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# Impact of climate change on livestock production in Bangladesh - A review

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## ABSTRACT

Livestock plays a crucial part in the global food chain; however, its production and supply could be jeopardized due to climate change-related risks. Therefore, this study gathered information regarding adverse climatic livestock production, adaptation, and mitigation strategies to the hazards' impact, finding research opportunities, and suggesting ideas for policymaking. The impact of increased temperature, altered rainfall, drought, flood, riverbank erosion, salinity, natural calamities like cyclones, etc. on livestock production was reviewed and reported in this article. They are responsible for reducing the availability and quality of fodder and water, declining livestock growth and reproduction, spreading diseases, and posing a threat to animal genetic resources. On the other hand, Bangladesh is anticipated to descend under water as a result of sea level rise resulting in a saline incursion into cropland and freshwater, drastically affecting crop and livestock production, especially in coastal regions. The impact of the hazards can be reduced through following some mitigation and adaptation strategies such as adopting and improving local breeds, practicing mixed farming systems, embracing climate smart livestock management systems, providing insurances for the losses to farmers, and so on. Feeding practices can be altered during flood by providing tree leaves, UMB, unconventional feeds. In conclusion, this review provided a compiled knowledge of climate change affecting livestock production, identifies the research gaps and suggests further research opportunities in this sector.



## Introduction

Greenhouse gas emissions, which cause the atmosphere to warm, are the primary cause of global warming (IPCC, 2013; Rojas-Downing *et al.* 2017). It has an enormous effect on agricultural production, including livestock and fisheries. Livestock products are crucial to world food security because they provide 17% of global caloric and 33% of global protein (Rosegrant *et al.* 2009, Rojas-Downing *et al.* 2017). Bangladesh's economy relies heavily on agriculture, and the livestock sector is a valuable part of it. According to DLS (2022), animal farming shares 1.90% of the total GDP, while the growth rate was 3.10% in the fiscal year 2021-2022. The current livestock population in Bangladesh is 432.379 million (M) including 24.7 M cattle, 1.508 M buffalo, 26.774 M goat, 3.752 M sheep, 311.8 M chicken, and 63.845 M duck (BBS, 2022). Although the livestock sector in Bangladesh grew steadily in recent years (DLS, 2022), its growth is at a risk due to climate change-derived disasters. Previous research shows that the average global temperature has risen by 0.13°C per decade over the past fifty years; this is about twice times as fast as the 0.07°C per decade increase seen in the fifty years before that (Shi *et al.*, 2018). In the 20th century, the average yearly temperature across the globe has risen by 1.5 degrees Celsius (IPCC, 2018). IPCC predicts that

