy consumption and urbanization. However, these studies have not yet achieved enough conclusions and thus this topic still need investigation. For instance, Kong, Wang et al. (2021) studied the link between urbanization and carbon emissions in China. The results show a U-shaped association between urbanization and environmental degradation. (Bao & Lin, 2021) Based on provincial data, the spatial vector autoregression model was used to explore the relationship between economic growth, carbon emissions and technological innovation from 2003 to 2017. The results of this study indicate that the study variables were positively correlated. Pece, Simona et al. (2015) examine the relationship on economic growth and technology innovations in Central and Eastern European countries. Using patents, trademarks, and R&D spending as innovation indicators, we found a positive relationship between innovation and economic growth. (Pala, 2019) examined the impact of technology on economic growth in 25 developing countries Using a random coefficient model and using R&D and researchers, they reveals that R&D spending had a significant negative impact on economic growth in some countries in the study sample. Mukhtarov, Humbatova et al. (2020) examine the association between energy and economic growth. The authors used the ARDL model and collected the data from 1993 to 2015. The results show that economic growth increases renewable energy consumption. Financial development was also found that rises renewable energy. Another study by Godil, Sharif et al. (2020) studied the nexus between institutions, ICT and carbon emission using QARDL and data from 1995 to 2018. The study shows that economic growth along institutions raises carbon dioxide while ICT reduce emission. (Chien et al., 2021) also conducted such a study using ARDL for the period 1980 to 2018. The study country was Pakistan and the authors found that economic growth significantly increases carbon emissions, and the EKC hypothesis is validated. They further show that renewable energy and technological innovation can negatively impact carbon emissions. Globalization is a significant source of increased carbon dioxide emissions in Pakistan. Suki, Suki et al. (2022) examine the relationship between renewable energy consumption, technological innovation, and carbon emissions in Malaysia. Using a bootstrapped ARDL model, the findings suggest that using renewable energy can help reduce environmental degradation, and technological innovation can reduce ecological footprint and carbon emissions. Their study also confirmed the EKC hypothesis. Khoshnevis Yazdi and Golestani Dariani (2019) used Indonesia data from 1971 to 2019 and examine the nexus

between urbanization, economic growth and carbon dioxide. Using vector error correction model and found the existence of pollution haven hypothesis while there was found a unidirectional causal relationship from economic growth, FDI and economic growth to carbon dioxide emission. Other studies have also conduct such investigation such as the study of Ponce de Leon Barido and Marshall (2014) validate the findings of above study. These authors conducted a study to examine the nexus between carbon dioxide and urbanization in 80 countries from 1983 to 2005. The authors used fixed and random effects models and reveals that urbanization rise carbon dioxide.

Chen, Liu et al.) studied the nexus between urbanization and carbon dioxide emission by considering the transformative role of government effectives from 1996 to 2018 in OECD countries using FGLS and correlated errors models. The authors found the existence of U shape association between urbanization and carbon dioxide. They further evidence the government effectiveness transformative role in this association. Some authors also believes that quality institutions also effect the nexus between urbanization, industrialization and carbon dioxide such as Wu and Madni (2021) studied the nexus between institutional quality, transportation and industrialization with carbon dioxide emission in the belt and road countries from 1996 to 2018. The study implemented panel threshold regression and found the threshold level of institutional quality in the sample countries. Institutional quality above the level, carbon dioxide doesn't destroy the environment while below is related to environmental degradation. Most of the studies indicates that urbanization increase carbon dioxide emission. A study is conducted by Zhang, Song et al. (2021) used China data from 2000 to 2012 to examine the nexus between urbanization, population and carbon dioxide emission. GMM, two stage least square models were employed to the data for analysis and the results illustrate that temporary residence has a marginal influence on urbanization and carbon dioxide emission nexus. Likewise, Kahouli, Miled et al. (2022) explore the association of trade, urbanization, economic growth and carbon dioxide emission. The time period of the study is from 1971 to 2019 and data sample country is Saudi Arabia. The authors used ARDL and VECM models and found that the use of energy and carbon dioxide enhance economic growth while on the other hand, energy consumption degrade environmental quality. Martínez-Zarzoso and Maruotti (2011) used data for different countries groups from 1975 to 2015 and explore the effect of urbanization on carbon dioxide emission. The authors found that urbanization above unity differently affects the income groups. Kong, Wang et al. (2021) studied urbanization and carbon emissions in China. The results show a U-shaped association between urbanization and environmental degradation. Energy consumption and economic growth is also widely debated and most of the previous studies shows that energy consumption drive economic growth as well both energy use for production and economic growth increase carbon dioxide and leads to environmental degradation. A study by Gierałtowska, Asyngier et al. (2022) investigate the nexus between urbanization, renewable energy and carbon dioxide from 2000 to 2016 in a sample of 163 countries. The authors analyzed the data with GMM model and found U-shape association between urbanization and carbon dioxide. The author further expresses that the effect of renewable energy on carbon dioxide is negative. They also found the existence of EKC hypothesis in the sample countries. (Bao & Lin, 2021) used provincial data and applied the spatial vector autoregression model to explore the relationship between economic growth, carbon emissions and technological innovation from 2003 to 2017. The findings show that technological innovation, economic growth and carbon dioxide are positively correlated over time. (Pece, Simona et al. (2015) examine the relationship between innovation and economic growth in Central and Eastern European countries. Using patents, trademarks, and R&D spending as innovation indicators, we found a positive relationship between innovation and economic growth. (Pala, 2019) examined the impact of technology on economic growth in 25 developing countries Using a random coefficient model and using R&D and researchers, they found that R&D spending had a significant negative impact on economic growth in some countries in the study sample. Mukhtarov, Humbatova et al. (2020) examine the association between energy and economic growth. The authors used the ARDL model and collected the data from 1993 to 2015. The results show that economic growth increases renewable energy consumption. Financial development was also found that rises renewable energy. Another study by Godil, Sharif et al. (2020) studied the nexus between institutions, ICT and carbon emission using QARDL and data from 1995 to 2018. The study shows that economic growth along institutions raises carbon dioxide while ICT reduce emission. 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**Methodology**

This study uses panel data from 1976 to 2019 for the belt and road initiative countries and investigate the nexus between urbanization, economic growth, industrialization, energy consumption and carbon dioxide emission. The study uses both static and dynamic panel models to examine this association. The models include ordinary least square, fixed effect model, two step difference GMM and two step system GMM. However, before the formal analysis, this

study first implemented a panel unit root test to test the stationarity of the data. After performing these preliminary tests, we further conduct formal analysis using static and dynamic panel models. These estimators include OLS, fixed-effects models, two-step differencing, and two-step systematic generalized method of moments (GMM). The GMM model was proposed by (Arellano & Bond, 1991) and is considered a recent application of the topic, and most studies have focused on this estimator when dealing with panel data. First, the study uses static models, OLS, and fixed effects to deal with heterogeneity. These static estimators were used to compare the results of the current study with previous studies and to compare the results with dynamic model results. By using a GMM model, it will deal with endogeneity issues related to study variables Kinyondo, Pelizzo et al. (2021). The system GMM model handles grouping equation differences s at the horizontal level. The instrument specified in the model is the variable delay value of the level in the difference equation. The variables also studied are the horizontal equation and the first difference mean. Monte Carlo simulations by (Blundell and Bond, 1998) show that the SGMM model is most effective at estimating this dilemma. The over descriptive constraint test was replaced by the Sargan test with the Hansen test, and Arellano and Bond's serial correlation test was also used. Most of the results of these tests confirmed our study expectations. Hansen test values give recognition and show the effectiveness of the instrument. The baseline empirical models are presented below in form of generalized method of moments. The first equation shows the direct effect of urbanization and economic growth along other explanatory variables while empirical model in equation 2 presented the nonlinear association between the study variables.

$$CO2_{it} = \beta_0 + \beta_1 CO2_{it-1} + \beta_2 URB_{it} + \beta_3 ECG_{it} + \beta_4 IND_{it} + \beta_5 ENR_{it} + \beta_6 TR_{it} + \varepsilon_{it} \quad (1)$$

$$CO2_{it} = \beta_0 + \beta_1 CO2_{it-1} + \beta_2 URB_{it} + \beta_3 (URB)^2_{it} + \beta_4 ECG_{it} + \beta_5 (ECG)^2_{it} + \beta_6 IND_{it} + \beta_7 ENR_{it} + \beta_8 TR_{it} + \varepsilon_{it} \quad (2)$$

In equations 1 and 2, CO2 is carbon dioxide emission taken as metric tons per capita, URB is urban population, ECG is economic growth taken as GDP per capita, IND is industrialization, ENR is energy consumption while TR is international trade. Likewise, the square of urbanization is taken to examine the nonlinear association and also the square of economic growth is taken to test for the Environmental Kuznets Curve. The data for all selected variables were downloaded from the world bank database world development indicator. Table 1 present the variables explanation and table 2 shows the variables statistics. Likewise, the correlation is given in table 3. It is believed by large number of researchers that an increase in urban population is also related to an increase in carbon dioxide emission Li, Fang et al. (2019); Khan, Han et al. (2021). Urbanization transfers a rural to urban transition and moves an agricultural economy to an industrial economy (Muhammad, Long et al. (2020). When there is an increase in urbanization, the emission level will increase as inhabitant production and improvement in living standards as well as industrialization. However, it's also been argued that agglomeration in population due to the rise in urbanization enhances the energy use effectiveness and contributes to achieving economy of scale Solarin and Lean (2016). Several studies in preceding literature show that a rise in urbanization leads to a high level of production and raise carbon emission Ghisellini and Ulgiati (2020); Nguyen, Nguyen et al. (2018); Canh (2019);Khan, Weili et al. (2022). Carbon emissions are expressed as metric tons per capita in terms of environmental quality or degradation. This proxy has been used recently by Ibrahim D. Raheem (2019) and Khan, Weili et al. (2021). Similarly, it is generally accepted that the independent variable for considering its impact on carbon emissions is urbanization. Economic growth is measured as per capita GDP Aritenang (2021); Bouchoucha (2021, Hamdaoui, Ayouni et al. (2021); Khan, Weili et al. (2021). Previous studies claim that carbon emission is increased and the environment is polluted by the higher economic growth (Danish et al.,2018c; Ozcan and Apergis (2018). Likewise, it's been argued in previous research that a rise in economic growth rise carbon emission and degrade environmental quality. Krueger and Grossman (1995) ; Apergis and Li (2016); Bai, Feng et al. (2020) indicate that per capita income is a vital factor that affects the level of carbon emission. Several studies in the preceding literature used the square terms of GDP per capita to testify to the Environmental Kuznets Curve Stern (2004); Mader (2018). The environmental Kuznets Curve indicates that in the initial stage of growth rise carbon dioxide while when the country reaches a certain level of development, the emission level goes down. Based on the preceding studies, this study also adds the quadratic function of economic growth to test the non-linear effect of per capita growth on carbon dioxide emission.

**Table 1.** Variables description

| Variables description | Symbols |
|---|---|
| carbon dioxide emissions (metric tons per capita) | CO2 |
| Urbanization taken as total population | URB |
| Per capita gross domestic product | GDP |
| Industrialization | IND |
| Energy consumption | ENR |
| Trade | TR |

**Table 2.** Descriptive statistics

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| CO2 | 4.325272 | 4.150806 | 0 | 26.89927 |
| URB | 51.15108 | 18.30245 | 6.668 | 92.501 |
| GDP | 2.940403 | 5.59511 | -45.32511 | 24.97367 |
| IND | 30.62608 | 8.436977 | 12.17161 | 64.00978 |
| ENR | 1822.165 | 1299.566 | 105.4537 | 6232.732 |

| | | | | |
|---|---|---|---|---|
| TR | 82.0442 | 39.42683 | 8.384615 | 220.4068 |

**Table 3.** Correlation matrix

| | CO2 | URB | GDP | IND | ENR | TR |
|---|---|---|---|---|---|---|
| CO2 | 1.0000 | | | | | |
| URB | 0.7289 | 1.0000 | | | | |
| GDP | -0.0893 | -0.0814 | 1.0000 | | | |
| IND | 0.1557 | -0.0247 | -0.0134 | 1.0000 | | |
| ENR | 0.9569 | 0.7480 | -0.0814 | 0.1047 | 1.0000 | |
| TR | 0.2726 | 0.2540 | 0.0615 | -0.0430 | 0.3429 | 1.0000 |

**Results and discussions**

**Panel unit root tests**

Before the formal analysis using static and dynamic panel models, the stationarity of the variables was firstly checked employing CADF and CIPS unit root tests. These are second generation tests where its is assumed that each time series in the panel is distributed across each cross sections.

**Table 4.** Second Generation Panel unit root results

| | **CIPS** | | **CADF** | |
|---|---|---|---|---|
| Variables | **I(0)** | **I(1)** | **I(0)** | **I(1)** |
| CO2 | -1.667 | -3.575 *** | -0.284 | -3.831*** |
| URB | -1.629 | -2.402*** | -2.547*** | -2.110** |
| GDP | -3.641*** | -5.167 *** | -3.064*** | -4.299*** |
| IND | -2.308 | -5.070 *** | -2.049 | -3.723*** |
| ENR | -1.310 | -4.093*** | -0.891 | -3.130*** |
| TR | -1.793 | -4.813*** | -1.834 | -3.931*** |

**Note:** **, *** shows significance level at 5 percent and 1 percent respectively

Pesaran (2007) proposed second generation tests based on average lag and first difference of single series to enhance ADF regression. Thus, the single common factor is filtered out. There is a unit root in the panel in each country and thus it is tested alternatively the countries differences. The results are presented in table 4. All the variables are stationarity in first difference and in level.

After checking the stationarity of data, this study further forward to the formal econometric analysis using static and dynamic panel model. Table 5 present the direct effect of urbanization on carbon dioxide emission. The results indicates that the lagged dependent variable carbon dioxide is positive significant and the AR1, AR2 and Sargan test also fulfil the model requirements.

The findings shows that the sample countries urbanization leads to high carbon dioxide emission and worsen environmental quality. Considering the two-step system GMM results, a rise in the level of urbanization in the belt and road countries increase carbon dioxide emission by 0.004 percent if urbanization goes upward by one percent. The findings of this study are similar to Al-Mulali, Solarin et al. (2016); Khoshnevis Yazdi and Golestani Dariani (2019) regarding the effect of urbanization on carbon dioxide.

The findings shows that the sample countries economic growth also leads to high carbon dioxide emission and worsen environmental quality. Considering the two-step system GMM results, a rise in the level of economic growth in the belt and road countries increase carbon dioxide emission by 0.027 percent if there is a one percent increase in economic growth. Adebayo, Adedoyin et al. (2021) found similar results.

The findings shows that the estimated coefficient of industrialization is positive and significant that's leads to high carbon dioxide emission and worsen environmental quality. Considering the two-step system GMM results, a rise in the level of industrialization in the belt and road countries increase carbon dioxide emission by 0.006 percent with a one percent increase in industrialization in the belt and road countries. Khoshnevis Yazdi and Golestani Dariani (2019) also found that industrialization leads to carbon emission discharge.

Energy consumption is significant and positive. The estimated coefficient values indicate that a rise in the use of energy in the belt and road countries increase carbon dioxide emission. The findings further shows that when there is increase in carbon dioxide emission with the use of high amount energy worsen environmental quality. More specifically, 0.004 percent increase will occur in carbon dioxide if the use of energy increase by one percent. The findings confirm that energy use in the belt and road countries harms environmental quality by producing pollution.

International trade variables produce positive and significant coefficient. Thus the coefficient indicate that it reduce carbon emission and rise environmental quality. The findings shows that if there is increase in international trade in the sample countries will support the environmental quality enhancement. Specifically, taking the two-step system GMM model results, if a percent increase in the belt and road countries international trade occur, the environmental quality will be risen and the carbon emission will be reduced by 0.001 percent. Khoshnevis Yazdi and Golestani Dariani (2019) found opposite results for Asian countries.

**Table 5.** Urbanization and carbon dioxide emission

| Variables | OLS | Fixed effect | 2Steps Difference GMM | 2Steps System GMM |
|---|---|---|---|---|
| Urbanization | 0.009*** | 0.009*** | 0.003 | 0.004** |
| | (0.003) | (0.003) | (0.011) | (0.004) |
| Economic growth | -0.006*** | 0.006*** | 0.003*** | 0.027*** |
| | (0.002) | (0.002) | (0.000) | (0.000) |
| Industrialization | 0.029*** | 0.029*** | 0.015*** | 0.006*** |
| | (0.002) | (0.002) | (0.002) | (0.001) |
| Energy consumption | 0.002*** | 0.002*** | 0.001*** | 0.0004*** |
| | (4.320) | (4.430) | (4.370) | (3.365) |
| International trade | -0.003*** | -0.003*** | -0.002*** | -0.001* |
| | (0.000) | (0.000) | (0.0003) | (0.0002) |
| $CO2_{it-1}$ | | | 0.250*** | 0.804*** |
| | | | (0.005) | (0.012) |
| Constant | -1.195*** | -1.171*** | | 0.001 |
| | (0.228) | (0.148) | | (0.002) |
| Observations | 936 | 936 | 886 | 925 |
| R-squared | | 0.903 | | |
| Number of id | 37 | 37 | 37 | 37 |
| AR1 | | | -2.01 | -2.22 |
| | | | (0.045) | (0.027) |
| AR2 | | | -1.42 | -0.92 |
| | | | (0.154) | (0.357) |
| Sargan test | | | 1733.32 | 1377.01 |
| | | | (0.020) | (0.121) |

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The findings shows that the sample countries urbanization leads to high carbon dioxide emission and worsen environmental quality. Considering the two-step system GMM results, a rise in the level of urbanization in the belt and road countries increase carbon dioxide emission by 0.081 percent if urbanization goes upward by one percent.

As the effect of urbanization is positive and rise carbon dioxide emission however the estimated coefficient of the square term of urbanization shows that this coefficient give significant but negative sign thus indicates that urbanization will significantly reduce carbon dioxide emission when its reach a certain level in the belt and road countries. Thus, the findings confirm that there exist a U-shape association of urbanization and carbon dioxide emission.

The findings shows that the sample countries economic growth also leads to high carbon dioxide emission and worsen environmental quality. Considering the two-step system GMM results, a rise in the level of economic growth in the belt and road countries increase carbon dioxide emission by 0.027 percent if there is a one percent increase in economic growth. Consistent with findings from Zoundi (2017); (H. Khan, Weili & Khan, 2021b); economic growth increases emissions, further evidence from more researchers (Chien et al., 2021); Adebayo, Adedoyin et al. (2021). Economic growth reduces environmental quality. (Usman, Alola, and Sarkodie, 2020) also claim that economic growth puts upward pressure on the ecological footprint. Khoshnevis Yazdi and Shakouri (2017) obtained the opposite result. As the economic growth is positive and significant increase carbon dioxide however this study also tests the environmental Kuznets curve by taking the square of economic growth per capita. By checking the EKC hypothesis whether economic growth still increase or reduce emission when the countries reach a certain level of development, the results did not validate this hypothesis as the square term coefficient gives positive and insignificant results.

The findings shows that the estimated coefficient of industrialization is positive and significant that's leads to high carbon dioxide emission and worsen environmental quality. Considering the two-step system GMM results, a rise in the level of industrialization in the belt and road countries increase carbon dioxide emission by 0.001 percent with a one percent increase in industrialization in the belt and road countries.

The effect of energy consumption on carbon dioxide shown positively by the coefficients. Thus, a rise in

energy use increase carbon dioxide. The findings further shows that when there is increase in carbon dioxide emission with the use of high amount energy worsen environmental quality. More specifically, 0.004 percent increase will occur in carbon dioxide if the use of energy increase by one percent. The findings confirm that energy use in the belt and road countries harms environmental quality by producing pollution.

**Table 6.** Nonlinear association between urbanization and carbon dioxide

| Variables | OLS | Fixed effect | 2Steps Difference GMM | 2Steps System GMM |
|---|---|---|---|---|
| Urbanization | 0.041*** | 0.043*** | 0.0572 | 0.081*** |
| | (0.009) | (0.009) | (0.0488) | (0.085) |
| Urbanization Square | -0.000*** | -0.000*** | -0.000*** | -0.000*** |
| | (9.320) | (9.480) | (0.000) | (0.0006) |
| Economic Growth | -0.005** | -0.005** | 0.004*** | 0.027*** |
| | (0.002) | (0.002) | (0.000) | (0.000) |
| ECG Square | 7.110 | 7.080 | 1.940 | 1.490 |
| | (0.000) | (0.000) | (7.020) | (8.960) |
| Industrialization | 0.026*** | 0.026*** | 0.016*** | 0.001*** |
| | (0.002) | (0.002) | (0.002) | (0.002) |
| Energy consumption | 0.002*** | 0.002*** | 0.001*** | 0.0004*** |
| | (4.350) | (4.460) | (3.230) | (2.390) |
| International trade | -0.004*** | -0.004*** | -0.002*** | -0.000** |
| | (0.000) | (0.000) | (0.000) | (0.0003) |
| $CO2_{it-1}$ | | | 0.247*** | 0.811*** |
| | | | (0.0053) | (0.010) |
| Constant | -1.810*** | -1.822*** | | 0.001 |
| | (0.286) | (0.225) | | (0.001) |
| Observations | 936 | 936 | 886 | 925 |
| R-squared | | 0.905 | | |
| Number of id | 37 | 37 | 37 | 37 |
| AR1 | | | -1.97 | -2.25 |
| | | | (0.049) | (0.024) |
| AR2 | | | -1.43 | -0.89 |
| | | | (0.154) | (0.375) |
| Sargan test | | | 1723.62 | 1380.07 |
| | | | (0.000) | (0.000) |

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

## Conclusion

The current study examines the linear and nonlinear effect of urbanization on carbon dioxide emission by including industrialization, energy consumption and economic growth in this association. The belt and road countries data for the period of 1976 to 2019 have been collected from the world development indicator and employed generalized method of moments estimator for analysis. The findings shows that urbanization, industrialization, economic growth and energy use increase carbon dioxide emission and degrade environmental quality however the effect of international trade on carbon dioxide emission is negative thus shows that international trade significantly reduce carbon emission and leads to environmental quality. The study further found the U-shape association between urbanization and carbon dioxide emission however the Environmental Kuznets curve is not validated in this study shown by the square term of per capita GDP.