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by the turn of the 21st century, the average world temperature will have risen by 4 degrees Celsius (IPCC, 2007). According to the IPCC 4th assessment report (AR4), the monsoon rainfall would increase, and Himalayan glaciers would melt, resulting in a high river flow in Bangladesh, simultaneously (IPCC, 2007). Over the period 1900-2018, Sea Level Rise (SLR) around Asia was consistent with the global mean sea level change of 1.7 mm per year; however, for the period 1993-2018, SLR increased to 3.65 mm per year in the Indo-Pacific region and 3.53 mm per year in the Northwest Pacific, especially in contrast with the global value of 3.25 mm per year (Ranasinghe *et al.*, 2021). Based on a study of Ahmed and Suphachalasai, (2014) the sea level would rise between 0.18 to 0.79 meters at the edge of this century which would cause coastal area flooding and increase salinity in the freshwater channels. For these reasons, among the world's nations, Bangladesh is extremely prone to the consequences of climate change (IPCC, 2007; Ahmed *et al.* 2012a). Bangladesh can be divided into seven distinct climatic zones based on the entire climatic condition (Banglapedia, 2021). This categorization reveals the usual pattern of northwest to southeast isopleths (Table 1).The climatic hazards are different in those climatic zones such as the north-western part is prone to drought and the southern part is susceptible to cyclones. Simultaneously, climate change's consequences on livestock systems will be geographically and temporally heterogeneous (Rowlinson, 2008). Cyclones, salinity, flood, waterlogging, storm surge, thunderstorms, heat stress, and pest assault are all examples of broad categories of effects on the length of growing seasons for livestock consumables, grasses, and forage crops (Ali *et al.* 2020). According to the study of Fahim and Sikder (2022), people identified inundation (85.6%), hailstorms (61.6%), dense fog (53.8%), cyclones (48.1%), drought (44.4%), and thunder (38.8%) as the most serious climatic threats to agricultural growth and livestock rearing. In addition, 37.8% of respondents named cold waves, and 32.8% named heat waves as two of the most significant dangers (Fahim and Sikder, 2022). Besides, Bangladesh's yearly $CO_2$ emissions climbed by 3.6 percent year on year in 2011, while agriculture is responsible for 39% of the country's GHG emissions (CIAT and World Bank, 2017). In 2013, agricultural GHG emissions from cropland and livestock production were equal (CIAT and World Bank, 2017). By the year 2100, Bangladesh's average economic cost of climate change would be approximately 2% of GDP under C–C circumstances but more than 9% of GDP under the baseline scenario (Ahmed and Suphachalasai, 2014). Although Bangladesh is not to blame for global climate change, our people are in a horrible situation due to its effects (Ahmed *et al.* 2012b). Therefore, the climate change variables and their impact on the livestock sector should be addressed to take adequate measures before an emergency happens. Although only a few studies (Ahmed *et al.* 2012a; Ahmed *et al.* 2012b; Ahmed and Suphachalasai, 2014; Alam *et al.* 2017; Islam *et al.* 2018; Biswas *et al.* 2019; Ali *et al.* 2020; Fahim and Sikder, 2022) have quantified the impact of global warming on livestock productivity in Bangladesh, there is currently a paucity of a detailed study on these issues not only in Bangladesh but also in the whole Asia (Shaw *et al.*, 2022). Furthermore, earlier research on adaptation and mitigation measures for climate change-induced hazards demonstrated that animals can adapt to the hazards by changing feeding and farming techniques and associating management strategies to climatic changes (Bakshi *et al.* 2018; Samanta *et al.* 2021; Aryal *et al.* 2020; Ayeb-Karlsson *et al.* 2016; Delaporte and Maurel 2018; Maiti *et al.* 2014; Rahman and Obaydullah, 2020; Thornton and Herrero, 2014). Especial consideration is given to the local livestock breed improvement so that the effect of it can be mitigated (Islam *et al.*, 2018; Maiti *et al.*, 2014).

The accumulated information on climate change-related hazards and their effect on livestock production will help to address the existing knowledge and research gaps. Also, the present data will help to understand the scenario of climate change, formulate policies for our country, and draw international organization's attention to this issue. This review was accomplished to show the climate change effects on livestock production, focusing on Bangladesh.

## Materials and Methods

Considering the current climatic fluctuations of Bangladesh this review is focused on the impact of climate change on livestock production. The existing works of literature were compiled with fully directing on climate change issues affecting livestock productivity. The related information of this review is collected from the published research and review article, conference paper and from

different research and survey reports. This review will contribute to the livestock production strategies in the transformed climatic condition.

## Results and Discussion

### *Climate change variables and their impact on the livestock production sector*

#### *Temperature and Rainfall*

The most critical criteria for assessing and addressing the issues of climate change are temperature and rainfall (Islam *et al.* 2018). The pasture and water supply are highly dependent on the intensity and frequency of rainfall (Aklilu *et al.* 2013). A study showed that temperature and precipitation fluctuations were more noticeable in the past year in Bangladesh than they were 30 years before (Islam *et al.* 2018). By analyzing data of 2013-2021, an increasing trend was found for both temperature and precipitation though the precipitation showed fluctuation during that period (Figure 1).

**Table 1:** Climatic zones of Bangladesh

| Climatic zone | Regions | Major city | Coordinates |
|---|---|---|---|
| A | South-eastern zone | Chattogram | 22º22'N 91º48'E |
| B | North-eastern zone | Sylhet | 24º54'N 91º52'E |
| C | Northern part of the northern region | Panchagarh | 26º25'N 88º50'E |
| D | North-western | Rajshahi | 24º51'N 89º22'E |
| E | Western zone | Bogura | 24º22'N 88º36'E |
| F | South-western zone | Jashore | 23º17'N 89º20'E |
| G | South-central zone | Dhaka | 23º42'N 90º22'E |

***Source**: Banglapedia (2021)*

Bangladesh and its adjacent regions had warmed by 0.5 degrees Celsius over the preceding 100 years, according to the MoEF (2009). During 1976-2008, the annual average maximum temperature in all regions of Bangladesh rose at a pace of 0.018°C each year (Basak *et al.* 2013). The mean decadal increase in lowest temperature was maximum (0.21°C) in the dry region, followed by the terrace (0.18 °C) and the coastal regions (0.07 °C) (Rahman *et al.* 2017). However, the majority of zones show an increasing tendency of rainfall during the monsoon and post-monsoon seasons, but a large number of zones demonstrated a declining trend of total rainfall during the winter. These findings support general climate change projections that wet seasons would increase wetter and dry seasons would become dryer (Basak *et al.* 2013). Whereas, the terrace environment experienced a considerable increase in mean annual rainfall (59.6 mm) per decade, followed by the coastal (52.2 mm) and dry zones (38.6 mm) (Rahman *et al.* 2017). According to the study by Fahim and Sikder, (2022), in the Haor region of Bangladesh, 95.63% of people observed a hiking trend in temperature in the last ten years. On the contrary, 56.25% and 29.38% of people said that the rainfall has decreased and increased, respectively in that area. Based on the above explanation, we may say that Bangladesh's temperature and precipitation have changed over the decades. Consequently, due to the uncomfortable precipitation and temperature, animals may exhibit disrupted mating behavior and production loss, consistent with the findings of Abbas *et al.* (2019).

#### *Drought*

Soil moisture deficits that impact plant development and crop yields are called agricultural droughts. When soil moisture is low enough to reduce crop productivity and profitability, an agricultural drought is declared (Mannocchi *et al.* 2004). Severe drought persists primarily in the northwestern region of Bangladesh. Around 38% of areas in Bangladesh were classified as light drought vulnerable for livestock production; approximately 5.8% and 8.4% of sites were categorized as moderately and severely sensitive to drought for animal production, respectively (Biswas *et al.* 2019). Drought has a variety of adverse effects on livestock. Due to drought, Bangladesh's livestock sector could suffer losses between 15 and 80 million Taka (Ahmed and Suphachalasai, 2014). Droughts have historically afflicted 47% of places and enhanced the suffering of 53% of the inhabitants (Ahmed and Suphachalasai, 2014). Due to a drop in feed and fodder supply and severe water shortages, nearly 168 million cattle in India were impacted by drought in 1987 (CSO, 2000). Before it rained the following year, in Gujarat, it was reported that 18 million out of a total of 34 million cattle died (CSO, 2000). About 34.5 million livestock were impacted by a severe drought in 1999–2000 in the desert, drought-prone state of Rajasthan in the northwestern region of India; approximately 40 million cattle were impacted by drought in the following year (CSO, 2000; Sirohi and Michaelowa, 2007). According to Hossain *et al.* (2012), livestock in Bangladesh do not die during droughts, but their susceptibility to illness increases. According to popular opinion of drought-stricken regions, the severity and duration of droughts are rising in recent years (Hossain *et al.* 2012). The average annual precipitation in the western portion of the country is approximately 1400 millimeters,

as opposed to roughly 2150 millimeters on average across the nation (Fahim and Sikder, 2022). Therefore, western regions are much more prone to drought and experience more severe droughts than other regions. In the north-eastern region of Bangladesh, drought accounts for 44.4% of all other climatic dangers, according to research respondents (Fahim and Sikder, 2022). The average drought duration was estimated at 1.63 months according to Islam *et al.* (2018). Since dry areas are becoming drier and some regions are experiencing decreased rainfall and lengthened summer seasons because of climate change (Basak *et al.* 2013; Fahim and Sikder, 2022), drought intensity may increase in the near future, having a significant impact on freshwater availability and livestock fodder and feed cultivation.