From the findings, this study concludes that there is high level of urbanization in the belt and road countries and migration from rural areas to urban areas. This migration to cities effects the environment in the belt and road countries in several ways as the urban population increase, there will be increased air pollution, waste materials in cities and high population which worsen environmental quality. This urbanization in the belt and road countries can rise economic activities in cities however there is worsen environmental consequences. However, this urbanization in the sample countries increase pollution and worsen environmental quality in the initial stage while its will rise environmental quality when the urbanization reach a peak level. likewise, energy consumption for production and industrialization rise carbon dioxide emission in the belt and road countries as these sample countries are still developing or emerging countries that need to rise economic growth and living standard. Thus, increase energy use increase economic growth while both economic growth and energy rise carbon dioxide emission and degrade environmental quality. The environmental Kuznets curve isn't validated so thus it's a challenge for the belt and road countries to considered the environmental consequences while rising economic growth through production and industrialization that require high amount of energy. The solution maybe that the countries

need to invest in renewable energy to rise its use in production and industrialization so thus environmental degradation can be decreased as energy consumption, industrialization and economic growth all positively effect carbon dioxide in this study.

The countries are suggested to reduce the rapid growth of urbanization in order to control the rapid deterioration of environmental quality in urban areas. Likewise, the countries need to adopt strategies to use renewable energy in production and industrialization process to thus can minimize environmental consequences and well can attain economic growth. In case on the effect of industrialization on carbon emission, the countries should not fully be focused on increased industrialization in the initial stage to boost economic growth. alternatives should be investigated to keep economic growth increasing and to protect environmental quality. The international trade should be more advantageous to rise economic growth as well to increase renewable energy which can be the solution to economic growth and environmental problems. The findings concludes that most of variables in this study leads to high carbon dioxide emission except international trade and thus need proper attention. However, urbanization is beneficial for economic growth and the U-shape association between urbanization and carbon emission is also found thus indicates that its can rise environmental quality in later stages when its reach a higher level. while on the other hand, the economic growth EKC hypothesis is not validated thus the countries need special attention to economic activities.

This study is limited to the variables used. Future study may include institutional quality indicators and governance which may give important suggestion regarding economic growth activities such as the role of governance and institutions in conducting environmental regulation and economic activities rules to control the harmful effects of these factors on environmental quality.

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RESEARCH ARTICLE

# Financial Performance Analysis of Engineering Companies: An Empirical Study during the COVID-19 Pandemic in Bangladesh

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**Abstract**

As the largest crisis of the current world, the global pandemic "COVID-19" has wreaked havoc on the global economy, disrupting people's lives and wreaking havoc on financial markets and business industries. This scenario is almost the same in engineering companies. Due to the lockdown, a significant portion of construction activities were mostly restricted in the previous year, which had a massive impact on this sector. The pandemic's impact has caused numerous setbacks in this sector around the world. This study focused on 40 engineering firms and analyzed data from the COVID-19 period of 2019-2021. The key purpose of this study was to analyse the financial performance based on the determinants that have the most influence on the financial performance of the company. The findings of generalized linear model (GLM) show that, during the COVID-19 period, LNGPR had a positive impact on LNFP in engineering firms in Bangladesh, indicating that a 1% increase in LNGPR can increase LNFP by 0.80%. The variables LNLR and LNNPR have a positive impact on LNFP in engineering firms in Bangladesh, with estimated coefficient values of 0.44 and 1.22, respectively. LNDR has a significant impact on LNFP in engineering firms and a 1% increase in LNDR can enhance LNFP by 0.76 percent. However, variable sales growth has a negative impact during the COVID-19 pandemic. It is a positive sign that most of the variables have a significant and positive association with financial performance, except for sales growth. The authority should implement policies to restore sales growth and consistency in production distribution across countries.

**Keywords:** COVID-19; Engineering Companies; Financial Performance; Profit Ratio; Sales Growth

## Introduction

The Corona virus (COVID-19) pandemic has brought significant challenges to the development of the world economy and has had an unprecedented impact on the construction industry (Yilmazkuday, 2022). According to Ogunnusi et al. (2020), COVID-19 has disrupted many industrial sectors, but the construction industry has been particularly hard hit. Construction site employees and professionals are at a high risk of exposure to aerosol and droplet contamination as well as infection. The COVID-19 crisis has stakeholders concerned about the construction sector's stagnation (Gamil & Alhagar, 2020). Pathirana (2020) noted that because the virus prevented all humans from participating in any industrial work, the construction sector was initially targeted. According to Bsisu (2020), the "restrictions placed on construction projects as a result of the pandemic crisis have slowed economic growth, increased unemployment, disrupted the supply chain for construction materials, and increased investment losses." These effects are all due to the negative effects of COVID-19. As a result, this year's growth in the construction industry has been reduced from 3.1% to 0.5% (Global Data, 2020). Due to the corona virus pandemic, Bangladesh's engineering industry is currently experiencing difficult times, including a decline in the economy, haphazard development efforts, and the loss of jobs for workers. According to Financial Express, the construction industry is one of the 15 sectors that contribute to Bangladesh's GDP (gross domestic product). According to data from the "Bangladesh Bureau of Statistics (BBS)," the construction industry made up 7.8%

($16.686 billion) of Bangladesh's overall GDP in the 2019–20 fiscal years. In the event of employment, this is yet another massive sector that will generate job opportunities. According to the labor force survey, BBS (2017), the published that in the fiscal year, 2.1% of the total labor force was occupied in this sector, while it was 5.5% in the fiscal year 2017. Supporting this statement, Financial Express (2021) reported that around 3.5 million people are concerned in this sector, of which 100,000 are directly engaged in various professional activities like architects, graduate engineers, diploma engineers, and other human resources. Massive infrastructure development, including mega construction projects, has been undertaken by the country to become a developing country in 2026 (Yeasin, 2021; Aijaz et al., 2022). Business Standard (2021) published a report on the Real Estate and Housing Association of Bangladesh, where the findings showed that this pandemic situation has delayed around 50–60% of the construction projects, caused a delay in finishing projects, increased the budget for materials, and raised the issue of a workers' shortage. As a result of the adverse impact on the national economy of this virus, 3.24% of the budget allocation for the ongoing megaprojects has been reduced in the 2020–21 fiscal year (The Daily Star, 2020).For the engineering industry, determining the performance of engineering firms has become a research issue. The evaluation of a firm's performance as assess of the company's excellence includes two major aspects: financial performance and non-financial performance. When discussing the company's performance, several researchers, including Horta et al. 2018; Tripathi & Jha (2018) have focused on its financial performance. Since such an appraisal is crucial for a company's owners, shareholders, and financial institutions because it clearly defines the company's true status, performance reviews of engineering companies can offer an assessment of the business's operations. Due to the drastic pandemic, the construction sector is facing massive uncertainty. The effects of the COVID-19 pandemic on the world's construction industry have drawn important attention for research since the construction industry suffered from project setbacks, labor shortages, job cutbacks, increased costs, and financial uncertainty as a result of this crisis (Gamil & Alhagar, 2020). Several researchers have reviewed the effects of COVID-19 on the construction industry in their study. Gan and Koh (2021) reviewed the precautionary activities taken by the legal authority such as government, labour organizations, and trade union to protect the labor rights and maintain the minimum wage rate. Through a meticulous examination, Al Mansoori et al. (2021) found that the cost of labor and project prices is both increasing in the United Arab Emirates (UAE) due to COVID-19. Like other countries, in Bangladesh the pandemic has caused considerable delays in development projects across the country as the lockdown has limited both people and material supplies, causing many employees to lose their employment and others to be unable to work (Dhaka Tribune, 2022). According to a survey result, 90% of respondents felt that the pandemic was a curse on the construction sector, with roughly 51% of projects having partial stops and 40% experiencing total halts (Prothom Alo, 2022). Furthermore, this pandemic is pushing some engineering and construction enterprises to consolidate debt, pursue other sources of funding, or face bankruptcy. The current study aims to investigate the before and after effects of the pandemic (COVID-19) on the financial performance of Bangladesh's listed engineering companies. The study targets all companies listed under the engineering category on the Dhaka and Chittagong stock exchanges. However, the main objective of this study is to examine the financial performance of listed engineering companies in Bangladesh during the COVID-19 pandemic. The main aspects of the engineering industry and COVID-19's impact on it have been examined and cited with short descriptions. (a) To find out the significant determinants of the firm's financial performance of listed engineering companies during the pandemic period. (b) To find out the impact of determinants on the firm's financial performance of listed engineering companies during the pandemic period. In addition, this research has been following the structure where section two presents literature review, section three for methodology, section four for result analysis and discussion and section five for conclusion and recommendations.

**Literature Review**

Wuhan, the capital of central China, was the first place where COVID-19, a virus-borne infection brought on by the SARS-CoV-2 virus, struck. The World Health Organization (WHO) affirmed COVID-19 a global pandemic on March 11, 2020. The social, economic, and health sectors were particularly hard hit, and researchers found that the COVID-19 epidemic has slowed GDP growth and increased unemployment, inequality, and poverty nationwide (Kumar & Pinky, 2020; Amin et al., 2021; Ikram et al., 2021). The average GDP loss

experienced by the 178 countries in the world as a result of COVID-19 was 83,765.17 million dollars. On average, the economies of these nations would contract 16.04% of their total GDP, and on average, their economies would degrade by 7.67 years in 2020. The global recessionary phase began when the world's GDP shrank by 17.07% of its overall value over a seven-year period, reflecting a sharply declining trend brought on by COVID-19. Lockdowns, domestic tourism margins, air travel bans, unemployment, and changes in the human quality index as a result all had a negative impact on global economic growth (Rahman & Hossain, 2021; Majumder & Rahman, 2022). Before COVID-19, Bangladesh had a dynamic economy partaking in an exceptional increase in neediness decrease, instructive fulfilment, orientation uniformity, and other financial markets that upheld this turn of events. The GDP growth rate in FY 2019–20 was only 5.24%, down from 8.15% the previous year. However, the engineering sector of Bangladesh assumes an undeniably crucial role in the economy because of the progress of urbanization and a variety of huge framework projects attempted by the public authority. The development market is one of the 15 significant areas contributing to the GDP, and it includes projects such as infrastructure, transportation, trade and organization, energy and power plant development. The engineering sector posted 9.92% growth in 2017–18, up from 8.77% in 2017 and 7.50% in 2016–17. Because of the increased emphasis on urbanization and the numerous infrastructure projects undertaken by the government, the development industry in Bangladesh contributed to the pre-pandemic situation. There were also development projects undertaken by general individuals and individuals with a confidential interest in lodging, which contributed 9.6% to the development work. According to Voumik et al. (2022), during the pandemic period, the progress of these ventures generally ceased, as well as other ongoing megaprojects being redacted at Payra, Maheskhali, and Matarbari. Bangladesh has undertaken a few megaprojects to lay out a prepared and unhampered correspondence network in the nation, including the “metro rail projects, the Padma Bridge, the passage under the Karnaphuli Stream, and the Dhaka Raised Freeway from Hazrat Shahjalal International Air Terminal to the Kutubkhali Dhaka-Chattogram thruway” which are likewise stopped in this emergency. However, the public authority takes different approaches to supporting the development work of activities impacted by the Corona virus. Alongside mega projects, the infrastructural development of Bangladesh additionally relies on the land area, including different forward and reverse linkage businesses. The Financial Express (2021) revealed that the commitment by land area and alongside the forward and reverse linkage enterprises in gross domestic product was 8% of gross domestic product, while the gift goes up to 12–14%. However, because of the pandemic, this area took a gigantic hit during the primary lockdown, which caused devastation in the housing market. The obvious reason for this is that merchants began withdrawing properties from the market, anticipating lower costs, and property looking was dialled back and nearly slowed down as people became more concerned about their health security.

The COVID-19 pandemic forced the entire world to visage it, which inevitably led to significant changes in all regions, from economics to social (Chen & Yeh, 2021). Every business sector and industry suffered as a result of the COVID-19 epidemic on a global scale (Brodeur et al., 2021). Policies were implemented to reduce the impact of the COVID-19 lockdown and social distancing measures (Wang et al., 2020). Khatib and Nour (2021) saw that the corona virus pandemic altogether affects a few parts of business, for example, execution, administration, construction, liquidity, and influence level. Shen et al. (2020) examined the effects of Corona virus on organizational execution using financial data and discovered that Corona virus had a negative impact on organizational execution. In India, Das and Patnaik (2020) found that different enterprises like telecom, the travel industry, avionics, the auto industry, and transportation are the most affected by the current crisis. Various researchers examined the association between COVID-19 and economic performance through their studies (Goswami et al., 2021; Debata et al., 2020). According to Fu and Shen (2020), COVID-19 has had a significant negative impact on the performance of China's energy industries. “The listed companies' poor performance immediately following COVID-19 may be attributed to organizational culture in dealing with challenges and crises.” According to Forbes (2002), the company's financial performance may have been negatively impacted by the low income level of the population at the time of the pandemic. Because of the extreme pandemic development, the area is confronting enormous vulnerability. According to the International Monetary Fund (IMF), the global GDP will fall by up to 3% in 2018 due to the ongoing pandemic situation. The corona virus threatens a wide range of laborer occupations around the world. In the event of a pandemic, limited human development has had a negative impact on development efficiency as well as development firm

execution, which unavoidably falls. To decrease the frosty impact of the corona virus pandemic, the government was compelled to stop numerous development projects. During this present circumstance, numerous enormous development organizations as well as little development organizations confronted financial misfortunes. Jallow et al. (2020) showed that challenges in overseeing exercises, bringing about delays. In Ghana, development projects experienced a decreased work rate, delays in instalments, and an expansion in material expenses during the pandemic time frame (Agyekum et al., 2021). In India, Alsamhi et al. (2022) found a massive contrast in complete pay, net deals, net benefit, profit per share, and weakened profit per share when the pandemic hit the travel industry, neighbourliness, and shopper areas. The review added that a massive distinction was made in complete pay-net deals when the pandemic was in developing and food areas, whereas there was no huge contrast between net benefit, profit per share, and weakened income per share when the pandemic was in building and food areas. Besides, Endrijatno and Surjandari (2022) found that in Indonesia, the pandemic condition didn't essentially influence the decrease in that frame of mind of the development organization, where the organization could make do with its capacities and keep up with its presentation. According to a survey response by 28% of individuals from the Associated General Contractors of America (AGC), ventures in the United States were also delayed or stopped.

A number of empirical researches have been demeanour to explore the impacts of COVID-19 on different sectors in Bangladesh's economy. In light of both essential and optional information, Islam (2020) concentrated on the effect of Corona virus on the piece of clothing area in Bangladesh, and found that because of Corona virus, the piece of clothing area in Bangladesh confronted a 3.18 billion dollar drop in orders, the store network of unrefined substances was seriously upset, and the products of the RMG area are 11.43% lower compared with the earlier year, but 72.4% lower than the earlier month in July 2020. This concentrate additionally added that the month-to-month development pace of the commodities in the RMG area was negative in FY 2019–20. In her review, Elahi and Rahman (2021), Rahman & Dilanchiev, (2021) distinguished the eruption of the worldwide inventory network as the fundamental explanation that is seriously impacted by the time period. Because of work in Bangladesh, Islam (2020) cantered that because of Corona virus, the economy's development rate dropped sharply, causing the financial emergency and a large number of individuals lost their positions, all the more explicitly, 11 million positions were lost amid the time of lockdowns, and consequently, the economy suffered by 3% of the workforce losing their positions, of which a portion of 1,000,000 positions were looted. In his review, Saha et al. (2020) saw the danger of joblessness because of the Corona virus. The researcher discovered that the global and local economic downturns are to blame for a shortage of jobs in the clothing, transportation, travel industry, banking, security, and training sectors. On account of the RMG sector, the orders from worldwide purchasers were contracted, industrial facilities stayed shut, and laborers' contracts were ended. Genoni et al. (2021) saw that the labor market in Bangladesh, both at the broad and concentrated edges, including significant variety across regions and orientations, is impacted by the Corona virus. At the same time, long-term outcomes of neediness, food security, and future income are also influenced by market laborers' long-term job losses. This pandemic is additionally connected with elevated degrees of vulnerability in the gig market, producing pressure and tension that might cause wellbeing and mental issues.

Observing the socioeconomic impact of COVID-19 and its policy inferences for Bangladesh Pak et al. (2020) found specific sectors, including the leather, textile, and apparel sectors, have suffered reduced output, while agriculture product, manufacturing, services, and other sectors have been faced a reduction of output. The result is supported by other studies. During the period of the COVID-19 pandemic, "garments and knitwear products, petroleum, cement, and other non-metallic mineral products declined sharply while drug and pharmaceutical products increased." In addition, "the nominal wage rates in the industry and service sectors declined, the export of goods, imports of goods, and service payments had fallen, and the exports of the RMG sector had fallen largely due to the COVID-19 pandemic" (Hossain & Alam, 2022). Horaira (2021), Sufian and Hoque (2022) and Nekmahmud et al. (2022) added that because of the pestilence, both domestic and guests dropped their visits, and many flights have been cancelled due to different travel limitations. Therefore, organizations lose cash and laborers lose positions. According to Mohiuddin (2020), the per capita daily pay of metropolitan slums and provincial poor has dropped by 80% as a result of the current countrywide closure authorized by the government, where a large portion of this population (40 percent to 50 percent) took credit to meet day-to-day expenses in Bangladesh. Once more, Ali et al. (2021), Elahi and Rahman (2021), Majumder and Rahman

(2022) concentrated on the effects of Corona virus on Bangladesh's economy, where he found that because of Corona virus in Bangladesh, the Gross Domestic Product, trade volume, and settlements had a slump of 18.09%, 18.08%, and 19.73% separately, causing a downgrade of $40,984.34 million, $6540.97 million, and $3941.45 million in the year 2020, respectively, and this downturn went on for 3 years, 2 years, and 2 years from 2019 separately. Once again, the global unemployment rate would rise by 1.38%, while in Bangladesh it would rise by 2.43%. Shahriar et al. (2021) saw that the corona virus caused an unfavourable effect on Bangladesh's economy, which impacted the lives of a large number of individuals when their pay sources were hampered. Furthermore, it was normal that the yearly misfortune of 53 million dollars was raised because the pace of the graduate joblessness rate expanded from 47% to 58% in 2020. Ali et al. (2021) added that understudies at Bangladeshi colleges have been experiencing unlimited mental stress side effects as the fear of academic postponement has progressed throughout the Corona virus time frame.

However, from the literature review, it can be said that existing studies focused on the impacts of COVID-19 on the manufacturing, engineering, construction, and service sectors of Bangladesh and the economy as a whole. In these studies, the researchers analyzed the effect of COVID-19 on the financial performance of selected factors based on secondary data and explained it qualitatively. These studies are too narrow in scope to draw any firm conclusions about the effects of COVID-19 on a specific sector of Bangladesh. Because the urban informal economy, particularly the construction sector, has been severely impacted by COVID-19, the urban informal economy is seriously affected by the lockdowns. As a result, this study was the first to examine the impact of COVID-19 on the performance of listed engineering companies in Bangladesh during the pandemic period.

## Methodology of the Study

### Scope and Data

The study considers the engineering sector listed on the Dhaka Stock Exchange (DSE). The time period studied is 2019–2021. Secondary data were obtained from the Dhaka Stock Exchange website, journals, theory books, and so on. This study's cross-sectional unit is engineering firms listed on the DSE. While the data used in this study is listed on the Dhaka Stock Exchange and the Chittagong Stock Exchange in 2018–2021, the Company's selection process used a simple selection process based on random process. The criteria used for selecting the cross section units are as follows: (a) selected companies listed on the Dhaka Stock Exchange before 2019. (b) Selected companies publish financial and annual reports on the Dhaka Stock Exchange consecutively from 2019 to 2021. (c) Selected companies are not delisting. (d) Companies that provide complete data according to the required variables.

### Variable Justification and Calculation Process

a. Sales Growth: The primary source of capital for the businesses is sales revenue. Additionally, sales revenue affects the financial health of manufacturing companies (Wamiori et al., 2016; Rahman & Majumder, 2021).

b. Liquidity Ratio: Current ratio is a "measure of relative liquidity that takes into account differences in absolute size. It is used to compare companies with different total current assets and liabilities". Current ratio can be measured by the formula:

CR = ($Current\ Assets$/ $Current\ Liabilities$) x 100.

c. Debt Policy: Debt policy is a choice made by the company's executive management regarding the amount of external funding obtained through debt as a source of command and control funding for the business (Enekwe et al., 2014; Harahap et al. 2020). The following formula can be used to gauge debt policy.

DER = $Total\ Liabilities$ /$Total\ Equit$y

d. Gross Profit Ratio: GPR calculated by using the formula (Gross Profit or Income / Sales) x 100.

e. Net Profit Ratio: NPR calculated by using the formula (Net Profit or Income / Net Sales x 100) where net profit determined by Total Sales – Sales Returns.

f. Financial performance: Financial performance serves as the study's dependent variable. An analysis of financial performance is done to determine whether the company's rules regarding the proper and correct use of finance are being followed (Fatihudin, 2018; Oskouei, 2019). Creating a report that complies with "General Accepted Accounting Principles (GAAP)" requirements. Financial performance can be measured by the formula.

ROA = ($Earnings\ after\ Tax$ /$Tot$ ) x 100.

**Generalized Linear Model (GLM)**

Multivariate regression analysis is important where we have used GLM to see how the independent variables affect the dependent variable. An analysis known as multivariate regression analysis links the dependent variable to two or more independent variables (Rahman et al., 2022; Rahman & Habib, 2021; Majumder & Rahman, 2020; Rahman & Majumder, 2022). To understand how the independent variable affects the dependent variable, use the GLM regression analysis. Equations 1 and 2's error terms' normal distribution was followed by the GLM.

$$\mu_{it} = \delta_0 + \delta_1 x_{it} \quad (1)$$

$$y_i \sim N(\mu_i, \varepsilon) \quad (2)$$

However, the econometric model of selected variables is presented in equation 3 to 5.

$$FP = F(DR, GPR, LR, NPR, SG) \quad (3)$$

$$FP_{it} = \delta_0 + \delta_1 DR_{it} + \delta_2 GPR_{it} + \delta_3 LR_{it} + \delta_4 NPR_{it} + \delta_5 SG_{it} + \varepsilon_{it} \quad (4)$$

$$LnFP_{it} = \delta_0 + \delta_1 LnDR_{it} + \delta_2 LnGPR_{it} + \delta_3 LnLR_{it} + \delta_4 LnNPR_{it} + \delta_5 LnSG_{it} + \varepsilon_{it} \quad (5)$$

Where i indicates cross unit, $\varepsilon$ is error term, and the t is the time. Ln= Natural Log for all the selected variables, FP = Financial Performance, $\delta_0$ = Constant, $\delta_1$ to $\delta_5$ = Regression coefficients, LnDR = Debt Policy, LnLR = Liquidity Ratio, LnSG = Sales Growth, LnGPR= Gross Profit Ratio and LnNPR= Net Profit Ratio.

**Result Analysis**

This study has considered several factors, such as debt policy, liquidity ratio, sales growth, and gross and net profit ratios, to measure the financial performance of engineering companies during the COVID-19 period because those factors play a key role in ensuring the performance of a company. However, Table 1 displays descriptive statistics results using several criteria, including mean, maximum and minimum value, standard deviation, and skewness with kurtosis value and sum sq. deviation. However, the estimated mean value of the variable LNFP is -2.55, the median value is -3.17, the maximum value is 2.50 with a minimum value of -8.08, the skewness is 0.34 with a kurtosis value of 3.24, the standard deviation is 2.37, and the sum sq. deviation is 264.37. The mean value of the variable LNDR is 0.06, the median value is 0.09, the maximum value is 2.16, the minimum value is -2.28, the skewness is -0.27 with a kurtosis value of 2.94, and the sum sq. deviation is 44.01. The anticipated mean value of the data LNGPR is -1.59, the median value is -1.54, the maximum value is -0.89 with a minimum value of -2.55, the skewness is -0.48 with a kurtosis value of 2.62, the standard deviation is 0.42, and the sum sq. deviation is 8.20. The estimated median value of the data LNLR is 0.41, the mean value is 0.46, the maximum value is 2.20, the minimum value is -0.86, the skewness is 0.81 with a kurtosis value of 2.62, the standard deviation is 0.55, and the sum sq. deviation is 14.26. However, the estimated mean value of the variable LNNPR is -2.92, the median value is -2.86, the maximum value is -1.45, the minimum value is -5.09, the skewness is 0.54 with a kurtosis value of 3.22, the standard deviation is 0.87, and the sum sq. deviation is 35.41. The anticipated mean value of the variable LNSG is -1.76, the median value is -1.89, the maximum value is -0.69 with a minimum value of -3.85, the skewness is -0.14 with a kurtosis value of 3.21, the standard deviation is 0.90, and the sum sq. deviation is 38.02.

**Table 1: Descriptive Statistics of the Variables**

| | LNFP | LNDR | LNGPR | LNLR | LNNPR | LNSG |
|---|---|---|---|---|---|---|
| Mean | -2.55 | 0.06 | -1.59 | 0.46 | -2.92 | -1.76 |
| Median | -3.17 | 0.09 | -1.54 | 0.41 | -2.86 | -1.79 |
| Maximum | 2.50 | 2.16 | -0.89 | 2.20 | -1.45 | 0.69 |
| Minimum | -8.08 | -2.28 | -2.55 | -0.86 | -5.09 | -3.85 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Std. Dev. | 2.37 | 0.97 | 0.42 | 0.55 | 0.87 | 0.90 |
| Skewness | 0.34 | -0.27 | -0.48 | 0.81 | -0.54 | -0.14 |
| Kurtosis | 3.24 | 2.94 | 2.62 | 5.32 | 3.22 | 3.21 |
| Sum Sq. Dev. | 264.37 | 44.01 | 8.20 | 14.26 | 35.41 | 38.02 |

Source: Authors Estimation

**Table 2: Correlation Matrix among the Variables**

| | LNFP | LNDR | LNGPR | LNLR | LNNPR | LNSG |
|---|---|---|---|---|---|---|
| LNFP | 1 | 0.164 | 0.288 | 0.221 | 0.489 | 0.020 |
| LNDR | 0.164 | 1 | -0.325 | -0.405 | -0.050 | 0.221 |
| LNGPR | 0.288 | -0.325 | 1 | 0.551 | 0.478 | 0.119 |
| LNLR | 0.221 | -0.405 | 0.551 | 1 | 0.339 | -0.102 |
| LNNPR | 0.489 | -0.050 | 0.478 | 0.339 | 1 | 0.252 |
| LNSG | 0.020 | 0.221 | 0.119 | -0.102 | 0.252 | 1 |

Source: Authors Estimation

Table 2 shows the correlation matrix, where the statistics show the correlation between the variables. There is some positive and negative correlation among the variables. LNFP and LNDR, for example, have a positive relationship with a correlation value of 0.164; LNFP and LNGPR have a positive relationship with a correlation value of 0.288; LNFP and LNLR have a positive liaison with a correlation value of 0.221; LNFP and LNNPR have a positive association with a correlation value of 0.489; and LNFP and LNSG have a positive link with a correlation value of 0.020. LNDR and LNGPR have negative relations, and the correlation value is -0.325; LNDR and LNLR have negative relations, and the correlation value is -0.405; LNDR and LNNPR have negative relations, and the correlation value is -0.050; and LNDR and LNSG have positive relations, and the correlation value is 0.221. LNGPR and LNFP have a positive relation, and the correlation value is 0.288; LNGPR and LNNPR have a positive relation, and the correlation value is 0.478; and LNGPR and LNSG have a positive relation, and the correlation value is 0.119. LNLR and LNFP have positive relations, and the correlation value is 0.221; LNLR and LNNPR have positive relations, and the correlation value is 0.339; LNLR and LNSG have negative relations, and the correlation value is -0.102. LNSG and LNGPR have a positive association, with a correlation of 0.119; LNSG and LNNPR have a positive relationship, with a correlation of 0.252. A test for equality between the series has been presented in Table 3. Anova F-test and Welch F-test are used to continue the test, where the tests are significant at the 1% level to show mean equality between the series.

**Table 3: Test for Equality of Means between Series**

| Method | df | Value | Probability |
|---|---|---|---|
| Anova F-test | (5, 597) | 131.10 | 0.00 |
| Welch F-test* | (5, 245) | 299.92 | 0.00 |

Source: Authors Estimation

**Figure 1: Representation of Data Dimensions/Growth during the Time Period**

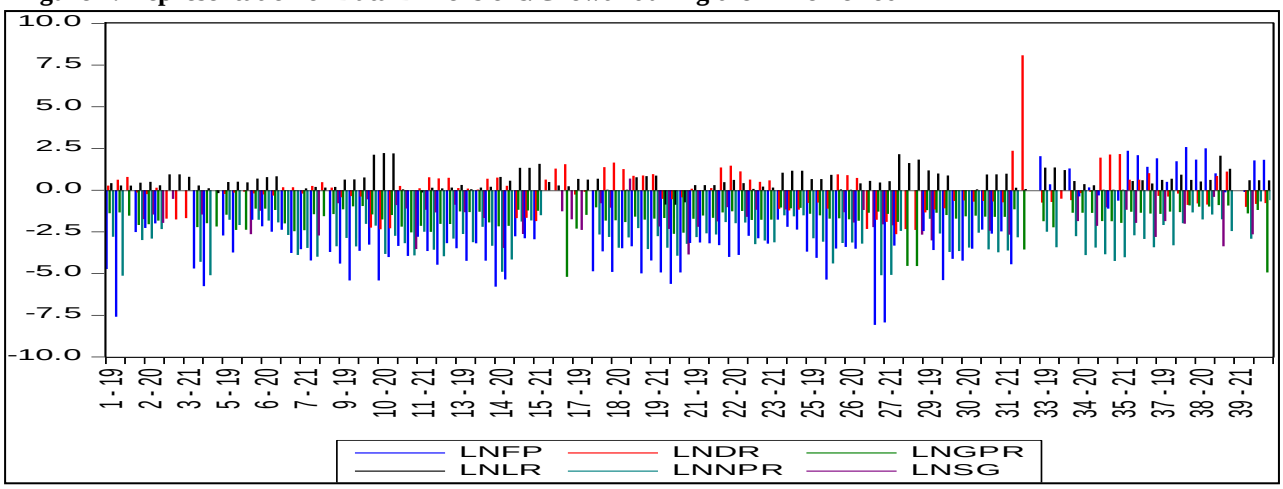


Figure 1 shows the data dimensions and growth during the COVID-19 time period of 2019–2021 to estimate the econometric model; the variables are in log form. However, the maximum variables are showing a negative trend over the time period. Using negligible variables and the selected cross-section unit, firms have negative growth for selected variables. However, the results of the generalized linear model (GLM) have been presented in Table 4, where the dependent variable is financial performance (LNFP). During the COVID-19 period, engineering companies in Bangladesh have played a vital role in ensuring sustainable growth and development. The independent variable, such as LNDR, has a significant impact on LNFP in engineering companies, and the estimated value of the coefficient is 0.76, which indicates that a one percent increase in LNDR has been able to boost LNFP by 0.76 percent. There is a positive interlink between the variables LNDR and LNFS; this sign is expected for a company. However, the pandemic crisis did not hamper the maintenance of the relation between those variables, which is suggested by the accounting theories.

**Table 4: Results of Generalized Linear Model (GLM)**

| Variable | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| Dependent variable: LNFP | | | | |
| LNDR | 0.76 | 0.35 | 2.16 | 0.03 |
| LNGPR | 0.80 | 0.95 | 0.84 | 0.40 |
| LNLR | 0.44 | 0.70 | 0.63 | 0.53 |
| LNNPR | 1.22 | 0.41 | 2.97 | 0.00 |
| LNSG | -0.44 | 0.36 | -1.23 | 0.22 |
| C | 1.26 | 1.71 | 0.74 | 0.46 |
| **Model Fit Evidences** | | | | |
| Mean dep. var | -2.55 | S.D. dep. var | | 2.37 |
| Akaike info criterion (AIC) | 4.40 | Schwarz criterion (SIC) | | 4.64 |
| LR statistic | 20.66 | Prob(LR statistic) | | 0.00 |
| Pearson SSR | 177.20 | Pearson statistic | | 4.22 |

Source: Authors Estimation

**Table 5: Confidence Interval Estimation of Generalized Linear Model (GLM)**

| Variable | Coefficient | 90% CI | | 95% CI | | 99% CI | |
|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High |
| LNDR | 0.76 | 0.17 | 1.36 | 0.05 | 1.48 | -0.19 | 1.72 |
| LNGPR | 0.80 | -0.80 | 2.40 | -1.12 | 2.72 | -1.77 | 3.37 |
| LNLR | 0.44 | -0.74 | 1.61 | -0.97 | 1.85 | -1.45 | 2.32 |
| LNNPR | 1.22 | 0.53 | 1.91 | 0.39 | 2.05 | 0.11 | 2.33 |
| LNSG | -0.44 | -1.05 | 0.16 | -1.17 | 0.29 | -1.42 | 0.53 |
| C | 1.26 | -1.62 | 4.13 | -2.19 | 4.70 | -3.35 | 5.87 |

Source: Authors Estimation

On the other hand, the independent variable, LNGPR, has also had a positive impact on LNFP in engineering firms in Bangladesh during the COVID-19 period, and the estimated value of the coefficient is 0.80, indicating that a 1% increase in LNGPR can enhance LNFP by 0.80 percent. There is a positive correlation between the variables LNGPR and LNFS, which is a positive sign for a company. However, the pandemic crisis did not prevent the accounting theories from maintaining the relationship between those variables, such as LNGPR and LNFS. The variables LNLR and LNNPR have a positive impact on LNFP in engineering firms in Bangladesh during the COVID-19 period, and the estimated values of the coefficients are 0.44 and 1.22, where LNNPR is significant at the 1% level but LNLR is insignificant. There is a positive correlation among the variables LNLR, LNNPR, and LNFS; this is strength for a company. However, the pandemic crisis did not prevent the accounting theories from maintaining the relationship between those variables, such as LNLR, LNNPR, and LNFS. The coefficient of the variable LNNPR is 1.22, which means a 1% increase in LNNPR enhances LNFP by 1.22 percent. However, the variable sales growth has a negative impact during the COVID-19 pandemic situation. In Bangladesh, sales growth in the engineering sector faces a crisis because of the pandemic crisis, lockdown, and other restrictions. The coefficient of variable sales growth is negative to explain the financial performance, but this result is not significant. The model fit evidence shows no inconsistency, and the probability value of the LR statistic is significant at the 1% level when considering the minimum SIC and AIC criteria. In addition, the results of the confidence interval estimation of the GLM model presented in Table 5 consider 90%, 95%, and 99% intervals to justify the coefficient estimates and impact of the selected variables on the financial performance of engineering companies.

**Conclusion and Recommendation**

Due to the fact that businesses can now be run anywhere in the world, financial performance is the main criterion used by investors worldwide. In order to fulfil commitments and accomplish the objectives set by the organization's top management, management used financial performance techniques. The share price and investor interest will significantly rise as the company's financial performance improves. Financial performance gives investors and creditors crucial information they can use to decide whether to trust a company with their money. Financial performance is one of many indicators that can be used to assess an organization's present state and future potential. The stakeholder must examine the factors that affect financial performance. Management should be aware of the factors affecting a company's financial performance because it matters to both investors and internal stakeholders. Financial performance measures the company's overall financial health, including the effectiveness of the top management's leadership. The COVID-19 pandemic has negatively impacted the performance of many businesses and the economy as a whole in Bangladesh. Despite the fact that it experienced steady growth for the previous five years, the engineering sector is not immune to the recession. The goal of the current study is to determine how the pandemic (COVID-19) has affected the financial success of some engineering sectors in Bangladesh. All companies listed on the Dhaka Stock Exchange in Bangladesh are the subjects of the study. This study considered 40 engineering firms and analyzed data from the COVID-19 period of 2019–2021. Key findings during the COVID-19 period indicate that LNGPR has a positive impact on LNFP in engineering firms in Bangladesh, and the estimated value of the coefficient is 0.80, indicating that a 1% increase in LNGPR

can increase LNFP by 0.80 percent. During the COVID-19 period, the variables LNLR and LNNPR have a positive impact on LNFP in engineering firms in Bangladesh, with estimated coefficient values of 0.44 and 1.22, respectively. LNDR has a significant impact on LNFP in engineering firms, and the estimated value of the coefficient is 0.76, indicating that a 1% increase in LNDR can boost LNFP by 0.76 percent. During the COVID-19 pandemic, however, variable sales growth has a negative impact. Since the financial performance of engineering firms during the COVID-19 pandemic has not yet been examined in the context of Bangladesh, the study is distinctive in that it does so. Additionally, by examining Bangladeshi sectors, this study offers useful insights to regulators and policymakers about the adverse effects on industries as a result of the pandemic. Because COVID-19 has had a major effect on sales growth, the authority should concentrate on maintaining that growth. Government initiatives on domestic production and distribution would be a great addition to helping the country recover from this crisis. The key limitation of this study is the lack of updated data availability to compare post-COVID-19 scenarios. A future study should focus on the total number of firms and the post-COVID-19 evaluation of financial performance.

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RESEARCH ARTICLE

# A Facile Review on the Legal Issues and Challenges Concerning the Conservation and Preservation of Biodiversity

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**Abstract**

The defective environmental changes caused by climate change have a drastic harmful effect on natural habitats and species. This is concerning the fact that there are signs that the increase in the intensity of temperature often has (caused by human activities) an effect on biodiversity. However, the threat posed by climate change to biodiversity is expected to increase, given the harmful human activities. The scientist has identified that if the present rates of global warming continue by 2030, it will result in a significant detrimental impact on biodiversity. In this regard, this study adopts a doctrinal method of study in examining the current causes of climate change, the effect of climate change on biodiversity, and several global legal frameworks concerning the preservation and conservation of biodiversity. The study also detailed the lacuna inherent in the conservation and preservation of biodiversity, and possible legal and scientific method for revamping biodiversity. The study further concluded and recommended that adopting this possible solution it will curtail harmful human activities that often cause climate change that negatively affect biodiversity.

**Keywords:** Climatic Change; Biodiversity; Legal; Framework; Environmental

## Introduction

Preservation and conservation of biodiversity are fundamental for the sustainable relationship between man and it environment. The uniqueness of this relationship is well articulated in various legal frameworks on biodiversity conservation. Various studies have shown that the well-being and economic prosperity of all people depend largely on man's harmonious living with Mother Earth. That is because, we depend on the earth for our basic and non-basic needs for daily survival including food, medicine, recreation, water, air, security, etc. (United Nations, 2022). Given the vast benefits derived from the richness of the environment, it is only natural for stakeholders within and across state lines to form an alliance in other tackle the continued loss of biodiversity and the threat it poses to nature and human well-being. There is ample scientific evidence that biodiversity is fast dissipating at an unprecedented rate in human history (IPBES, 2019). In this regard, several global frameworks have been formulated and adopted to address this menace. Starting from the Rio Earth Summit of 1992 to the "Kunming-Montreal Global Biodiversity Framework of 2022, all of which are aimed at arresting the ongoing loss of biodiversity. Most conservation techniques take into consideration, science, economics, religion, and law.

However, this study tends to focus on the legal aspect of biological conservation.

Before 1950, no legal attention was given to pollution and ecological issues (Ukhurebor and Aidonojie, 2021; Aidonojie et al., 2020). This is concerning that before 1950, just a few bilateral and multilateral agreements tend to regulate international environmental issues (Ijaiya et al, 2018; Dzidzornu, 2004). Most of the international agreements in the operation focused more on unrestrained and controlled national sovereignty over natural resources (Aidonojie et al, 2022; Riget et al. 2016). Furthermore, these international environmental agreements also regulate ecological issues related to boundary waters, navigation, and the rights to fishing along shared waterways (Aidonojie et al, 2022; Ladychenko et al., 2020). In this regard, it suffices to state that no international legal framework concerning the conservation of climate earth and its biodiversity from any form of harmful human activities that may cause depletion of the ozone layer. In this regard, human activities that could be harmful to the environment were unchecked, leading to climate change, and drastically affecting the conservation of biodiversity.

However, the incessant climate change and depletion of the ozone layer, resulting from global industrial stride and the indiscriminate exploitation of biodiversity, has led to the deterioration of climate earth biodiversity (Cifci and Oliver, 2018). In this regard, to curtail harmful human activities, several international laws from 1950 till date have been agreed upon and adopted by several nations that make up the international community to ensure the conservation and preservation of climate earth biodiversity from harmful human activities (Charney, 1995).

Although, it suffices to state that introducing an international environmental legal framework concerning the preservation of climate earth and its biodiversity is one of the greatest achievements of the international community (Megan et al. 2020; Aidonojie, 2023; Anani et al. 2022). However, it has been observed that although several international environmental legal frameworks tend to provide for the preservation and conservation of biodiversity. Unfortunately, there is still a high rate of emission of Methane (CH4), water vapour ($H_20$), Nitrous Oxide ($N_20$), and Carbon dioxide ($C0_2$) as stipulated in the various international legal frameworks Auta et al., 2017; Aidonoie et al., 2022). Furthermore, there has been a deterioration of biodiversity across the global environment resulting from harmful human activities. However, this continuous environmental hazard affecting biodiversity stems from the fact that most member states have a poor commitment to the agreement as it contains various international ecological legal frameworks (Max et al, 2017).

It is concerning the above that this study tends to embark on a study concerning the current trending of the causes of climate change and the effect of climate change on biodiversity. Also, the study will also examine the legal framework as a panacea concerning the preservation and conservation of biodiversity. Furthermore, the study will also identify the challenges inherent in the legal framework preservation and conservation of biodiversity and the way forward of revamping the legal framework concerning the preservation and conservation of biodiversity.