***Flood***

Bangladesh is a country with over 200 rivers flowing through it, and scientists anticipate that as a result of changing climate patterns, floods will continue to climb over their typical range (Ahmed *et al.* 2012a). According to a statement from the Ministry of Fisheries and Livestock of Bangladesh, in 2022 the northern and northwestern districts of Bangladesh had disastrous floods that harmed over two million cattle and five million poultry (The Financial Express, 2022; The Business Standard, 2022). The prices of livestock climbed up in the Eid-ul-Adha of this year because of that loss. In contrast, some farmers sold their livestock at a cheap price because the flood swept up the crop fields and the feed of the animals (The Daily Star, 2022). So, flooding has the ultimate effect on both producers and consumers. The average flood duration was estimated at 1.0 months (Islam *et al.* 2018). Approximately 34.48 percent of Bangladesh's land area is subject to moderate to high flood risks (Biswas *et al.* 2019). In 43.88 percent and 22.65 percent of locations, respectively, the risk of floods was low or extremely low (Biswas *et al.* 2019). Therefore, weak animals frequently drown, especially in low-lying locations (Biswas *et al.* 2019). Ahmed (2006) discovered that average summer rainfall would increase by 10.0-15.0 percent in the 2030s and 27.0 percent in the 2075s, resulting in devastating floods. Mid-May to mid-October is the flood season in Bangladesh's coastal region. The dam in this location is incapable of protecting the floodwater, and occasionally, the Payra River's strong water flow also contributes to the flood. Moreover, flash flood is the most frequent climate change hazard in the Haor areas of Bangladesh that happens from late March to July season (Fahim and Sikder, 2022). During the flood, the seasonal crops and fodders are washed away which leads a feed scarcity and freshwater unavailability for animals. In July-August 2022, Pakistan experienced mounting evidence of climate change which is the record-breaking devastating flood. According to the British Red Cross (2022), this country had tremendous heat in April 2022, with the peak temperature reaching 49°C, might be causing Himalayan and Hindu Kush glaciers to melt. Additionally, excessive heat can reduce the earth's ability to absorb water. As a result, the Indus River surged, a vast area was flooded, and eight lakh animals perished (British Red Cross, 2022).

Considering the above discussion, we can say that, Bangladesh is a riverine country, so global warming can lead to a devastating flood that can inundate most of the cultivated land of our country. Bangladesh faces annual floods every year that damage crops, livestock habitats, and people's livelihoods. If the annual flood corresponds with the climate-derived unexpected floods, not only the livestock population but also the entire food security of our country will be questioned.

***Salinity***

Coastal areas are particularly vulnerable to salinity problems (Hughes, 2008). Ali *et al.* (2020) published a study on Barguna, Bangladesh, demonstrating that saline water from the Payra and Bwrisher rivers flooded the study area's low-lying terrain. Salinity has a year-round influence but is most significant in the winter and least during the rainy season. According to a questionnaire survey, salinity deprives livestock of drinking water and degrades the grass on the land region (Ali *et al.* 2020). According to Alam *et al.* (2017), Kalapara coastal region of Bangladesh was affected by salt around 200 ha of fodder crop areas each year. As a result, feed scarcity is a critical concern for livestock and other animals. Due to their excessive reliance on salinity-affected fodder plants, the animal suffers from various deleterious repercussions, including immune system failure, diarrhea, skin disorders, liver fluke infestations, and weight loss (Alam *et al.* 2017). Rashid *et al.* (2014) conducted a study on farmers' perceptions of climate change in the Khulna, Bangladesh and discovered that river water remains salty for two months longer than it did forty years ago, resulting in a drop in the output of Rabi crops and Aman rice. Hossain *et al.* (2012) stated that the sufferings of livestock on the shoreline are significantly more than in other regions of Bangladesh; consequently, the density of livestock is declining in the coastal regions, especially in the southwest of the country. Possible reasons for the loss of coastal animal populations include a lack of fresh water, the spread of shrimp farming, and the lack of adequate grazing habitat (Hossain *et al.* 2012). During the period of 1990-2015, soil salinity increased in most of the coastal area of Bangladesh. This area's agriculture growth is threatened by the rise of very high saline soil from 1% in 1990 to 33% in 2015 (Rahman et al. 2018). Climate change will

exacerbate the saline water incursion condition due to the rise of the sea level of those areas resulting in an ultimately negative effect on the livestock population growth.