**Literature Review**

The term conservation may mean to carefully preserve and protect something from loss, decay, or destruction. In this context, it may be referred to as the official supervision of rivers, forests, and other natural resources in other to preserve and protect them through prudent management. Conservation may also be considered as the act of protecting Earth's natural resources including air, water, soil, and wildlife in a manner that may be useful for present and future generations. This process may entail maintaining the diversity of species, genes, and ecosystems. The distinction between the term "conservation" and "preservation" is somewhat unclear as the use of these terms has varied over time. For convenience, some scholars, however, used them interchangeably this is because both terms are similar to the extent that they tend to achieve the goal of protecting biodiversity. However, technically speaking, conservation and preservation are different. This is evident from the method and technique they apply to achieve the same purpose.

Conservationist seeks to protect the environment through the responsible use of natural resources. On the other hand, preservation seeks to protect the environment from harmful human activities, at the extreme, preservation proposes the prohibition of man from using the environment as a remedy to extinction and climate change. It is unthinkable for humans not to use natural resources. The reason is that life on Earth is sustainable through its usage. The goal of the relevant legal framework on biodiversity protection has been on

conservation rather than preservation in its technical sense (Santiago-Avila, Treves, & Lynn, 2019). This is because with or without man's intervention the loss, erosion, and extinction of biodiversity are inevitable. Thus, a relevant strategy has been adaptation and mitigation. Adaptation measures are necessary to curb the shortcoming of many stakeholders to curb their GHG emissions as required by various international, regional, and local legal frameworks (Spier,2019).

No meaningful discussion on conservation can be made without first recourse to Rio de Janeiro Earth Summit. Rio Summit laid down the foundation for global commitment toward environmental protection. It was at this event that world leaders under the auspices of the United Nations formally made the needed commitment to the protection of the environment while pursuing economic development. A major feature or fallout of this event was the signing of the Biodiversity Treaty. Rio Summit suffered a setback because of the failure of member nations to make full commitments. Especially, from the countries in the global North. Again, it should be recalled that the requirement of member nations to take inventories of wild animals, plants, and all endangered species.

The Convention on Biodiversity (CBD) at Rio has been supplemented by Cartagena, Nagoya Protocol as well as the recent Kummin-Montreal global biodiversity framework (GBF). According to Steinhauser, et al (2022), the major thrust of this Framework target is to reverse the loss of biological diversity, ensuring sustainable use of its component, and the fair and equitable sharing of benefits arising out of the utilization of genetic resources. The introduction of GBF is meant to strengthen and maintain balance in the protection of the environment through the integration of its objective with the provisions of the Convention on Biological Diversity, the Cartegena Protocol on biosafety, and the Nagoya Protocol on access and benefit-sharing more efficiently and effectively. A major challenge in this Framework may arise concerning the financial requirement of developing countries. As emphasized by Rampheri, et, (2022) they stated that the challenge is that most developing countries do not have enough finances to tackle such issues, and many grappling with development needs so adequately face the required conservation needs.

However, policymakers believe that protecting the human right to a clean, healthy, and sustainable environment, in line with the 1986 United Nations Declaration on the Right to Development is at the heart of full and better implementation. Meanwhile, other scholars such as Kanu (2022) posit that preservation of the environment is possible, through the conceptualization of nature as a mother, source of life, and nourisher. The concept of motherhood brings to bear other virtue such as respect, love, and care which may help in strengthening or promoting a good environment.

In the case of Nigeria, the most recent attempt to conserve the environment has been toward reducing the amount of carbon emission in the atmosphere through a national legislative framework for the mainstreaming of climate change actions. The Act shows Nigeria's commitment to the global agenda of environmental sustainability. Nigeria is also a signatory to the United Nations Framework Convention on Climate Change (1992) and its associated Kyoto Protocol (1997). The country, following the agreement of COP26, has enacted the Climate Change Act 2021. In summary, the Act seeks to provide a framework for achieving low greenhouse emissions (GHG), inclusive green growth and sustainable economic development, and a climate-resilient society. One of the major goals of this enactment is to formulate programs for climate change mitigation and adaptation. In the world of environmental protection and sustainability, adaptation, and mitigation are complementary strategies, which virtually all nations within the global terrain (Spier,2019).

**Methodology**

Given the rate of climate change and its effect on biodiversity, this study tends to examine the current impact and challenges of climate change on biodiversity and the various international regulatory frameworks concerning climate change and the preservation of biodiversity. In this regard, the study adopts or uses a doctrinal research method. The essence of adopting a doctrinal research method is to examine various primary international legal frameworks that regulate how man relates to his environment in curtailing the drastic effect of the harsh climate change. Further, a doctrinal method was adopted or used to examine some international laws concerning the preservation and conservation of biodiversity. However, the doctrinal research method was also adopted in examining various scholarly literature in journal articles, online sources, and textbooks to enable the researcher to critically analyse and review the current trending and effect of climate change on biodiversity. The

essence of the analysis of the scholarly literature is to reveal the fact that there is a need to revamp the various legal frameworks as a panacea in the conservation and preservation of biodiversity from the harsh effect of climatic change.

## Result and Discussion

### Current Trending of the Causes of Climate Change

The consensus among scientists and researchers is that climate change is caused by the emission of greenhouse gases (GHG) such as water vapour ($H_20$), Methane (CH4), Carbon dioxide ($C0_2$), and Nitrous Oxide ($N_20$) into the atmosphere (Zahir, et al. 2021; Aidonojie et al., 2022). These gases can absorb ultraviolet radiation coming to the earth from the solar system, which ordinarily ought to exit outer space but is trapped in the atmosphere. A high concentration of these gases in the atmosphere triggers the problem of global warming (known as the greenhouse effect.)

Anthropogenic activities and natural factors have been identified as the two driving contributors (forcings) to GHG emissions. Unfortunately, a significant amount of the gases has been released daily by human-related activities since industrial development (Kamshat et al., 2020). According to Ahad et al. (2017), the release of GHG by human activities is partly responsible for the increase in the global atmospheric temperature since the mid-20th century.

Global warming is the factual expression of climate change due to too much concentration of GHG in the atmosphere. Greenhouse gases usually act as a blanket or shield trapping heat generated from fossil fuel combustion within the earth, thus, preventing the release of these harmful gases into space, leading to an abnormal rise in the heat level in the earth. Fabio et al. (2021) noted that $C0_2$ and CH4 play the most active role in global warming. However, Alejandro et al., (2017) in their study, observe that $CO_2$ alone contributes about 75% of the total greenhouse gases released worldwide. A similar review of atmospheric activities between 1970-2010 reveals that $C0_2$ by anthropogenic processes contributed approximately 78% of the total greenhouse gases.

Reports by several agencies such as the America Chemical Society (ACS), the America Association for the Advancement of Science (AAAS), and other empirical research published in scientific journals reveal that Anthropogenic activities such as the burning of fossil fuel (E.g., gas, and coal.), deforestation for farming purposes, and other agricultural related activities, play a key role in the total emission of greenhouse gases. In their study, humans' quest for civilization and economic prosperity contributes significantly to GHG emissions into the atmosphere. The ACS, while acknowledging human influence on the changing world climate weather condition, noted that the change in earth's weather conditions is a direct response to the ever-increasing concentration of greenhouse gases in the atmosphere introduced by man with negative implications for the ecosystem (Andrii et al., 2019; Majekudumi et al., 2022). Similarly, the Intergovernmental Panel Assessment Report on Climate Change (IPCC) under the sponsorship of the United Nations, after a period of assessment and evaluation of scientific literature, came to the same conclusion in its Fifth Assessment Report (AR5). IPCC is a team of an expert on climate issues drawn from all over the world by the United Nations to provide a scientific explanation of the ongoing change in the global weather condition, to identify its potential consequences to the environment and the socioeconomic activities of humans to proffer a scientific solution(mitigation) through the adoption of policies and deployment of effective technologies (Robert et al., 2022) In its AR5 of 2014, human input contributed to the rise in atmospheric temperature especially the through the emission of $CO_2$ in manufacturing plants, and vehicular activities. This is traced to the emergence of the industrial revolution.

Consequently, greenhouse gas emissions into the atmosphere have increased tremendously, particularly due to industrial growth in the world population. According to this group of scientists, there is an undeniable connection between industrialization and human civilization. However, the report concluded that there is a very high probability that the release of GHG through human-related activities is the most dominant driver of the increase in the earth's surface temperature from 1951-2010, coupled with other anthropogenic forcing acting together. (Marcelo et al, 2018; Aidonojie et al, 2022).

From the preceding analysis, it goes without saying that among the two drivers mentioned earlier, human-induced greenhouse emissions have the most profound impact on ozone layer depletion and the notorious greenhouse effect compared with natural processes. Essentially, nature's contribution to the release of greenhouse gases, according to Gupta and Pennan (2022) occurs predominantly during a volcanic eruption, in which $CO_2$ is released into the atmosphere. However, the amount of C02 released during this period of volcanic activity is small concerning the

amount emitted by human activities. In addition, the variation in solar radiation, changes in the earth's orbital activities, and rotation around the sun are other natural processes that contribute to climate change.

**The Effect of climate change on Biodiversity**

Several studies have sought to give a pragmatic explanation with empirical certainty, the apocalyptic effect of climate change on biodiversity as a result of extreme weathers events culminating in the loss of natural habitat for various terrestrial and aquatic species, depletion of the world population through death triggered by heatwaves, storms, drought, cyclone, harmattan, and floods. The effect brought by the change in climatic composition, no doubt, is staggering. Notably, the most affected component of the ecosystem is the alteration of the structure of the natural habitat for diverse species.

As a result of a change in the average weather condition, extreme events have progressively impacted biodiversity globally. While the effect may differ across continental lines, the general effect is that it alters the ecosystem and exposes the species to hazards. Due to the disproportionate annual rainfall, intense flood, and wide fire in the ecosystem, many biological species have been forced to relocate and secure an adaptable environment for their continuous existence. While unable to safely migrate to a new geographical location, they will have to exit the lifecycle, thus, shrinking the already depleted population of the species. The gradual extinction of some endangered species is more worrisome, mainly in the Savannah or African region.

Water supply and controlled temperature are the two components necessary for the survival of plants and animals. However, the shortage of water supply (its pollution) and the increasing atmospheric temperature are the major characteristics of global climate change, which can affect the continued existence of these species in the ecosystem. Also, the abnormal rise in heat levels will affect agricultural practices. Indeed, agricultural activities have been severely affected by the intensity and frequency of rainfall throughout the year, affecting productivity. In the same vein, the dropping of acid rain in some climes is known to have a destructive effect on farm products. This also has a catastrophic impact on global food security (Marcelo et al, 2018). It should be noted that environmental disruption is not new to our ecosystem. However, the current climate change has the potential to endanger all species found in both aquatic and terrestrial environments, including man.

The adaptation in the species transformation in the new environment only plays a minimal role in its survival (Robert et al., 2022). Furthermore, he observes that the behavioral, morphological, and Physiological modification of species is most times the direct response to the change in climate conditions. For example, he said painted turtles grew larger in warmer years and attained sexual maturity faster during warm seasons.

Many nations depend on the interactions within and around the aquatic environment. However, with the rise in sea temperature coupled with the shrinking of the glacial, activities in aquatic habitats have dwindled. Considerable evidence has shown that ice will continue to melt, the ocean will rise, and the human mortality rate will increase due to the rise in air and water pollution. Also, for instance, in Bangladesh, it was observed that the problem of an outbreak of cholera was high due to the abnormality in the frequency of rainfall. The same is predicted for other developing countries with poor water and sewage infrastructures. Aside from these social factors, global warming has been detected to impact the spread of infectious diseases depending on the countries' socioeconomic conditions (Abejon and Garea, 2015).

Speaking on the impact of climate change on the world's ecosystem, Endre Ivinnereim (Augustine, 2021) rightly stated that climate change is a problem with global consequences. According to him, the consequence of global warming can not be fenced off but may be mitigated. This explains the collective responsibility approach by international policymakers like the United Nations. By mitigation, we mean the human strategy or activities employed to reduce the human-induced emission of greenhouse gases into the atmosphere by national governments, companies, and more recently by an individual with appreciable knowledge of the impact of climate change on biodiversity. For instance, Greta Thunberg, the young environmental activist, became famous after her protest at the Swedish parliament in 2018. Since then, her campaigns brought other teenagers and college students like herself from European nations and some Asian countries to the awareness of the devasting impact of global warming.

A fallout of this collective responsibility by the international community is driven by the desire to reduce the anthropogenic emission of GHG through active implementations of policies, agreements, and protocols. For instance, the United Nations Framework Convention

on Climate Change (UNFCCC) is believed to be the first and major international treaty addressing the emission of GHG and its associated Kyoto Protocol (1997). However, relevant stakeholders and observers have heavily criticized these regimes for lacking the necessary 'binding' ingredient for proper implementation needed to flatten the curve and prevent further deterioration of biodiversity in the ecosystem. However, a significant portion of EU countries having the foresight of the impact of global warming on natural habitats have taken the initiative to limit industrial emission of GHG within their jurisdiction despite the nonbinding nature of these international treaties/agreements.

It is indisputable that 'we,' including the biological species, are most vulnerable to climate change. Evidence shows that several biological species which are unable to adapt have gone into extinction. Global warming is a precarious phenomenon introduced by man and has an irreversible consequences if proactive steps are not taken. This truth was rightly emphasized by Antonio Guterres, the United Nations Secretary-General. In his opening remarks at the Katowice Climate Change Conference (COP 24) in 2018, when he said "We are in trouble" In a rather apologetic appeal for urgent action, he added, "We are in deep trouble with climate change." In his speech, he noted that the concentration of $C0_2$ in the atmosphere was the highest in 3 million years and still growing.

**The Legal Challenges Concerning Preservation and Conservation of Biodiversity**

Given the causes and effects of climate change on biodiversity, it suffices to state that the international community has through various methods and legal frameworks curtail some of these challenges in mitigating the conservation of biodiversity. However, despite the efforts of the international community to preserve and conserve biodiversity, there are still major challenges mitigating the smooth operation of the international community in preserving and conserving biodiversity. Some of these challenges are examined as follows;

**Poor Level of Implementation and Enforcement**

However, it is also relevant to note that some member states, such as some developed and developing member states who are the signatory to most international treaties, conventions, and protocols, have refused to accede or comply with the directive in most relevant international law environmental regulatory framework concerning biodiversity. This is concerning the fact that there are poor enforcement methods and implementation of the concerned international treaties. For example, most developed and developing countries have refused to commit themselves to reduce the emission of Methane (CH4), Carbon dioxide (C02), and Nitrous Oxide (N20), undue exploitation of the environment as stipulated by the various global environmental legal framework. However, despite this violation by members state, there are no strict penalties or deterrents from refusing to commit themselves to preserving and conserving the climate of Earth, which will protect and conserve biodiversity. Currently, the hash and drastic climate change affecting biodiversity and climate earth is a pointer to the fact that most countries are still carrying out harmful activities that are detrimental to biodiversity and climate earth.

Furthermore, it also suffices to state that most conventions or treaties concerning the preservation and conservation of biodiversity often rest the responsibility of enforcement and implementation on member states. For example, the Convention on International Trade in Endangered Species of Wild Fauna and Flora tends to place restrictions on preserving and conserving them against indiscriminate harvesting and use without due permission from the appropriate body (that is, members' state). This concerns that Articles III, IV, and V of the Convention on International Trade in Endangered Species of Wild Fauna and Flora protect endangered species from indiscriminate exploitation. The provision stipulates that member states must have prior approval in importing or exporting any wild fauna and flora red-listed in appendix I, II, and III of the convention. Furthermore, Article VIII of the Convention Concerning Trade in Endangered Species of Wild Fauna and Flora empowers contracting states that where there is a violation of the convention, an appropriate measure in enforcing the provision of the convention.

Given the above, it suffices to state that giving members state the sole responsibility in implementing and enforcing issues as it affects the global environment may be detrimental and lead to inadequate implementation and enforcement. This is concerning the fact that most members state may not have the capacity to ensure sue implementation and enforcement like an international institution or body.

**Inadequate or lack of Commitment by Members State**

Concerning this study, it has been identified that several international environmental legal frameworks tend to provide for the preservation and conservation of biodiversity. However, irrespective of the above relevant legal framework concerning biodiversity, it suffices to state that one of the challenges mitigating the preservation and conservation of biodiversity could stem from the fact that there are poor or low levels of commitment by most member state in acceding to the agreement as contained in the various international environmental treaties. For example, in 1997, nations had to come together during the Kyoto Protocol to proffer an enabling solution in curtailing, reducing, and mitigating the level of industrial activities that release gasses that cause global warming. In this regard, the Kyoto Protocol was adopted due to the drastic emission or release of greenhouse gasses concentration in the atmosphere, thereby causing climate change and global warming, which had most of its challenges with member states committing themself to the protocol. This is concerning the fact that nations such as USA and China withdrew their membership. Given that the USA and China withdrew their commitment to the protocol in 2012, Canada also withdrew from the summit. Their withdrawal is because the biggest two emitters (China and the USA) are not part of the protocol agreement. Furthermore, given the fact that it will amount to the Canadians to reduce their industrialization and employment opportunity drastically. According to the Canadian environment minister, he said

> "The Kyoto Protocol does not cover the world's largest two emitters, the United States and China, and therefore cannot work," Kent said. "It's now clear that Kyoto is not the path forward to a global solution to climate change. If anything, it's an impediment." signing Kyoto was one of the previous government's biggest blunders, allowing us to continue creating jobs and growth in Canada.

This is concerning the fact that, if members state has effectively complied with the directive as regards, the reduction of emission of water vapour ($H_20$), Methane (CH4), Carbon dioxide ($C0_2$), and Nitrous Oxide ($N_20$), reduction of bush burning as stipulated in global environmental treaties and convention, the level of drastic climate change affecting biodiversity would have been curtailed or minimize. However, the current report has shown that climate Earth is still severely undergoing global warming and climate change, owing to harmful activities of man that are catastrophic to climate Earth.

**National Legislation Constrain in Implementing International Treaties**

Although most nations have seen the need to form an international institution in resolving issues that tend to have an international flavor. However, the various international laws that have been enacted recognize the fact that members state still possess sovereign power within their society or state. They are exercised and realized in distinct ways. In this regard, virtually all countries' constitution provides for their sovereignty and supremacy of their contents. Therefore, any law inconsistent with the said provision or content of the constitution will be declared null and void. Concerning this, it suffices to state that, in most developing countries, their constitution places restrictions or constrains concerning the recognition and enforcement of international treaties, conventions, and protocols. For example, in Nigeria, virtually all international treaties, conventions, and protocols are not enforceable by section 12 (1) of the Nigeria Constitution, except such international instruments have been domesticated by the National Assembly. Section 12(1) of the Nigeria Constitution provides thus;

> No treaty between the Federation and any other country shall have the force of law to the extent to which any such treaty has been enacted into law by the National Assembly.

This position of the Nigeria constitution has been aptly given judicial recognition in the case of *Abacha V. Fawehinmi (2000) 6 NWLR (PT. 660) P. 228 at 228*, where Ogundare JSC held that before an international treaty becomes binding and enforceable in Nigeria, such treaty must be enacted into law by the National Assembly. Also, in the case of *Mhwun V. Minister of Health & Productivity & Ors (2005) 17 NWLR PT. 953, P. 120*, the court held that the provisions of an International Labour Convention could not be invoked and enforced by Nigeria court unless an Act of National Assembly has domesticated it.

The above provision of the Nigerian constitution serves as a constraint and restriction on the international

environmental legal framework concerning the preservation and conservation of biodiversity within the Nigerian territory.

**Poverty and Poor Level of Technological Development in most Developing countries**

Given the level of poverty and slow pace of technological development in most developing states or countries, it may also serve as a challenge in ensuring the effective preservation and conservation of biodiversity. This is concerning the fact that these developing countries may not have the capacity to adapt or adopt sophisticated technology or scientific method that could preserve and conserve biodiversity. In this regard, given the poor level of their economy and technological development of most developing countries, it may lead to such countries engaging in some industrial activities that could be harmful to biodiversity.

**The Possible Ways of Revamping the Conservation and Preservation of Biodiversity**

Varied predictions on the effect of climate change on the natural system indicate that delay in mitigation may cause irreversible consequences on the ecosystem. In this regard, the timely intervention, the environment, and diverse species (plants and animals) in the ecosystem may be conserved or salvaged from the brink of extinction.

Given the above, it suffices to state that the following mitigating measure that could revamp and complement the available international environmental legal framework should be considered if the ecosystem will be preserved.

**a. Role of the Government of Signatory States in the Conservation of Biodiversity**

The essence of the calls for sustainable development that ensures the effective preservation of biodiversity by the international community through the relevant legal framework is very pertinent to the existence of man and its environment. However, the protection of and conservation of biodiversity cannot be fully realized without the stake input of signatories' states in their respective domains. This is concerning the fact that the aim and essence of the relevant international legal framework that tends to preserve and conserve biodiversity will only have a better effect of implementation if, at the local level, there are legal frameworks that provide for the preservation and conservation of biodiversity within their territory. In this regard, it suffices to state that the government of all signatories should, through national environmental legislation, replicate most of the provisions of the international ecological legal framework that curtails the ongoing activities (such as the emission of Methane (CH4), Carbon dioxide (C02) and Nitrous Oxide(N20), undue exploitation of the environment and bush burning) that destroy biodiversity. Furthermore, states party must go through administrative measures to take proactive preventive and protective measures concerning the preservation and conservation of biodiversity. Some of these administrative measures that could be adopted in ensuring the preservation and conservation of the marine environment;

i. Setting up a task force to curtail incessant and indiscriminate exploitation of biodiversity and curtailment of bush burning
ii. Declaring specific days for environmental sanitation
iii. Setting up a mobile court to summary try individuals violating or refusing to adhere to environmental sanitation that seeks to curtail minor pollution within their environment

However, irrespective of the above, the government of the signatory state should endeavor to create a Lilly way for effecting and implementing an international environmental legal framework concerning biodiversity. In this regard, there should not be any national or state constitutional and legal restrain restricting the international community from effectively implementing the relevant international environmental legal framework concerning biodiversity within members or signatory states. Furthermore, given the global-scale impact of climate change, collective international policies are needed to utilize regional support effectively.

**b. Adopting a New Scientific method that compliments Relevant International Legal Framework on Biodiversity**

The need to develop international and states environmental law was triggered and necessitated by the need to protect life and preserve the ecosystem from hazardous substances that may be very harmful and result in the pollution of the environment. However, it suffices also to state that the introduction of hazardous substances to the environment that results in the depletion of the ozone layer is mainly a result of the harmful industrial

activities of humans arising from exploiting natural resources of climate Earth. Therefore, given the harmful activities of human industrial activities, it has degenerated into an environmental problem such as pollution of the environment, deforestation, desertification, acid rain, the destruction of the ozone layer, and climate change.

It concerns the above that a scientific researcher has scientifically driven them in inventing scientific methods to preserve and conserve climate earth, which will ensure the conservation of biodiversity. It must be noted that one such scientific method that has been adopted is Nanobiosensor. According to scientific study, nanobiosensor has been scientifically proven to be relevant in various scientific research. This is concerning the fact that the introduction of the scientific concept of nanobiosensor for environmental monitoring is aimed at ensuring prevention and control of the introduction of hazardous substances or constituents that may contaminate or pollute the environment (Vincent et al., 2015).

Furthermore, another scientific discovery that could also be relevant in conserving and preserving biodiversity is nanotechnology. According to a scientific study, nanotechnology involves the designing and making use of devices and systems ranging from 1-100 nm scale (Fei Ma and Chun-yang, 2018). The relevance and essence of utilising nanotechnology are based on the sensing and detection of harmful substances that could cause pollution. In this regard, the use of nanotechnology involves the use of nonmaterial in detecting pollutants and hazardous substances (Nafiseh et al., 2016).

Given the above, it suffices to state that given the relevance of current scientific discovery (such as the nanobiosensor and nanotechnology that complement and strengthen the already existing international environmental legal framework for conservation and preservation of the environment) as relating to scientific preservation of the environment, such scientific measure should be adopted to complement the implementation of the current international legal framework as it relates to the preservation of biodiversity.

### c. Strict Sanctioning Erring Countries or States Violating International Legal Framework on Biodiversity

However, despite this violation by members' states, there are no strict penalties or deterrents from refusing to commit themselves to preserve and conserving climate earth, preserving and conserving biodiversity. It suffices to state that most developed and developing countries have refused to commit themselves to reduce the emission of Methane (CH4), Carbon dioxide (C02), and Nitrous Oxide(N20). Furthermore, it was also observed that the continuous and undue exploitation of resources within the environment is prohibited by the various global environmental legal frameworks. This is concerning the fact that the current hash and drastic climate change affecting biodiversity and climate earth is a pointer to the fact that most countries are still carrying out harmful activities that are detrimental to biodiversity and climate earth. In this regard, the international community must, via the relevant international legal framework and various mechanisms, ensure strict compliance of members' state of the various scheme stipulated in an environmental legal framework to ensure proactive conservation and preservation of biodiversity. Furthermore, it is also required that the International Court of Justice should be given adequate judicial power concerning erring states whose activities tend to pose a threat to climate earth

### d. Re-engineering the polluters-pay principle with strict liability

It suffices to state that the need for the protection of climate earth biodiversity should not only be statutorily recognized. Rather there should be an imposition of strict liability where polluters are strictly held responsible for any of their actions that threaten the biodiversity of their neighboring state or within the international community. These principles of polluters pay have been aptly observed by the court in Trailsmelter Case (Xingang et al., 2022). The principles seem to have been adopted in several cases in the past, such as the Netherland Case that occurred in 2008. In the Netherlands case, four Nigerian farmers and with some relevant stakeholders of the international community known as Friends of the Earth filed a lawsuit concerning Shell Company oil spillages in three villages in Nigeria. In deciding on the lawsuit, the Dutch Court issued a decision compelling Shell Company to pay compensation to the farmers and ensure clean-up of the affected community. Furthermore, in the lawsuit of *United States of America V. Shell Offshore Inc. and Shell Exploration and Producing Company*, Shell Company was ordered by the court to pay Forty-Nine million dollars ($49,000,000) for engaging in an unauthorized gas flaring. The above represents the practice of polluters pays principles in the past; however, there seems to be a

lack or inadequate use of the polluters pay principles against those whose activities endanger the climatic biodiversity. Hence, it is required that the international community ensure that the polluter's pay principles are incorporated into international treaties and conventions and ensure effective enforcement and compliance of the polluter pay principles.

**e. Mitigate Greenhouse Gases Emission (Decarbonization)**

Having noted that the most dominant GHG emitted daily by human activities is Co2, and the same is released during fossil fuel combustion, a drastic reduction is required to keep the earth at a low temperature. Adopting friendly environmental technologies is key. Such mitigation procedure is in line with Article 2 of the UNFCCC.

**f. Reforestation and Effective Forest Management**

The farm practice of deforestation should be discouraged. Deforestation contributes significantly to the emission of co2. According to Anuradha et al., deforestation contributes approximately a quarter of the increase in the level of co2 in the atmosphere. Thus, reforestation may be a viable option for restoring the needed balance in the ecosystem. It should be noted that in the event of wildfires occasioned by climate change, there is usually a structural imbalance for most organisms in the forest. The herbivorous habitat is primarily affected, leading to shifting geographical locations with attendant hazards to predators along the way. To curtail this climate change, as an alternative to reforestation, Anuradha et al. recommended that forest management practices be implemented to enable the forest to cope with forest disturbances under climate.

**g. Encourage the Use of Renewable Energy**

The fact that a large percent of the world population still depends on fossil fuels for energy is evident in the ever-global increase in temperature. However, many nations and multinational companies have started investing in alternative energy sources (wind and solar). Renewable energy help to reduce the amount of pollution in fresh water and the marine environment. For instance, many regions rich in biodiversity and marine life have been negatively affected during explorative activities for mineral resources.

**Conclusion**

This study has identified that climate change and global warming arising from harmful human activities pose a great danger to climate earth's biodiversity. The study also observed that the conservation and preservation of climate earth biodiversity is a key and a central focal concern of the international community. This is concerning the fact that several international environmental laws concerning the preservation and conservation of climate earth biodiversity have been agreed on and adopted by members of the international community.

However, the study further identifies that despite the various international environmental legal frameworks concerning the preservation of climate earth biodiversity from harmful human activities. There is still an increased rate of deterioration of climate earth biodiversity arising from the detrimental activities of humans. The reason for the current increase rate of climate earth biodiversity stems from various reason which has been identified in this study above. Hence, concerning these challenges, the study tends to identify some probable solutions in revamping the international environmental legal framework concerning the preservation of biodiversity as follows;

i. The government of signatory states to international environmental treaties, conventions, and protocols in biodiversity conservation must ensure they commit themselves to their role as stipulated in the various international environmental legal frameworks.
ii. There is a need to adopt a new scientific method that compliments relevant international legal frameworks on preserving biodiversity.
iii. The international community must adopt a strict sanctioning method against erring countries or states violating biodiversity's global environmental legal framework.
iv. The international community should re-engineer the polluters-pay principle with strict liability against erring states whose activities threaten their neighboring state.

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REVIEW ARTICLE

# The Role of Parliamentarians in Implementing SDGs in Pakistan: A Qualitative Study Incorporating Lessons Learned across Eight Countries

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**Abstract**

The Sustainable Development Goals (SDGs) provide a comprehensive framework for addressing social, economic, and environmental challenges facing countries around the world. The role of parliaments in implementing the SDGs has been widely recognized, but the extent of their impact remains uncertain, particularly in developing countries such as Pakistan. This paper aims to investigate the role of parliament in implementing the SDGs in Pakistan and to draw lessons from other countries that have successfully integrated the SDGs into their legislative processes. To achieve this objective, a qualitative research design was employed, which included a comprehensive analysis of lessons learned from other countries. The findings suggest that while the Pakistani parliament has taken steps towards aligning its policies with the SDGs, there is still a long way to go in terms of effective implementation. Lessons learned from other countries indicate that parliamentary oversight, public participation, and capacity building are key factors in successful implementation of the SDGs. The paper concludes with a series of recommendations for enhancing the role of parliament in implementing the SDGs in Pakistan.

**Keywords:** SDGs; Parliament of Pakistan; implementing SDGs; developing countries; environmental challenges

## Introduction

In 2015, countries adopted the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals, building on the success of the Millennium Development Goals (MDGs). However, the Sustainable Development Goals (SDGs) are a blueprint for achieving a much more sustainable future for all people (OECD, 2017). The main purpose of the SDGs was to address the global challenges being faced by international communities, and poverty eradication is the overarching target of this new agenda. A few of the other issues include inequality, environmental degradation, illiteracy, peace, and justice. Each goal interconnects with the others; therefore, it is important to incorporate all 17 goals and leave none unaddressed (Hák et al., 2016). Moreover, these new goals are unique in their nature as they call for action by not only the poor or developing countries but also the rich-income countries to promote long-term sustainability, inclusive development, and prosperity while protecting their environment. Furthermore, Goal 16 (Goetz & Jenkins, 2016), also known as the governance goal, reflects the Inter-Parliamentary Union's (IPU's) and United Nations Development Program's (UNDP's) long-held view that democratic governance is not only an end in itself but also a means to achieving sustainable development through strong legislative and other important national institutions (Kettunen et al., 2018).

With the advent of the SDGs, the global community has turned its focus to the question of their effective implementation, both at the national and international levels. To ensure the successful implementation of SDGs, there is a need for an effective structure of procedures, functional institutions, and legal frameworks to not only promote but also implement SDGs to achieve desired results in the long

run (Kaushik, 2019). Each country will have its own level of prioritization of the goals/targets according to its capacity, understanding, and circumstances; therefore, countries must be provided enough space to determine and implement the goals they feel are most important to them. Moreover, it is not necessary that all 17 goals are relevant to every country; however, a strong commitment towards achieving them and effective implementation policies must be made by the national actors, including the Parliament, for the accomplishment of those targets that are applicable in their case (Oosterhof, 2018; Kettunen et al., 2018). Therefore, with the help of the national parliament, countries should translate global sustainable development goals into national sustainable development targets, each according to their needs (Hassan, 2022).

It is perhaps true that a country's parliament can act as a catalyst in implementing the SDGs, as it is widely believed that without a political will, the probability of success of progressive reform in any country is almost equal to null. Therefore, for the implementation of the SDGs through an effective institutional structure, the political environment of that particular country should be conducive to such progressive changes (Biermann et al., 2022). The issue is that the political arena, for the most part, is dominated by self-interests at the cost of the common good/interest which hinders the proper functioning of our legislative or administrative processes (Ugoani, 2017).

Therefore, the 2030 Agenda for Sustainable Development puts emphasis on localizing SDGs in national practices by coordinating the already existing national policies towards a common target that fulfills the agenda of "Green Growth" (Lee et al., 2016). Each country will therefore have to identify its own priorities in this regard and move towards localizing such targets with the help of parliamentarians and national actors for effective implementation. Moreover, the national development plans of countries should be adjusted by the Sustainable Development Agenda (Meuleman, 2021). These new development plans should encompass all possible dimensions of inclusive growth by tilting towards a much more holistic policy intervention against anti-development-related challenges, i.e., poverty. The SDGs provide an opportunity for all parliamentarians to illustrate their focus and commitment towards public welfare and well-being and the improved health of the environment. Furthermore, the SDGs have laid down a framework based on which national actors can pursue their own targets and move towards prosperity (Chungong & General, 2018).

It is of great concern as to how parliament can play a role in the implementation of the SDGs. Parliament is a key institution under which a state runs, the legislative body is responsible for making laws that describe the rights and obligations of state-actors towards one another, which enables a state to function properly. The Parliament also plays an important role in the budget allocation process, as they approve how much and where the budget should be allocated (Hege & Brimont, 2018). As not only the law-makers but also the elected representatives of their people, parliamentarians have a major role to play in promoting people-centered development; therefore, parliamentarians must ensure their citizens' needs and interests are being fulfilled through government-initiated programs or plans (Adiputri, 2021).

Moreover, the emphasis on the importance of parliaments and stakeholders getting involved in the national implementation of SDGs became stronger after the first review of the UN of MDG implementation in 2005; it was argued that it was extremely important that these goals were not being implemented in isolation, further arguing that engagement of the parliament would lead to much more progress in the country (Adiputri, 2021).

Undoubtedly, parliamentarians are responsible for supporting and monitoring the implementation of the SDGs within a country and promoting the 2030 Sustainable Development Agenda (Lee et al., 2016). Parliamentarians have a special role to play in Goal 16 of the SDGs, which is "Sustaining Peace and Good Governance," as they are the promoters of peace and justice for all and responsible for building effective and accountable institutions at local levels (Hope, 2022). This goal can only be completely achieved through the participation of parliamentarians through effective law-making, representing the interests of the public, and ensuring accountability and inclusiveness through proper monitoring (Kettunen et al., 2018). The presence of accountable and transparent institutions that take timely actions will guarantee proper implementation and desired outcomes, as implementation rests critically on accountability. Therefore, in order to achieve national sustainability goals, parliamentarians must look into unexplored areas to improve the effectiveness of their systems and processes (Guha & Chakrabarti, 2019).

An inclusive process can help nationalize and institutionalize the SDG agenda. In this process, a national SDG group is established that is responsible for providing guidance regarding the implementation of these goals. The parliamentarians are also included in these group activities, as their participation can help incorporate nationals' views and provide institutional support (Fitsilis & De Vrieze, 2020).

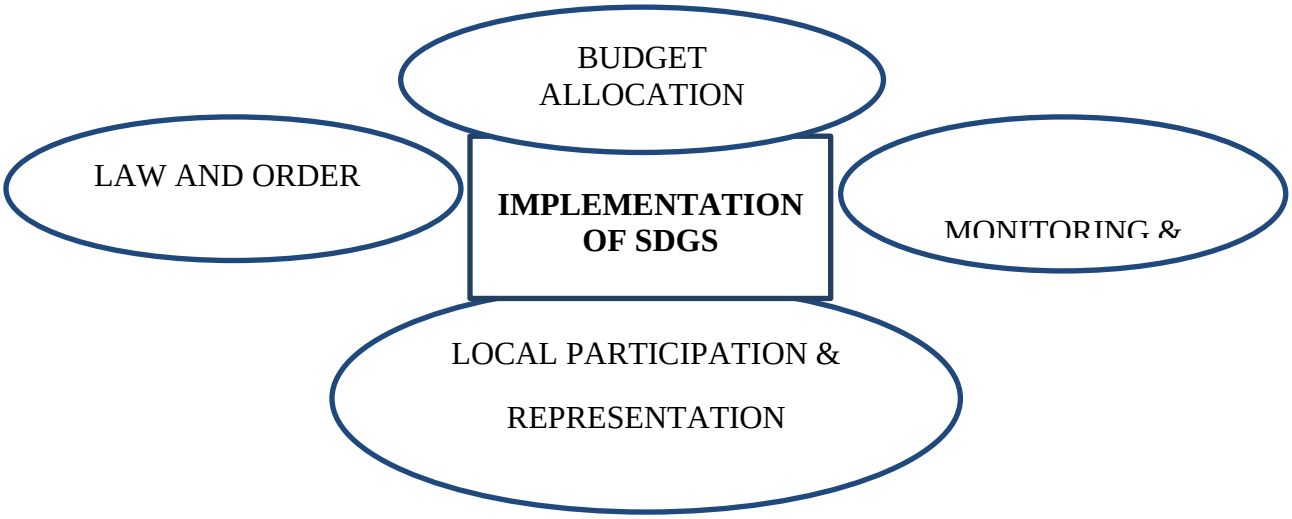


**Figure 1.** Proposed elements for implementation of the SDGs

Moreover, the national development plans are reviewed by the governments to ensure they are in accordance with the SDGs for achieving inclusive growth in the country. Public participation and consultation would further help in the efficient and effective implementation of national development targets. Lastly, monthly progress reports by the governments could be helpful for monitoring and evaluating the status of targets post-implementation to see if they are on track (Walshet et al., 2019).

The proper implementation of the SDGs depends on the following tools at the national level, as mentioned in Figure 1. All four dimensions that enable the implementation of the SDGs can be managed by the parliament. Law-making behaves as an enabling tool for the national implementation of SDGs in a way that a country's legislature that promotes equality, a pro-poor policy agenda, inclusiveness, public accountability, and local participation in decision-making can better ensure the national preparedness towards achieving SDGs (Fitsilis & De Vrieze, 2020). Therefore, parliamentarians must be mindful of the kind of legislature their governments have proposed in the country and whether or not it promotes human rights. Moreover, the successful implementation of the SDGs depends on budgeting. The parliamentarians should carefully engage in this process by evaluating how much of the government funds are being allocated to their national SDGs and identifying if sufficient funds are being allocated, especially to areas that are vulnerable and socially excluded (Fitsilis & De Vrieze, 2019). Monitoring and Evaluation includes the pre and post assessment of government policy interventions in achieving national development plans, M&E will help national actors keep track of the progress of their national sustainable development targets. Lastly, local participation and representation act as an enabling tool in pointing out gaps and weaknesses in the national implementation of the SDGs, as local citizens and stakeholders can bring forward their wider concerns and how they can be effectively met (Tam, 2022).

A self-assessment toolkit designed by the Inter-Parliamentary Union in order to support parliaments in becoming "fit for purpose" and carrying out their prime functions of legislation, budgeting, and representation on the SDG agenda. This self-assessment mechanism is used as a tool to provide assistance to parliaments around the world for their preparedness to firstly engage with the SDGs, look for different strategies, processes, and mechanisms that will ensure and support the implementation of the SDGs (Oosterhofm, 2018). Parliamentarians will get to identify multiple opportunities, practices, and gaps that need to be filled; as a result, they can easily institutionalize the sustainable development agenda in their national policies and legislative processes. Moreover, self-assessment may help governments identify their capability and capacity in terms of their preparedness for involvement in the 2030 Agenda and implementation of the SDGs in their respective countries. It will allow the governments to realize where they currently stand and where they want to go (Bexell & Jönsson, 2022). Furthermore, for the parliaments to stand strong on their human rights agenda, they need to include women and other minority groups within the country either through new electoral laws under which new deserving candidates could be hired or through participatory

development. This way, the issues captured by the Sustainable Development Targets will have legitimacy, as now the citizens will demand them (Dirth & Zondervan, 2019).

On October 15, 2017, the Inter-Parliamentary Union (IPU) and the United Nations Development Program released the second Global Parliamentary Report; the aim of this report was to highlight the role of Parliament in the implementation of SDGs around the globe (Chiniaeva & Chiniaeva, 2021). Additionally, the 2030 Sustainable Development Agenda has also emphasized the role of Parliament in holding its government accountable for actions taken to eradicate extreme poverty and work towards green growth (Bexell & Jönsson, 2022). According to the report, the parliamentarians are given a golden opportunity to increase their participation and engagement in government-led actions to promote sustainable development in the country through proper implementation. Since the role of parliaments is also law-making, they can easily translate the language of the SDGs into their national law, which will compel the government to take initiatives and timely actions (Mulholland, 2017).

During the Declaration of the 2030 Sustainable Agenda, it was clearly stated

> "We acknowledge the essential role of national parliaments through their enactment of legislation and adoption of budgets and their role in ensuring accountability for the effective implementation of our commitments."

The Sustainable Development Goals Partnership Platform has also initiated the idea of having a Parliamentarian Assembly for the implementation of SDGs on a voluntary basis, in which parliamentarians and other actors will join hands to advocate the efforts to implement SDGs in national plans or legislations for their effective implementation (Tam, 2022).

**Methodology**

This study adopted a case study research methodology that included a thorough examination of lessons (case studies) from parliaments in other countries. The synthesis of the aforementioned study designs creates a thorough analysis. The goal of the current study was to develop lessons learned on the function of parliaments in implementing the SDGs. The field of SDG interactions has rapidly advanced since the adoption of the 2030 Agenda in 2015, but the field is still relatively new. This paper could serve as the basis for the future research studies.

Data triangulation was employed to ensure the validity and reliability of the findings. This process has been found to be helpful in corroborating findings, supplying more complete data, and improving comprehension of the subject matter under consideration. The insights derived from comparative case studies were synthesized to formulate a set of recommendations for enhancing the role of parliament in implementing the SDGs in Pakistan.