***Riverbank erosion***

Riverbank erosion has had a detrimental influence on agriculture and the livestock sector for a more extended period. As a result of bank erosion, pasture, and grazing area are rapidly disappearing (FAO, 2009). According to a study, the Payra river site in the study region was eroding throughout the rainy season and autumn, limiting pasture and grazing acreage (Ali *et al.* 2020). Some responders have lost cattle and dwelling land in Bangladesh due to riverbank erosion (Ali *et al.* 2020). In a study of the Netrokona district, the river bank erosion has been marked at 8.8% among the other hazards (Fahim and Sikder, 2022). Many families are displaced by erosion, but victims in low-eroded areas adapt by selling land and livestock and moving to new char areas in Bangladesh (Karim, 2014). On the other hand, Assam's rural economy derives a substantial portion of its revenue from livestock and poultry production. River bank erosion caused the loss of farmland, livestock, and poultry farms for almost a quarter of the respondents, according to a study by Kamal and Abedin, (2019). Another study was conducted in 2019 at the Rajbari and the Tangail districts revealing that 7.04 percent of the respondents lost their livestock due to riverbank erosion. While in the Barisal district 86.56% respondents lost their livestock (Islam *et al.*, 2022). After losing their animals, individuals became more helpless, unhappy, and anxious (Hossain *et al.* 2021). Considering the above debate, it can be concluded that Bangladesh's river bank erosion poses a high risk to both people and animals. Each year, it has a negative influence on the livelihoods of people and their assets, such as animals. Simultaneously, the situation may worsen due to the melting of Himalayan ice and glaciers, which would cause a massive increase in river flow and have a devastating effect on the land.

***Natural disasters and the rise in sea level***

Natural disasters strike Bangladesh regularly, wreaking havoc on crops, livestock, and towns (Biswas *et al.* 2019). Climate changes accelerate the occurrence of these dangers (Hossain and Deb, 2011, Hossain *et al.* 2012), resulting in varying degrees of damage across the country. The IPCC's Third and Fourth Assessment Reports (AR3 and AR4) released in 2001 and 2007 warned the global community to prepare for 88 cm SLR and an increase of 1.7° C global temperature in this century. This will impose an uphill battle for coastal low-lying 22 deltaic countries and their 170 million coastal residents (IPCC, 2001; IPCC, 2007; Hossain and Majumder, 2018). By combining data from various sources, including the IPCC, the National Adaptation Programme of Action (NAPA) for Bangladesh estimated that sea levels could rise by 14, 32, and 88 centimeters between 2030 and 2100 (MoEF, 2005). Climate-driven SLR has also increased the frequency and severity of tropical cyclones, monsoonal storms, and tsunamis, increasing flood events, gradually inundating and degrading tidal wetlands, shorelines, river deltas, and other low-lying land features (Ahmed and Suphachalasai, 2014). Hotspots for cyclones spanned around 17% of the territory while 22% of the area was affected by high and extremely high storms/tides and nothing could be done to avoid the thunderstorms (Biswas *et al.* 2019). Hailstorms cause more livestock damage in the north and northwest region of Bangladesh, encompassing around 23.8 percent of the country during the period of 2009-2014. Tornado damage is widespread in 84 percent of the locations (Biswas *et al.* 2019). Moreover, in Bangladesh, the Bay of Bengal is a favorable place for tropical cyclones and depressions to develop, it accounts for around 40% of all global storm surges, alone (GoB, 2008). During Cyclone Sidr in 2007, almost 90% of the residents of the region being investigated lost their animals (GoB, 2008). For these reasons, the coastal areas and lowland people and their livestock are posed more risk than other areas people; hence, their sufferings may rocket up due to global warming.

***Problems associated with livestock production due to climate change***

***Grasslands and fodder production***

Increased temperature, $CO_2$, and/or precipitation variations all affect fodder production (Sawalhah *et al.* 2019). The pasturelands, fodder production, and quality of grasses can deteriorate in many ways. Extensive drought, reduced rainfall, flooding, and waterlogging all have a direct effect on the growth of palatable grass species, the regeneration of fodder species in the pasture, the drying of wetlands, pastureland, groundwater, torrents, the decline of forest fodder, and the diversity and quality of livestock fodder (Dahal, 2011; Bekele, 2017; Biswas *et al.* 2019;). Changes in pasture productivity, species composition, and behavior may also induce changes in the nutritional availability of animal diets due to fluctuations in the quantities of water-soluble sugars and nitrogen (McKeon *et al.* 2009; Izaurralde *et al.* 2011; Rojas-Downing *et al.* 2017). As temperatures rise, plants may make more lignin and other parts of their cell walls, which could make them harder to digest and make it harder for livestock to get the nutrients they need (Thornton *et al.* 2009; Sanz-Sáez *et al.* 2012; Polley *et al.* 2013). It will degrade the characteristics of plant materials converting from C3 (plant which produces initial product with three carbon atoms) to C4 (plant which produces initial product with four carbon atoms), reducing animal nutrient

availability (Thornton *et al.* 2007). A study in Bangladesh demonstrated that there is an inverse relationship between temperature and the yield of rice and wheat which are reduced by 28 and 68 percent, respectively (DAE, 2007). On the contrary, the combination of a doubling of