**Lessons Learned from Other Parliaments**

The IPU is actively supporting parliaments in assessing their capacity to work on the SDGs in Fiji, Mali, Djibouti, Serbia, with Namibia, Kenya, and Sri Lanka in the pipeline, to name but a few (Nanda et al., 2020; Guet et al., 2020). We have organized regional seminars for parliaments in the Asia Pacific region, Sub-Saharan Africa, Central and Eastern Europe, and Central Asia, and the list goes on. We also promote parliamentary engagement and contributions to country SDG reports to the UN, a process that takes place every summer at the UN in New York. I have just come from this year's session, where there is growing evidence that governments and parliaments are working together to move forward with the SDG agenda. That is a good lesson worth emulating (Sherr et al., 2020).

**Samoa**

The International Labor Organization (ILO) has been the only tripartite agency of the United Nations (UN) since 1999, and it brings together governments, workers, and employers from all around the world in order to set labor standards. In 2016, UN agencies, in partnership with multiple Government Ministries of Samoa, including the Office of the Clerk and Legislative Assembly (OCLA), held a special workshop aimed at training new members of the Parliament on the 2030 Agenda and the Sustainable Development Goals (Guerrero-Ruiz et al., 2021).

**Malaysia**

Malaysia is one of the countries facing issues with food security. Many rice fields in the country are being converted into housing colonies or commercial areas. Penang State Legislative Assembly, YB Dr. Norlela, State Assembly Person for Penanti, has been working to spread awareness about this issue among the general public. She is doing so through the Penang Paddy Festival, whose goal is to not

only raise awareness about the hardships faced by paddy farmers, but also shed light on the rapid urbanization of agricultural land in Malaysia (Abd Rahman & Yusof, 2020).

**Azerbaijan**

In a speech on the role of Parliament in the implementation of the 2030 Agenda, Ghulam Isaczai mentions how all state institutions in Azerbaijan have been actively participating in the implementation of the SDGs. He went on to explain the important role of parliaments as powerful agents of change. In his own words,

> "Parliaments play an important role in the localization, implementation, and monitoring of the SDGs. Parliamentarians are close to the people and can serve as advocates, mobilizers, and first-line 'ambassadors' for the SDGs. In representing those who elected them, and offering a platform for communication, parliaments can ensure an ongoing dialogue with civil society over the SDGs."

According to him, parliaments must not only incorporate SDGs into national laws but also monitor their implementation by ensuring that the government is held accountable to the people for national progress in terms of achieving SDGs (Aliyev, 2019). Additionally, parliaments can contribute a great deal by guaranteeing that national development is inclusive and participatory, and that sufficient financial resources have been allocated for its success. Isaczai also commends parliaments from around the world that are taking notable action to advance the SDGs. As a few examples, he shares that the Parliament of Kazakhstan adopted a statement committing itself to the promotion of the SDGs in parliamentary affairs. Whereas, the National Assembly of Pakistan established an SDG Task Force to promote debates, engage MPs, and increase awareness of the SDGs. And finally, the Parliament of Trinidad and Tobago established a new Joint Select Committee on the Environment and Sustainable Development (Taghieva, & Hashimova, 2019).

He concludes his speech by naming a few of the important legislations on which the Parliament of Azerbaijan has worked:

- The draft legislation on mandatory flour fortification is essential to reduce anemia, especially among women and children.
- Review of current legislation on inclusive education in order to build an enabling environment to achieve the SDGs goals on quality education for all.
- The adoption of the new **Law on the Rights of Persons with Disabilities** is important, as it would help to accelerate reforms in this field.
- Adoption of the revised **law on youth policy** will bring current legislation in line with best international practices.

**United Kingdom**

The UK adopted the SDGs in 2015 and has since committed itself to not only achieving these goals domestically, but to helping other countries do the same. In order to gauge the progress made since 2015, the UK Government will be presenting its Voluntary National Review to the UN in July 2019. For this purpose, the International Development Committee held an inquiry into UK progress on the SDGs, inviting written submissions on the government's progress on the SDGs (Jones & Comfort, 2020).

**Finland**

Finland has been one of the most successful states in terms of SDG promotion. It has made commendable efforts in the field, including follow-up reports by Civil Society Organizations on Finland and the 2030 Agenda, which not only compare the current condition of SDG achievement in the country to UN standards, but also highlight what the country must do to improve in areas even if it is already doing well (Taghieva, & Hashimova, 2019). According to their Government Report on the Implementation of the 2030 Agenda for Sustainable Development, one of the basic principles regarding the implementation of the SDGs is Society's Commitment to Sustainable Development (SCSD) - The Finland We Want by 2050. It consists of 8 goals for Finland to achieve by 2050, and was updated to align it with the 2030 Agenda, making them synonymous. This commitment presents Finland's national interpretation of the 2030 Agenda and, thus, is a plan adopted by the entire Finnish society to achieve the SDGs. In short, the SCSD is an implementation mechanism that enables citizens, businesses, organizations, municipalities, and other stakeholders to participate in the implementation of the 2030 Agenda (Väänänen & Pöllänen, 2021).
In 2016, a number of studies were carried out to assess Finland's preparedness to implement the 2030 Agenda on

the basis of indicator-based material, stakeholder opinions, and literature. The results are divided into Finland's success areas, which it must sustain, and critical points, which require urgent action (Gade et al., 2022). Such studies and reports have been used in the creation of Finland's SDG Plan. To further make use of this data, different stakeholder groups, the Finnish National Commission on Sustainable Development, and the Development Policy Committee organized multiple events in which proposals were presented by the Expert Panel on Sustainable Development to highlight key priority areas for Finland, which served as valuable reference material and guidelines for the Plan (Ylönen & Salmivaara, 2021).

**Sri Lanka**

In October 2018, the Parliamentary Select Committee on the 2030 Agenda for Sustainable Development, in collaboration with the United Nations Development Program (UNDP) and the Inter-Parliamentary Union (IPU) of Sri Lanka, held a workshop on the critical role of Parliament and parliamentarians in implementing the Sustainable Development Goals. The aim of the workshop was to help parliamentarians and their members assess their preparedness to engage with the SDGs and identify additional strategies, mechanisms, and partnerships to support the implementation of the SDGs more effectively. Honorary speakers in the workshop included not only members of the Sri Lankan Parliament and notable government officials, but also speakers from the private sector, non-governmental organizations, and youth organizations (Wijegoonawardana, 2019).

**The Republic of Seychelles**

Despite their small size and many constraints, the groups of islands that make up the Seychelles have been demonstrating commitment towards the achievement of the SDGs not just at the international level but in regional partnerships and agreements and in national policies, action plans, and institutional frameworks (Baker et al., 2023). Through global initiatives such as the Global Island Partnership (GLISPA), Seychelles has been successfully engaging leaders from over 60 countries and has joined hands with overseas territories for island conservation and sustainable use of natural resources. In collaboration with UNDP Seychelles, the National Assembly of the country hosted a panel discussion on Engaging Parliament on the Sustainable Development Goals, to celebrate their first International Day of Parliamentarianism. Members of the Department of Economic Planning and the Bureau of Statistics gave presentations with regards to SDGs in relation to their respective organizations (Gungadeen, & Paull, 2020).

The 2020 Sustainable Development Outlook for Seychelles highlights the current condition of the SDGs in Seychelles and how to improve them. Using macro-indicators such as economic development and social well-being, the Outlook also presents warning trends that may hinder the process of achieving the SDGs. This provides great assistance in formulating the next step to achieve a more sustainable Seychelles (Etongo, 2022).

**Australia**

Among other efforts, Australia has also established a reporting platform that provides official government data on the SDG indicators (Allen et al., 2020). In December 2017, the Australian Senate requested that its Foreign Affairs, Defense, and Trade References Committee examine and report on the SDGs. This report was to include not only the understanding of SDGs among the wider Australian community and government but also a cost-benefit analysis in terms of SDG implementation in the country. Additionally, the Committee recommended the following to the Australian Government:

- Publish a national SDG implementation plan that includes national priorities and regular reports of Australia's performance against the goals;
- Provide an indicator-based assessment to Parliament at least every two years that tracks Australia's performance against the Goals;
- Establish a national SDG secretariat to, inter alia, provide support to the existing interdepartmental committee;
- Provide effective coordination of Australia's actions to implement and report on the SDGs;
- Develop a framework to ensure that its agencies include the SDGs in their annual reporting by 2020-2021;
- Support state, territory, and local governments to create their own plans for the implementation of the SDGs in their jurisdictions;
- Partner with "private and tertiary sector" stakeholders to develop and disseminate Australian guidance on reporting against the Goals; and

- Identify opportunities to assist small and medium enterprises (SMEs) to build capacity to access sustainable procurement and reporting systems.

**What role can Pakistani parliamentarians play in implementing the SDGs in Pakistan?**

Pakistan has shown great commitment towards the 2030 Agenda for Sustainable Development; moreover, it was one of the first countries to ever approve of the agenda in 2015. On February 16, 2016, the Pakistani Parliament approved the Sustainable Development Goals as the national Development Plan (Dobrowolski, & Sułkowski, 2019). Furthermore, it is one of the few countries to create a Parliamentary SDGs Secretariat under the National Assembly; this was indeed a vital step taken to promote sustainable growth in the country. The 18th Amendment touched upon several other functions, including that of providing social services to the provincial governments through the federal governments. Moreover, Pakistan has had panel discussions on the SDGs with other actors involved in order to strengthen efforts to promote and achieve sustainable development in Pakistan along with the eradication of poverty (Galli et al., 2018). Additionally, Pakistan's Vision 2025 has established 7 pillars that the country has to achieve, these pillars are in full alignment with the Sustainable Development Goals, therefore, and it can be argued that efforts have indeed been made to incorporate the 2030 Sustainable Development Agenda in the country's national planning (Katramiz et al., 2020).

Through the involvement of the Ministry of Planning, Government of Pakistan, and Planning and Development Departments of provincial governments, along with the support of the United Nations Development Programme, Pakistan has launched a five years joint project called "National Initiative for Sustainable Development Goals to Institutionalize the 2030 Agenda" (Latif et al., 2022). National and international actors are working towards the coordination, reporting, monitoring, and financing of the SDGs in the country. They are also providing policy prescriptions through R&D (Asad, 2019). Along with that, the team is also raising awareness among citizens and stakeholders regarding the 2030 Agenda and Sustainable Development Targets with the use of different communication tools and a variety of activities (Javeed et al., 2021).

It is important to remember the already existing mission on which Pakistan was built in the first place. While incorporating the historical targets, the parliament should address the SDGs in their relationship. As argued by the Inter-Parliamentary Union, it is important to first sensitize parliamentarians on issues like human rights, gender equality, and human well-being through capacity building (Tam, 2022). The first and foremost step should be to inform the parliamentarians and parliamentary staff and train them on their role in the national implementation of the SDGs. Once that is done, sessions should be conducted to initiate a debate among parliamentarians and parliamentary staff on the SDGs and their importance and analyze their capacity and preparedness for SDG implementation. An example is the Sri Lankan initiative (Albert et al., 2019). The stronger the parliament's relations and interactions with its government, citizens, stakeholders, etc., the higher the chances of achieving sustainable growth in the country. Additionally, different organizations working within the country can join hands with the Pakistani Parliament to promote local development preferences and needs through local participation, which can be difficult to identify at the state-level (Fatima et al., 2020).

Finland's Society's Commitment to Sustainable Development (SCSD) - The Finland We Want by 2050 is an implementation mechanism that enables citizens, businesses, organizations, municipalities, and other stakeholders to participate in the implementation of the 2030 Agenda (Räkköläinen & Saxén, 2022). Even though the Pakistani Parliament has established a national plan - Vision 2025, along with seven goals that are aligned with the SDGs - the implementation of sustainable development targets can only be achieved once every citizen takes responsibility to make efforts to promote green growth. The Pakistani Parliament must not only sensitize the masses at the grass-roots level but also utilize its legislative authority in order to incorporate the SDGs into the national laws of Pakistan. Doing so will normalize the concept of achieving sustainable development at a personal level, which in turn will compel every individual to work towards it to the best of their abilities (Abbasi et al., 2022).

The 2020 Sustainable Development Outlook for Seychelles highlights the current condition of the SDGs in Seychelles and how to improve them. Similarly, Finland has been reviewing its SDG Plan based on the studies conducted within the country regarding success areas that it must sustain and critical points that require urgent action. Additionally, these countries conduct multiple events in which proposals are presented by experts on sustainable development to highlight key priority areas for their respective countries, which serve as valuable reference

material and guidelines for their national agendas (Benzaken et al., 2022).

**Conclusion**

Pakistan is still facing a huge number of economic, governance, and security issues. It is important to notice that Pakistan was ranked 147 out of 188 countries in the year 2015 on the Human Development Index (HDI), which is the first indicator towards achieving sustainable growth (Olsen & Zusman, 2014). The human rights agenda is perfectly aligned with the SDGs; therefore, in order for the Pakistani parliament to engage itself in the implementation of the SDGs in the country, it must first shift its focus on the human rights dimension. Moreover, Pakistan ranks 143 out of 144 countries in the gender inequality index; this is also quite alarming, as without inclusive participation in the country, the Parliament may fail to establish rules that govern sustainability (Brollo et al., 2021). Furthermore, Pakistani society as a whole lacks a culture of accountability due to high levels of corruption both on micro and macro-levels. In the same way, the Parliament needs to safeguard the rights of minority groups and the public, respectively. The Pakistani Parliament, like all other parliaments, can play a vital role in the engagement and implementation of SDGs in the country through its alignment with the national plan (Khan & Ali, 2019).

However, in order for that to be successful, the Pakistani Parliament must be empowered to effectively and transparently pass laws in the country, engage itself in the budget allocation process, hold the government accountable for its commitment towards achieving a sustainable Pakistan, and monitor the implementation of SDGs by using an inclusive and participatory approach (KHAN, 2020; Xu et al., 2023).

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RESEARCH ARTICLE

# Effects of using P.juliflora leaves as additive in anaerobic digestion of poultry wastes

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**Abstract**
This study explores the influence of P.juliflora leaves as an additive in the anaerobic digestion of poultry droppings from layers and broilers. Six digesters (A, B, C, D, E, and F) were used with a retention time of 31 days. The dry weight content of the digesters include: 100% layer wastes (control), 100% broiler wastes (control), 95% layer wastes + 5% P. juliflora leaves, 90% layer wastes + 10% P. juliflora leaves, 95% broiler wastes + 5% P. juliflora leaves, and 90% broiler wastes + 10% P. juliflora leaves. Layer wastes plus 5% Prosopis Juliflora created 18% more biogas than layer wastes alone, and layer wastes plus 10% Prosopis Juliflora produced 22% more biogas than layer wastes alone, which was the control set-up. In comparison to digester broiler wastes alone, broiler wastes plus 5% and broiler wastes plus 10% both produced 20% and 24% more biogas, respectively. In conclusion, adding 5 and 10 percent of Prosopis Juliflora to poultry manure from layers or broilers has significantly increased the generation of biogas. Broiler wastes plus 10% Prosopis Juliflora yielded the most amount of methane and least amount of hydrogen sulfide, which makes it the most suitable substrate.

**Keywords:** biogas; renewable energy; digester; additive

## Introduction

The recent worldwide rapid population growth, along with the depletion of natural resources, has resulted in a significant increase in fuel prices. This has motivated a number of countries to investigate renewable and alternative sources of energy in order to fulfil their rising energy demands (Ajiboye et al., 2018). Reliance on traditional energy sources such as coal and petroleum has resulted in ecological imbalance, climate change, health risks, and resource depletion (Aragaw & Andargie, 2013). As a result, renewable energy sources such as solar power, biogas, biodiesel, wind power, and tidal power have emerged as the energy revolution's vanguard (Islam, 2012). Due to the continued use of fossil fuels and their associated environmental impact, particularly the influence of greenhouse gases (GHGs) on the environment, research focusing on the creation of alternative fuels from biological sources has expanded. Carbon dioxide (CO2) is the principal cause of growing GHG emissions in the atmosphere. Notably, worldwide energy demand is continually increasing, with fossil fuels still accounting for around 88% of total energy output today (UNEP, 2014). Anaerobic digestion (AD) is a promising, low-energy, and ecologically friendly technique. Recent research has shown that biogas produced using AD has significant advantages over other bioenergy sources (Nishio and Nakashimada, 2007). When opposed to fossil fuels, AD technology can dramatically cut GHG emissions by utilizing readily available resources. Furthermore, digestate, a byproduct of this method, is an ideal alternative to mineral fertilizers in crop cultivation. AD converts organic waste such as manure, food scraps, sludge, and agricultural leftovers into biogas in the absence of oxygen (Iqbal et al., 2014). Due to its minimal ecological impact (Esposito et al., 2012) and great energy recovery potential (Carrère, 2010), the AD process is preferred for transforming trash into fuel. Biogas from AD has significant advantages over other bioenergy production technologies, and it has the potential to replace fossil fuels (Ofoefule et al., 2010).

The anaerobic digestion of organic material produces biogas, which is mostly made of methane. Because the anaerobic degradation process is comparable to the underwater decomposition of organic material in wetlands, biogas is sometimes referred to as "marsh gas" or "swamp gas" (IBA, 2016). Biogas is a colorless, combustible gas made up of 50-70% methane and 20-40% carbon dioxide, with traces of nitrogen, hydrogen, ammonia, hydrogen sulphide, and water vapor (Lasisi and Ojomo, 2017). Biogas, a critical component of the carbon biogeochemical cycle, is naturally produced and can be used as an alternative energy source (Energypedia, 2016).

The current study seeks to assess the biogas yield of increased anaerobic digestion of two distinct breeds of chicken manure using Prosopis Juliflora. The study's objectives include: the design and construction of medium-sized digesters for waste decomposition, the analysis of the physio-chemical and microbiological properties of chicken droppings and Prosopis Juliflora, the evaluation of both the daily and overall cumulative yield of biogas, and the comparison of enhanced Prosopis Juliflora and non-enhanced biogas yield from various digesters.

**Literature Review**

Despite the economic and environmental benefits of producing biogas from various biological wastes utilising AD technology, the search for more inexpensive, renewable, and sustainable energy sources is pressing due to rising fuel costs (Fantozzi & Buratti, 2011). The poultry sector is a major source of worry, as waste from daily chicken feed is frequently used as organic manure. With the growing number of chickens grown in Nigeria, there is a pressing need to investigate alternate energy sources in order to mitigate the negative effects (Ekka et al., 2016). Several researchers have concentrated on producing biogas from a wide range of widely available agricultural and environmental wastes that are damaging to the environment (Awode et al., 2022). Although anaerobic digestion of biodegradable waste is thought to be a promising source of renewable energy, it has certain drawbacks. These include the slow decomposition of complex organic waste and the presence of carbon dioxide and hydrogen sulphide in the biogas produced (Wang et al., 2023). Before biogas can be utilized as fuel, these components must be eliminated.

However, the introduction of Prosopis juliflora during the anaerobic digestion process could significantly alleviate these restrictions, potentially increasing biogas generation while decreasing carbon dioxide and hydrogen sulphide emissions. Prosopis juliflora (P. juliflora) is a non-traditional feed resource that has been investigated for its potential as an addition in the anaerobic digestion of poultry wastes. Prabhu et al. (2021) evaluated the anaerobic digestion of several biomass wastes, including P. juliflora leaves, and discovered that P. juliflora pods produced the most biogas. Samadi et al. (2022) studied the co-digestion of poultry abattoir and vegetable wastes and discovered that a C/N ratio of 25:1 was ideal for biogas production. However, no particular research on the effects of employing P. juliflora leaves as an addition in anaerobic digestion of chicken wastes were found. Rajagopal et al. (2021) explored the combination of microalgae cultivation and anaerobic digestion of poultry wastes and discovered that the liquid digestate obtained after the digestion process may be used as a substrate for microalgae growth. The study employed various liquid digestate dilutions for microalgae growth and discovered that Chlorella vulgaris CPCC 90 could grow and utilize nutrients from a 10% diluted chicken manure digestate. Awode et al. (2022) evaluated the effect of biochar as a supplement on the anaerobic digestion of layer and grill poultry droppings. The biogas from the digester with the highest biochar content produced the most methane while creating the least hydrogen sulphide. According to the findings of this study, biochar can be utilized as a supplement to improve the efficiency of anaerobic digestion of poultry manure. Hakimi et al. (2021) explored the co-anaerobic digestion of chicken manure with sawdust and local herbs such as serai wangi, peppermint, and orange peel waste as biogas additions. According to the findings of this study, traditional herbs can be utilized as supplements to improve the effectiveness of anaerobic digestion of poultry manure. As a result, the current study makes an important contribution to the body of information on improving biogas production from poultry waste utilizing Prosopis juliflora.

**Methodology**

**Materials**

The construction of the digesters was done with: six black plastic kegs of 25 L capacity each (they served as the main digester chambers), six catheter bags of 500 ml (was used to collect the biogas produced), flexible rubber hose (were used to connect the catheter bags to the digesters), 12.5 mm back nuts, stop corks, 12.5 mm pipes, PVC gum (all used

for both the inlet and outlet of the digesters), thermometer, pH meter, weighing scale and syringe, (all used for various parameter's measurement), and Prosopis juliflora obtained from school farm are the waste to be used.

**Digester Design considerations**

In achieving one of the objectives of this research, some parameters were considered in designing and constructing effective and efficient digesters. The parameters include operating volume, digester volume and digester construction. They are briefly explained below.