**Table 2**: Adaptation and mitigation strategies of the climate change effects on livestock production

| Strategies | Sub-sections | References |
|---|---|---|
| Livestock breeding and rearing | Acknowledging and improving local breeds that have adapted to the local climate and feed sources<br>Improving local genetics through cross-breeding with heat and disease-tolerant breed | Islam *et al.* (2018); Maiti *et al.* (2014) |
| | Genetically improved livestock such as Khaki Campbel, Xinding rearing | Rahman and Obaydullah (2020) |
| | Changing breed, species of animal, switching from large to small ruminants or vice-versa, reduction of herd size | Thornton and Herrero (2014) |
| Farming practices | Mixed/integrated farming systems such as crop-livestock systems, alter integration within the system | Ayeb-Karlsson *et al.* (2016); Thornton and Herrero (2014); Delaporte and Maurel (2018) |
| Housing strategy | Climate resilient agricultural practices such as producing High Yield Variety (HYV) crops | Rahman and Obaydullah, (2020) |
| | Housing on raised lands, mud wall housing, offering a protective framework and cooling apparatus, disaster-resistant housing, planting trees around houses | Rahman and Obaydullah (2020); Jost *et al.* (2016); Das (2017) |
| | Changing micro-climate in the shed of livestock, | Maiti *et al.* (2014) |
| Feeding strategy | Changing feeding systems and ingredients during floods such as-<br>• Restricted feeding and watering<br>• Urea Molasses Block/Straw (UMB/UMS), Densified complete feed blocks (DCFBs), unconventional feeds, banana steam and leaves, water hyacinth, tree leaves, spineless cactus, etc.<br>• Reducing the amount of wastage by chuffing | Gebremariam *et al.* (2006); Bakshi *et al.* (2018); Samanta *et al.* (2021) |
| | Conserving fodder and establishing a feed bank | Samanta *et al.* (2021) |
| | In case of heat stress, additional crop residues, concentrate, mineral supplementation, and clean and fresh drinking water should be provided to the animal | Maiti *et al.* (2014); Aryal *et al.* (2020); Thornton and Herrero (2014) |
| | Improving rumen efficiency | (Das, 2017) |
| Fodder production techniques | Changing the feeding and grazing time<br>• Pastoral systems for fodder production<br>• Hydroponic grasses production | Maiti *et al.* (2014); Bakshi *et al.* (2018); Samanta *et al.* (2021) |
| Other management strategies | Improved fodder cultivation and grazing management, manure management, | Thornton and Herrero (2014); Rahman and Obaydullah (2020) |
| | Selling of few animals from a herd | Rahman and Obaydullah (2020) |
| | Adopt new and modern technologies such as artificial intelligence (AI) hazards identification, building water harvesting schemes for livestock | Islam *et al.* (2018); Hong *et al.* (2019); Delaporte and Maurel (2018) |
| | Mangrove plantation | Rahman *et al.* (2019) |
| | Livestock insurance, weather-index insurance, use of weather information | Maiti *et al.* (2014); Thornton and Herrero (2014) |
| Miscellaneous practices | • Providing more health care practices to the livestock such as vaccination, using a mosquito net to protect from mosquito<br>• Additional washing and water sprinkling of large ruminants during hot weather<br>• Increase awareness of people by training on Climate Risk Assessment (CRA) and preparing Climate Resilient Management Plan (CRMP)<br>• Migration of people and animals from disaster-prone areas<br>• Discovering alternative sources of income | Maiti *et al.* (2014) Rahman and Obaydullah (2020); Ayeb-Karlsson *et al.* (2016); Jost *et al.* (2016) |

atmospheric $CO_2$ concentration and a corresponding rise in temperature would boost rice production overall by 20% and decrease wheat productivity by 31% (Karim *et al.* 1999). Moreover, rising sea levels will inundate char areas, diminishing grazing opportunities (Samanta *et al.* 2021). Therefore, it is predicted that moisture stress, excessive water in the rainy season, and less water in the dry season may compel Bangladeshi farmers to limit the area devoted to seasonal crop production (Hossain *et al.* 2012). A major portion of livestock feed is made up of fodder and grains, so livestock productivity will be hampered if the production of principal crops is affected due to climate change.