**Operating Volume**

When a fixed amount of water is added to a known amount of feedstock, the operational volume of the digester is just the volume of slurry ratio in the digestion (Babatola, 2008, Ajiboye et al., 2018). For optimal digestion operation, it is common practice to use a digester whose total volume is less than the total volume of the slurry. According to Ahmadu et al. (2009), the operating volume of a digester is determined on the basis of a chosen retention time and the daily substrate input quantity of the operating volume is expressed in equation 1.

$$V_o = S_d \times RT\ (m^3/day \times number\ of\ days) \quad (1)$$

Where:

$V_o$ is the operating volume of digester,

$S_d$ is the daily substrate input and,

RT is the retention time, which is the interval of time the mixed slurry is allowed to decompose in the digester.

**Digester Volume**

The volume of a digester is equal to the volume of the substrate container, whether the container is prefabricated or ready-made. The number of ready-made 25-l containers is what constitutes the digester volume in this case. The digester capacity, also known as the total volume, must be more than the operational volume to accommodate the expansion of the slurry and the creation of biogas during fermentation. Slurry rise and biogas production require at least 20% of the total volume of the digester, which is why Ahmadu et al. (2009) and Otun et al. (2015) claimed that this volume should not exceed 80% of the total capacity of the digester. The total volume $V_T$ is thus given in equation 2.

$$V_T = V_0 \times 1.25 \quad (2)$$

**Digester Construction**

Each of the 25-liter containers had a hole drilled into its top and two holes drilled onto its sides. The top holes were roughly 1.5 centimeters in diameter. It was determined that a hose with an external diameter of 1.5 cm would be used to link the digester to the gas collection chamber (Catheter), while a hose with an interior diameter of 0.9 cm would be used for this purpose. Each keg had an additional hole cut in its base with a diameter of 4.1 centimeters; this hole served as the exit from which the slurry used in the pH measurement was drawn. Each digester was outfitted with a thermometer that read daily temperatures. The entire bio-digester system was made airtight by using rubber tubes and glue to seal any perforations.

**Sourcing and Collection of Materials**

The digester component materials were all procured from Oja-Oba market in Akure, Nigeria. Chicken manures for the two breeds (Layers and Broilers) were collected from the Agricultural research farm of the Federal University of Technology, Akure (FUTA), Nigeria.

**Pre-treatment of Waste Specimens**

These chicken manures were collected in black sealed polythene bags to preserve their original moisture. Pre-treatment was initiated at the point of collection, and it includes sorting, reduction in particle size and addition of water. Pre–treatment is done to enhance degradation of volatile solids, thus increasing biogas yield.

**Sample Preparation and Loading of Digester**

The samples were prepared by mixing the manure of each chicken breed in varying component using 50:50 (10 L of water +10 kg of poultry waste) for control sample A and D, 45:5:50 (10 L of water + 10 kg of poultry waste + 1 kg of prosopis Juliflora) for sample B and E, 40:10:50 (10 L of water + 10 kg of poultry waste + 2 kg of prosopis Juliflora) for sample C and F. The composition of the mixtures is shown in Table 1. The mixtures will each be loaded into the Six 25 liters digester fabricated. Thereafter, the set-ups were arranged well for digestion for 30 days**.** To ensure optimal digestion of substrate and to forestall the buildup of scum and layers that could kill off the bacteria

and limit biogas generation, the digesters were manually agitated at regular intervals. Each digester had a gas cylinder attached to its outlet, capturing the biogas it produced.

**Result And Discussions**

**Sample Pre-Analysis**

The analyses of the poultry waste consisting of the layer waste (LW) and broiler waste (BW) and their mixtures with Prosopis Juliflora in different ratios was carried out in the laboratory to determine their physico-chemical properties. Table 2 shows the moisture content, volatile solid, total solid concentration and the different constituents of the wastes such as ash, fat, crude protein, carbon content, nitrogen content.

Table 1: Detailed Composition of Each Mixture

| Mixtures | Digester Label | Type of Enhancement |
|---|---|---|
| CM Type 1 | A | Non Enhanced |
| CM Type 1 + P.juliflora | B | Enhanced with P.juliflora leaves (5%) |
| CM Type 1 + P.juliflora | C | Enhanced with P.juliflora leaves (10%) |
| CM Type 2 | D | Non Enhanced |
| CM Type 2 + P.juliflora | E | Enhanced with P.juliflora leaves (5%) |
| CM Type 2 + P.juliflora | F | Enhanced with P.juliflora leaves (10%) |

Table 2: Physico-chemical properties of the fresh poultry waste

| **Parameters** | **Digesters** | | | | | |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | F |
| **Moisture (%)** | 69.5 | 53.4 | 63.4 | 68.3 | 58.2 | 52.7 |
| **Fat (%)** | 4.3 | 6.7 | 4.2 | 3.9 | 6.64 | 6.28 |
| **Ash (%)** | 3.05 | 2.6 | 3.7 | 4.0 | 2.2 | 2.1 |
| **Fibre (%)** | 1.03 | 1.5 | 1.2 | 1.37 | 1.59 | 1.65 |
| **Crude Protein (%)** | 10.25 | 12.25 | 10.42 | 10.36 | 12.64 | 13.42 |
| **Nitrogen (%)** | 1.87 | 2.68 | 1.93 | 2.31 | 1.84 | 1.85 |
| **Total Solids (%)** | 32.3 | 29.2 | 29.67 | 28.45 | 26.4 | 27.3 |
| **Temperature($^0$C)** | 30 | 30 | 29.5 | 29 | 30 | 29.5 |
| **Carbon(%)** | 14.53 | 18.62 | 15.34 | 18.63 | 14.26 | 14.52 |
| **Carbohydrate** | 9.5 | 8.9 | 8.69 | 8.74 | 9.2 | 9.05 |
| **C/N Ratio** | 7.77 | 6.94 | 7.96 | 8.06 | 7.75 | 7.82 |
| **pH** | 5.6 | 5.6 | 6.25 | 6.3 | 5.7 | 5.95 |
| **Volatile Solids (mg/%TS)** | 27.75 | 28.5 | 28.24 | 27.59 | 25.85 | 25.7 |
| **Phosphorus** | 1.1 | 1.5 | 1.12 | 1.11 | 1.45 | 1.56 |
| **Calcium(%)** | 0.97 | 2.5 | 0.94 | 0.93 | 1.8 | 1.94 |
| **Potassium(%)** | 0.78 | 0.9 | 0.77 | 0.75 | 0.85 | 0.89 |
| **Magnesium(%)** | 0.35 | 0.32 | 0.31 | 0.32 | 0.3 | 0.37 |
| **Sodium(%)** | 0.2 | 0.25 | 0.26 | 0.23 | 0.23 | 0.26 |

**Daily, Average and Cumulative Biogas Yield from the Digesters**

The daily gas yield was measured and calculated through the difference in daily weight gain of the collecting bags and the increase in the weight gain of the bags. Figure 1 and 2 show the graphs of the daily and cumulative biogas yield of the digesters, respectively.

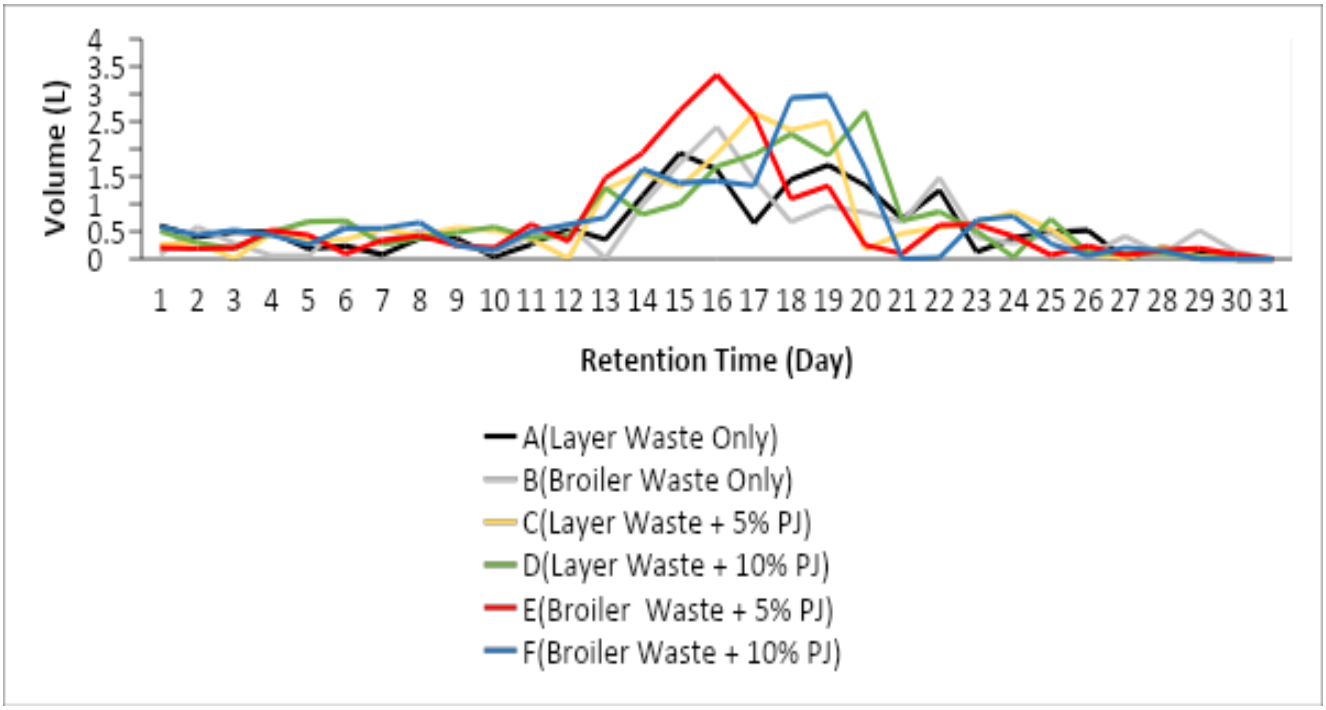


Figure 1: Daily Biogas Yield from digesters

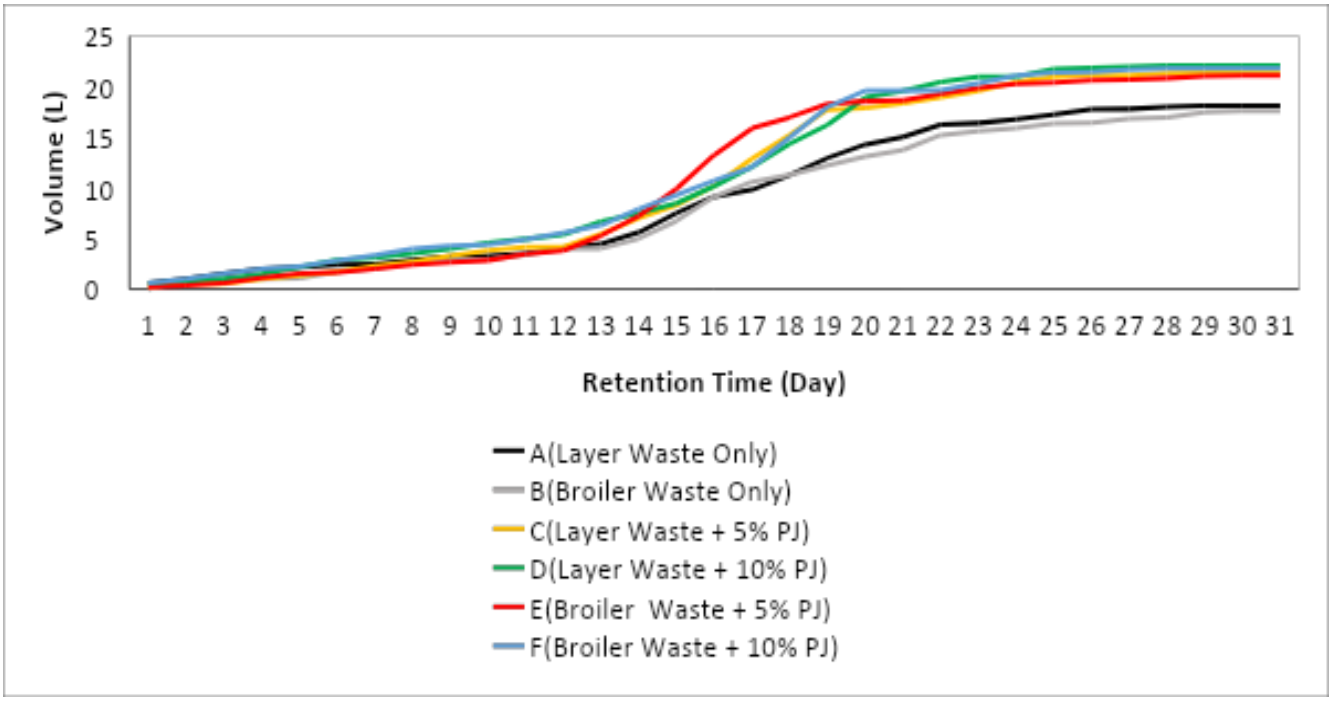


Figure 2: Cumulative Biogas Yield from digesters

The different peaks and troughs located along Figure 1 can be attributed to varying environmental and biological conditions of the different digesters.

As observed in figure 2 the biogas production began on the first day of the retention period in all six digesters due to the extended pre-fermentation period and shows the biogas yield of the digesters over the 30-day retention period which started in small amount on the first day and increased steadily on the subsequent days till the peak yield was reached, and the yield started decreasing drastically until it finally stopped producing biogas, this reduction in daily gas yield is due to the fact that the microorganisms responsible for the production of biogas have consumed a large part of the substrate thereby leading to a drop in biogas production. This same trend was also noticed by Kumar et al. (1987).

From figure 2, for the layer wastes the cumulative yield of digester C showed an 18% increase from the yield of digester A and digester D showed a 22% increase from the yield of digester A while for broiler wastes, digester E showed a 20% increase in cumulative yield from digester B and digester F exhibited a 24% increase in biogas yield.

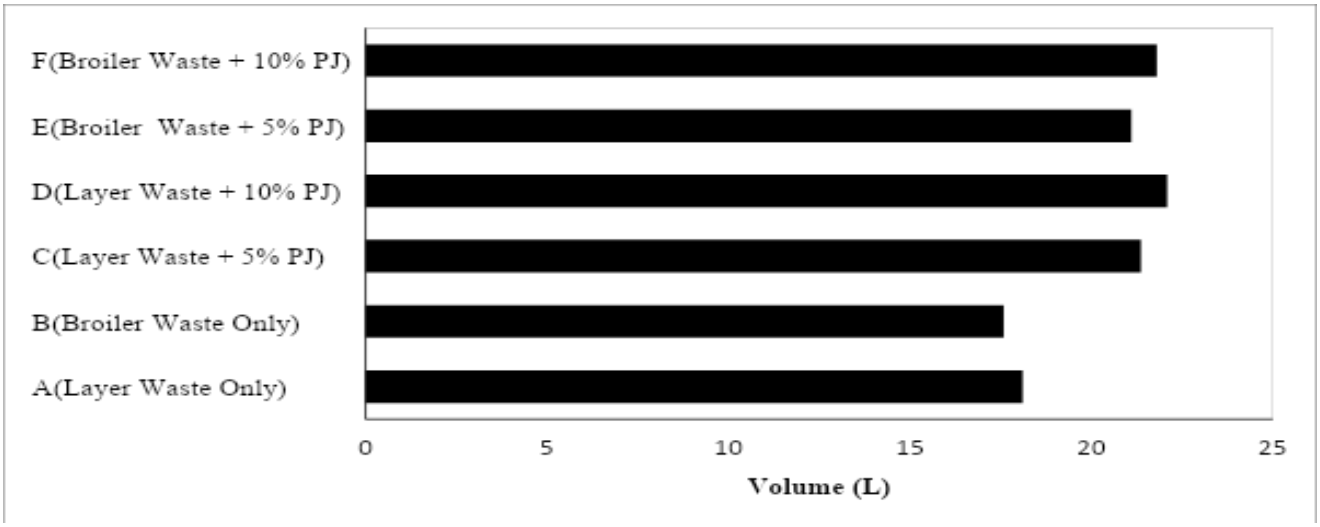


Figure 3: Total Biogas Yield from digesters

It could be seen from figure 3 that the highest biogas yield was from digester F for the broiler wastes and digester D for the layer wastes, but the broiler wastes had a higher yield than the layer wastes which may be due to the higher carbon to nitrogen ratio.

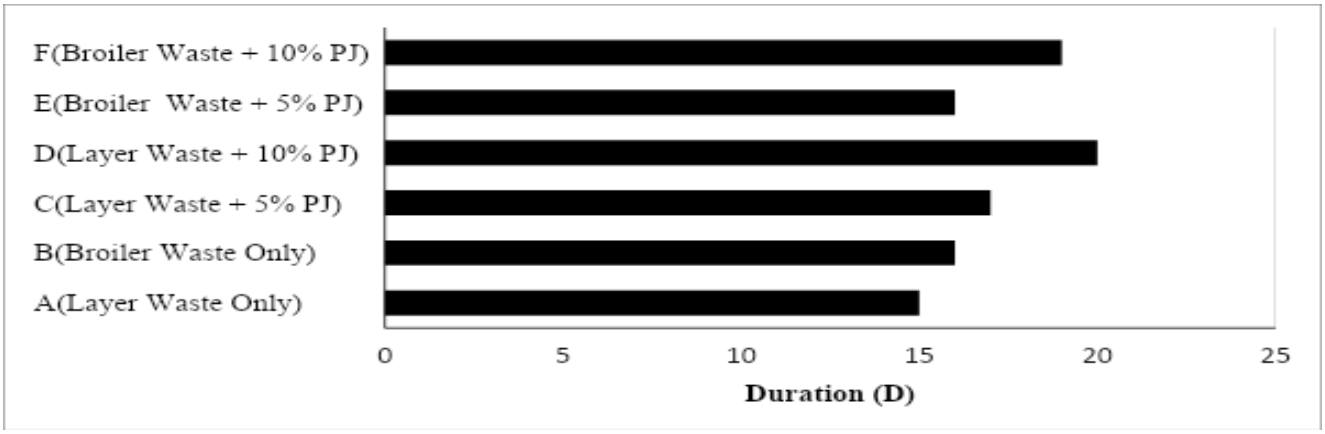


Figure 4: Duration to reach maximum yield

It could be seen from the Figure 4 that when compared to the control set-ups A and B, the set-ups containing Prosopis Juliflora took a longer time to reach their maximum yields as was evident from set-ups D and F which could be due to availability of substrate for the microorganisms to feed on.