***Water availability and quality***

The livestock industry will be impacted by water shortages because water is necessary for cattle consumption, crop farming, and product processing (Thornton *et al.* 2009). Simultaneously,

increasing temperatures will lead to an increase in water demand, a decline in water quality, and increasing competition for limited water resources (FAO, 2021). About 8 percent of all human water is used by animal production, and a rise in temperature may lead in two-to-three-fold increase in animal water consumption (Nardone *et al.* 2010). Around 3.7 tons of water are required to generate 30 g of protein from cattle while six times more water is necessary to produce the equivalent amount of protein from pigs. The entire annual water need for the production of animal products is around 2800 $km^3$, or 7.8 percent of the net precipitation on the world's landmasses (Nardone *et al.* 2010). However, with rising sea levels, more saltwater will enter coastal freshwater aquifers. Salination exacerbates the contamination of water sources by chemicals, organisms, and metals globally (Nardone *et al.* 2010). On the other hand, Bangladesh's groundwater is decreasing day by day in some areas due to excessive use of surface and groundwater for irrigation (Hossain *et al.* 2012). Therefore, it may be predicted that the drought-prone area's people of Bangladesh will suffer from water scarcity, on the other hand, the flood-prone area's people will be affected by the severe flood, and salinity in the future.

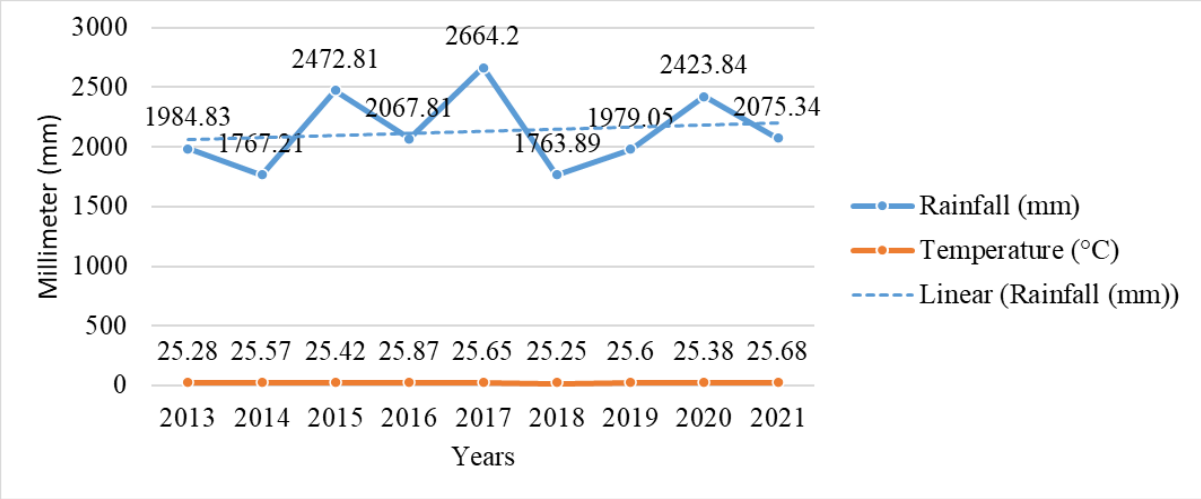


**Figure 1**: Average temperature and rainfall in Bangladesh during 2013-2021 (Trading Economics, 2023)

***Livestock diseases***

Most illnesses and parasites are weather-related (Bakare *et al.* 2020). It has deleterious effects on cattle health including availability and distribution of hosts, wildlife biodiversity, environmental persistence of pathogens, and agricultural and livestock rearing practices (Gale *et al.* 2009; Semenza and Menne, 2009; Rust and Rust, 2013). Wind-borne diseases such as FMD, as well as infections spread by ticks, flies, mosquitoes, midges, and other arthropods, may pose a significant threat in light of the changing environment. Bird migration and propagation may alter the geographical distribution of diseases such as HPAI (Highly Pathogenic Avian Influenza) and West Nile virus. Climate change can modify the transmission cycle of the majority of parasite infections (Forman *et al.* 2008). Observations indicate a correlation between the illness epidemic and the mass migration of animals, which is in turn influenced by climate conditions (Sharma *et al.* 1991). According to dairy farmers, the primary problem during floods is liver fluke infection. Milking animals succumb to mastitis disease when subjected to heat stress. Fog and smog have a substantial impact on animal health, which is a main feature of the dairy farming industry (Abbas *et al.* 2019). Thus, floods and excessive rain are associated with multiple leptospirosis epidemics (Lau *et al.* 2010). Additionally, salinity issues contribute to various skin diseases in the livestock sector (Hughes, 2008). Depending on the fodder crops affected by salt, animals will have immune system breakdown, diarrhea, skin diseases, liver fungus, sickness, and weight loss (Alam *et al.* 2017). Since Bangladesh is a hot and humid region where livestock migrates with their owners owing to flood, river bank erosion, natural disasters, etc., the likelihood of disease transmission and susceptibility to parasite infestation increase proportionally.