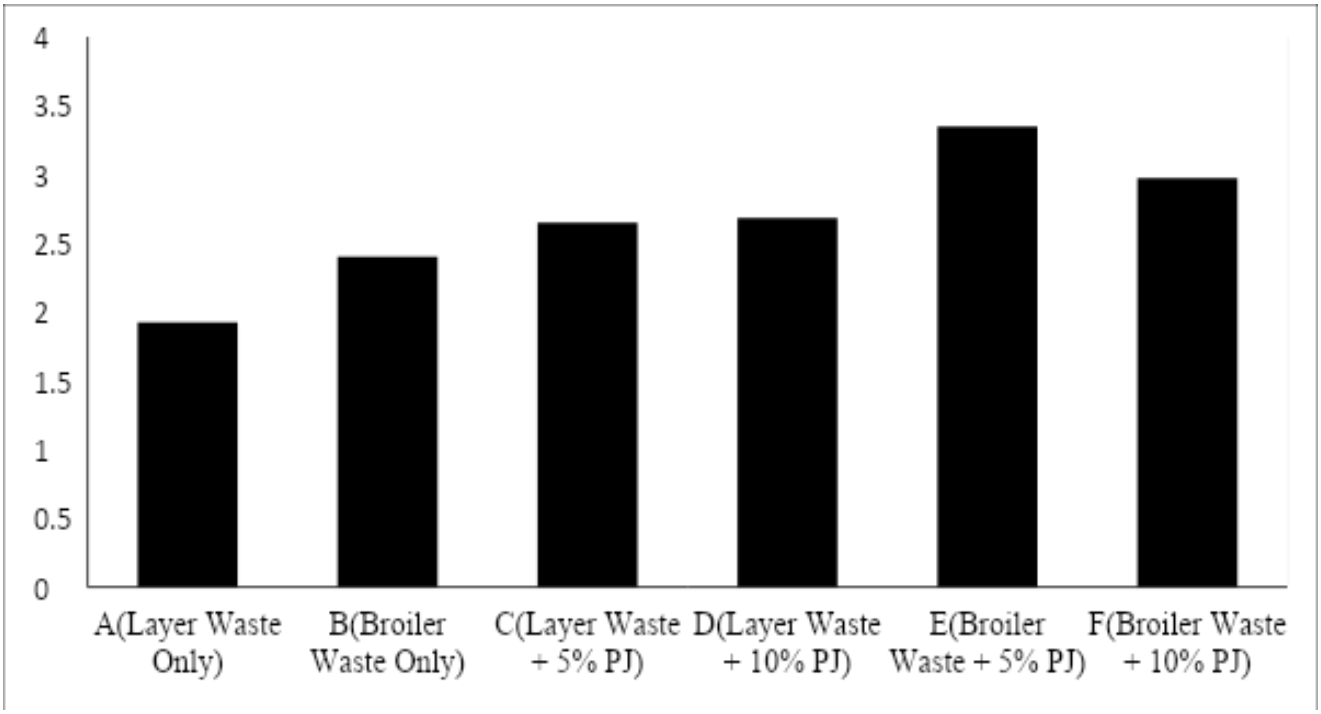


Figure 5: Maximum Biogas Yield from digesters

**Digester pH During Retention Period**

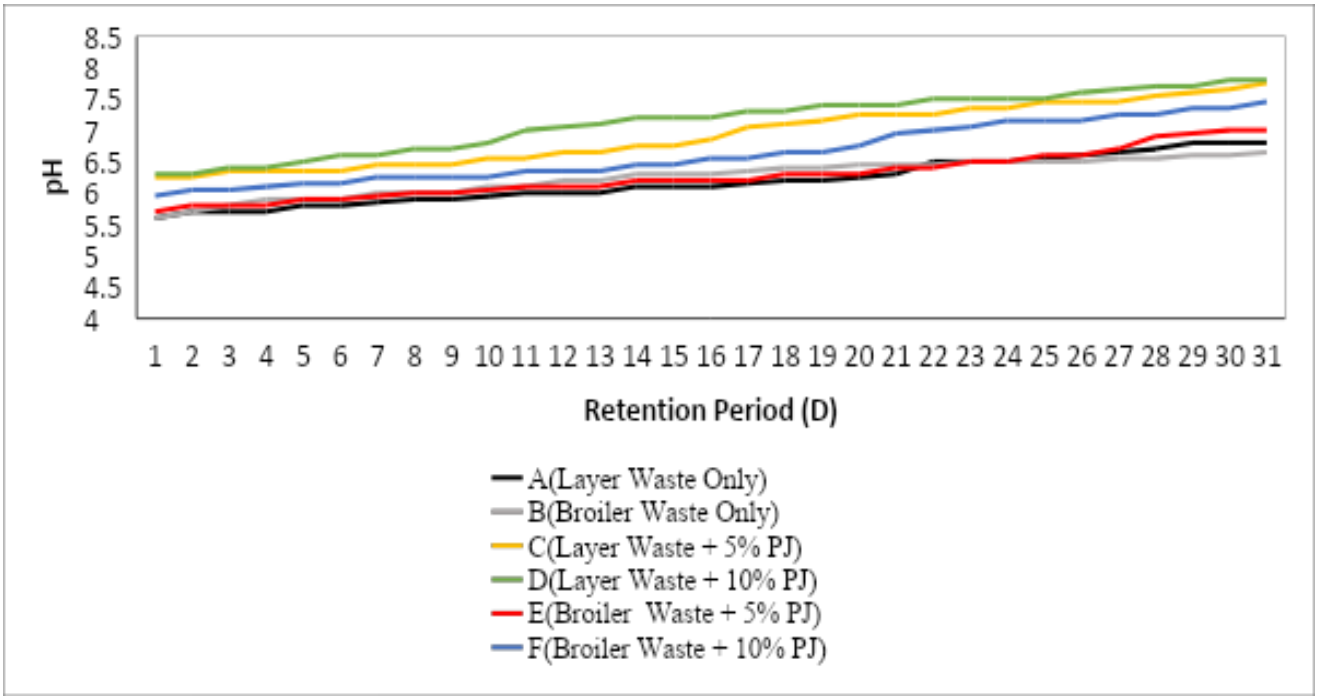


Figure 6: pH of Slurry in Digester

Figure 5 shows that maximum biogas yield was observed to be higher in the digesters containing Prosopis Juliflora when compared to the control set-ups and was even higher in the substrates containing 10% of Prosopis Juliflora when compared to that with 5% Prosopis Juliflora which may be due to the higher carbon to nitrogen ratio.

**Daily Monitoring and Comparison of the operating parameters**

**Digester Temperature During Retention Period**

The temperature of the digesters was also recorded daily for the whole period of biogas production. The average ambient temperature observed during the study was 37 $^0$C while the average digester temperatures for each of the five substrates digested were respectively 29.9 $^0$C, 29.9 $^0$C, 30.0 $^0$C, 30.1 $^0$C, 29.9 $^0$C and 29.9 $^0$C. These values show that there is negligible difference in the average digester temperatures for the six digesters, which provides a common base for comparison of results. The temperatures of the digesters fall in the mesophilic range and the pH falls within a range of 6.2 to 7.6 which is optimal for biogas production as reported by (Aremu & Agarry, 2013).

The pH of the substrates was observed to have increased steadily as shown in Figure 6 as the retention period increased from a slightly acidic to a more alkaline state as the acidogenic bacteria were displaced by the methanogenic bacteria to produce biogas.

**Digester pH During Retention Period**

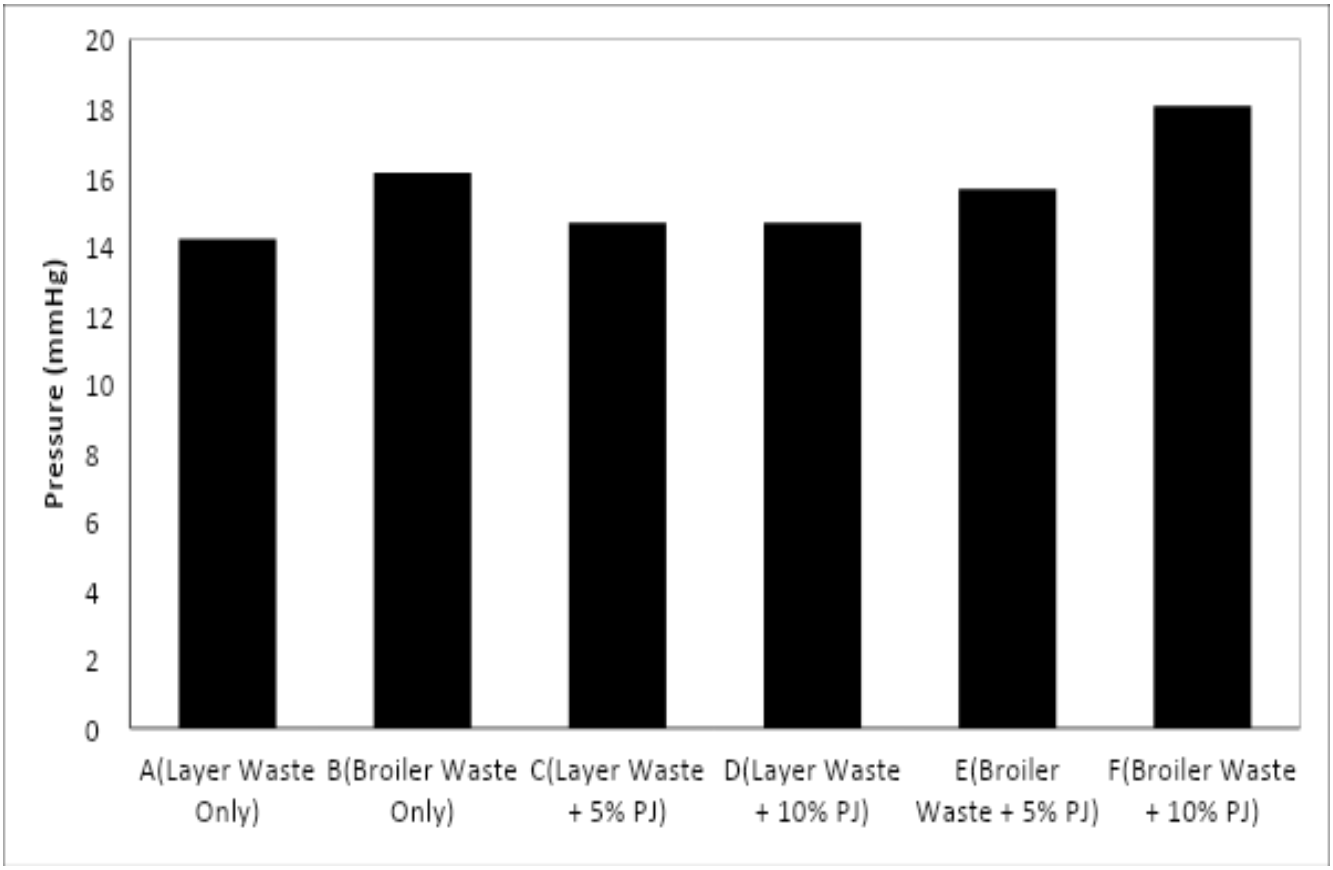


Figure 7: Average Pressure in Digester

The pressure inside the digesters were also observed through the pressure gauge installed in the digester and were recorded daily at the point of collecting the gas

collection bags. The average pressures of the six digesters are shown in the figure 7.

**Analysis of operating parameters**

All analyses were done with Microsoft Excel 2016**.**

**Regression Analysis**

Table 4: Estimates of multiple regression analysis

| Source | SS | df | MS | Number of observation: | 186 |
|---|---|---|---|---|---|
| | | | | F: | 532.54 |
| Model | 1563 | 6 | 1653.17 | Prob > F: | 0.000 |
| Residual | 521.65 | 179 | 3.23 | R-squared: | 0.960 |
| | | | | Adj R-squared: | 0.965 |
| Total | 2084.65 | 185 | 54.62 | Root MSE: | 1.6402 |

| Cumulative yield | Coefficient | Std. Err. | t | P>t | [95% Conf. | Interval ] |
|---|---|---|---|---|---|---|
| Waste type | -1.215 | .390 | -3.51 | 0.001 | -2.139 | -0.599 |
| Duration | 0.570 | .042 | 16.21 | 0.000 | 0.592 | 0.756 |
| Percentage addition of Prosopis Juliflora | 1.975 | 0.35 | 5.740 | 0.000 | -9.311 | 13.336 |
| Temperature | -0.245 | .150 | -1.76 | 0.070 | -0.559 | 0.032 |
| Pressure | 0.000 | .010 | 0.04 | 0.966 | -0.019 | 0.020 |
| pH | 4.285 | .887 | 3.87 | 0.000 | 1.682 | 5.181 |
| constant | -15.219 | 6.669 | -2.23 | 0.014 | -28.038 | -1.716 |

Table 5: Constituents of Biogas from GCMS analysis

| **Digester** | **Duration (Day)** | **Gas Composition(%)** | | | |
|---|---|---|---|---|---|
| | | $CH_4$ | $CO_2$ | $N_2$ | $H_2S$ |
| **C** | 10 | 53.60 | 41.99 | 3.11 | 1.36 |
| | 20 | 57.88 | 37.53 | 3.19 | 1.39 |
| | 30 | 60.40 | 35.29 | 3.05 | 1.26 |
| **D** | 10 | 56.44 | 39.29 | 3.02 | 1.25 |
| | 20 | 62.54 | 33.26 | 3.05 | 1.16 |
| | 30 | 63.79 | 32.16 | 2.96 | 1.10 |
| **F** | 10 | 58.85 | 36.49 | 3.62 | 1.04 |
| | 20 | 63.23 | 33.11 | 2.72 | 0.93 |
| | 30 | 66.08 | 30.59 | 2.51 | 0.82 |

According to Table 4, the cumulative yield decreases by 1.215 units for each change in the categorical variable waste type (e.g., from layer trash to grill waste). The waste type, duration pH, and constant (y-intercept) are the most significant variables in Table 4.3, with p values less than 0.05.

The relationship between the response and predictor variables is described in equation 4.1:

$$\text{Cumulative yield} = 0.57 * \text{duration} + 1.975 * \text{Percantage addition of PJ} - 0.245 * \text{temperature} - 14.877 \quad (3)$$

**Biogas Analysis**

From the experiment which was carried out, the highest biogas yields were recorded in digesters C, D and F. The gases produced from the 3 set-ups on the 10th, 20th and 30th day of the retention period were collected and taken to the laboratory for analysis of the constituents and the properties of the gas from the two samples. A Shimadzu GC gas chromatograph mass spectroscopy instrument was used.

From the Table 5 it can be seen that the methane composition increases with time, the carbon (IV) oxide decreases with time and the nitrogen and hydrogen sulphide gas also decrease with time. The decrease in the hydrogen sulphide gas is responsible for the reduction in odor of the feedstock with time.

The highest methane content was observed in the digester F i.e., broiler wastes and 10% Prosopis Juliflora on the 30th day but digester D showed the highest percentage increase in methane content; increasing by 13% from the 10th day to the 30th day and it is closely followed by digester F which shows a 12.28% increase. Figures 8, 9, and 10 show the correlations between biogas production in digesters C, D, and F and the relative amounts of methane and hydrogen sulfide in the gas.

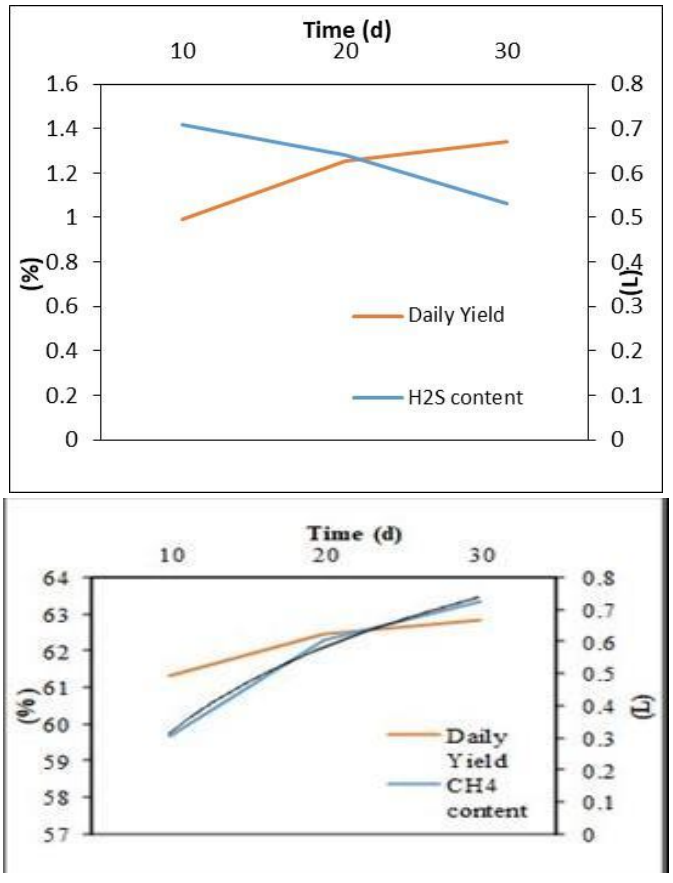


Figure 8: Digester C (a) $CH_4$ content & Daily Yield (b)$H_2S$ content & Daily yield

From figure 14 it could be noticed that in digester C the relationship between the daily yield and the methane content is positively correlated while the daily yield and hydrogen sulphide content are negatively correlated.

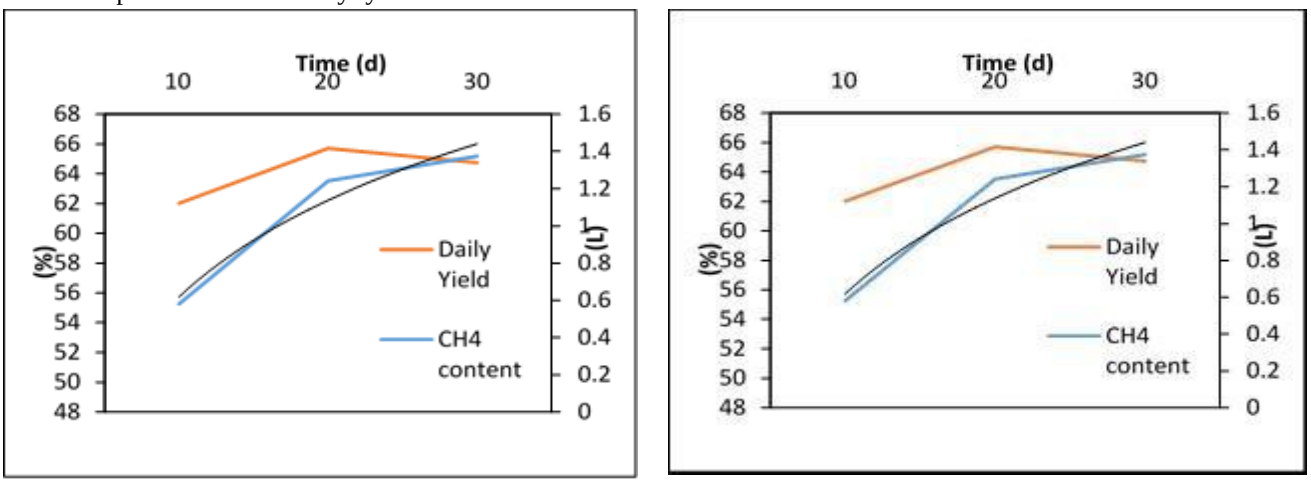


Figure 9: Digester C (a) $CH_4$ content & Daily Yield (b)$H_2S$ content & Daily yield

From figure 9 it could be noticed that in digester D the relationship between the daily yield and the methane content is positively correlated while the daily yield and hydrogen sulphide content are negatively correlated.

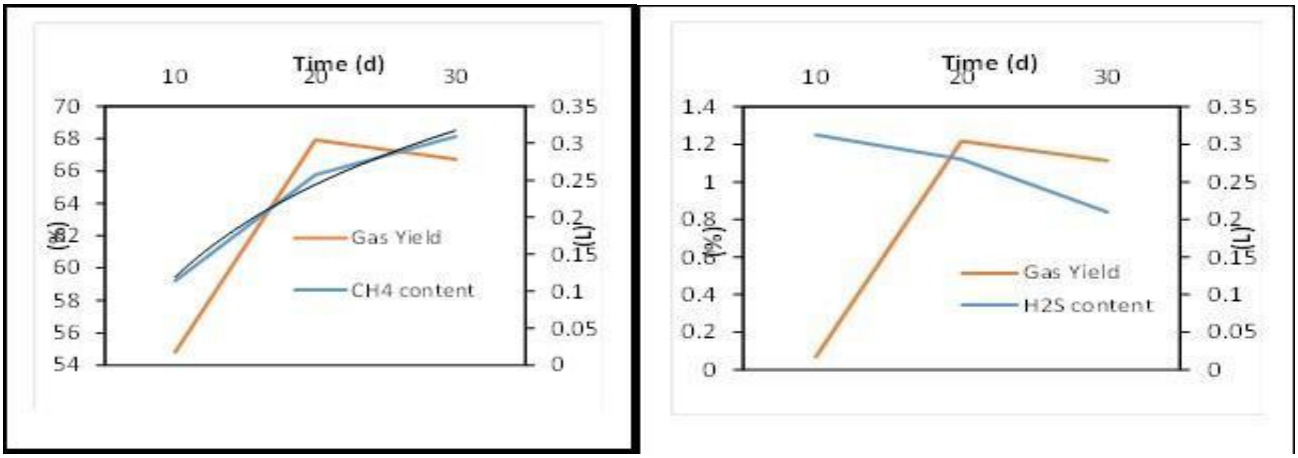


Figure 10: Digester F (a) $CH_4$ content & Daily Yield (b)$H_2S$ content & Daily yield

From figure 10 it could be noticed that in digester F the relationship between the daily yield and the methane content is positively correlated while the daily yield and hydrogen sulphide content are negatively correlated.

**Discussions**

The objective of this study was to study the effect of adding prosopis juliflora in controlled proportions to poultry wastes, namely layers and broilers. From the preliminary tests carried out on the wastes, it was observed that broiler wastes had a lesser carbon to nitrogen ratio than the layer wastes and the substrates containing Prosopis Juliflora had a higher carbon to nitrogen ratio than the control set-ups. This shows that there is a relationship between the carbon to nitrogen ratio and the biogas yield, as reported by Deublein and Steinhauser (2011). Biogas yield increased steadily from the time feedstocks were introduced until the third week, when it began to decline (possibly because microorganisms in the digester consumed the biodegradable part of the feedstock, causing the population of microorganisms to decrease, in turn decreasing the biogas yield (Kossman et al., 2001).

The highest biogas yields were recorded in the digesters using Prosopis Juliflora, with the layer wastes plus 10% Prosopis Juliflora digester producing 22% more biogas than the layer wastes only digester and the broiler wastes plus 10% Prosopis Juliflora digester. The biogas yield with the addition of Prosopis Juliflora was 24% higher than with just broiler wastes, corroborating what Thanarasu (2019) found.

After collecting and analyzing samples of gas on days 10, 20, and 30. It was determined that the methane content of the biogas increased with time. Methane was found in lower concentrations in the gas on day 10, but at higher levels on days 20 and 30. Sasse (1988) has also documented this. Digester F achieved the greatest H2S reduction, by a factor of 32.8%.

## Conclusion

This project research revealed the amount of the gas that can be produced from the two types of poultry wastes (layer wastes and broiler wastes) can be increased by adding prosopis juliflora at different proportions to poultry wastes (layer and broiler wastes).

According to the research, layer wastes plus 5% Prosopis Juliflora created 18% more biogas than layer wastes alone, and layer wastes plus 10% Prosopis Juliflora produced 22% more biogas than layer wastes alone, which was the control set-up. In comparison to digester broiler wastes alone, broiler wastes plus 5% and broiler wastes plus 10% both produced 20% and 24% more biogas, respectively. In conclusion, adding 5 and 10 percent of Prosopis Juliflora to poultry manure from layers or broilers has significantly increased the generation of biogas. Broiler wastes + 10% Prosopis Juliflora produced the highest amount of methane and least amount of toxic gas i.e. hydrogen sulfide, which makes it the most suitable substrate. This study provided information on the quantity and quality of biogas produced from the anaerobic digestion of chicken manure mixed with Prosopis Juliflora through enhanced scheme and established the importance of Prosopis Juliflora in the co-digestion of solid wastes for high biogas yield.

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**Conflict of interest**

The authors have no competing interests

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