***Heat stress***

Animal regulates its body temperature through the process of thermoregulation. When this process is hampered by physiological or environmental reasons, imbalance occurs in its body resulting heat stress (Aggarwal and Upadhyay, 2013). It alters different physiological and behavioural activities likely for pigs, a temperature increases of 1°C over their optimal growth temperature results in a 5% decrease in feed intake and a 7.5% fall in

inactivity. Furthermore, - 4°C to + 18.5°C is the thermoneutral zone for dairy cattle (Forman *et al.* 2008). When the ambient temperature reaches 27°C, the cow generates more heat than it can dissipate, resulting in heat stress. Therefore, heat stress significantly reduces reproductive capacity, milk production, and health in dairy cows, resulting in a loss of economic potential (Forman *et al.* 2008). Dairy farmers viewed heat waves as the primary hazard to their herd, followed by droughts, insect and disease infestations, flooding, and high moisture in the atmosphere (Abbas *et al.* 2019). It has been shown that both dairy and beef cattle have an adverse relationship between temperature and feed consumption (Gaughan and Cawdell-Smith, 2015). Beef cow intake drops by 3-5% as temperatures rise from 25 to 35 degrees Celsius; when heats exceed 35 °C, intake declines by about 30% (Brown-Brandl *et al.* 2005). Reduced feed intake due to heat stress is the leading cause of lost productivity in beef cattle. Several studies have demonstrated that the impact of temperature is more pronounced on high-production breeds than on low-production breeds (Gaughan and Cawdell-Smith, 2015). Approximately 3.6 kg less milk is produced per 1°C increase in temperature for high-productivity cows than for low-production cows (Staples and Thatcher, 2011). Even though *Bos indicus* breeds (such as Brahman) are more heat-tolerant than *Bos taurus* types, typically, their productivity (i.e., growth rate and reproductive success) is lower than that of less heat-tolerant varieties (Gaughan *et al.* 2010). Indigenous cows, which are better adapted to India's tropical environment, also show signs of climate's impact on milk production (Sirohi and Michaelowa, 2007). Due to the increasing temperature of the world, the production of high-yielding breeds in Bangladesh will be less effective than that of local breeds (such as Red Chittagong Cattle). Farmers would instead rear local breeds, while researchers would concentrate on enhancing the genetics and production of these local breeds. Otherwise, it will be difficult to persuade farmers to raise low-yielding varieties over superior ones.

***Livestock reproduction***

Climate change has a detrimental effect on livestock reproductive capabilities, affecting females and males. Additionally, heat stress impacts reproductive functions (Bekele, 2017). Under heat stress conditions, dairy cows' estrus cycle is lengthened, estrus symptoms are weakened, the estrus time is shortened, the gestation rate is decreased, and the fetal death rate is raised (Forman *et al.* 2008). Numerous farmers note a drop in animal conception rates during high humidity periods. They believe that female cattle are not ready for mating during periods of high heat and dryness that disrupt pregnancy and reproduction rates. Around 7% of farmers also noted that excessive rains at an inconvenient time disrupt the mating behavior of heat animals (Abbas *et al.* 2019). The hypothalamus mediates photoperiodic action; however, both male and female reproductive systems are affected by dietary and emotional stressors, which have a ripple effect throughout the hypothalamic-pituitary-gonadal axis. The consequences include abnormal gametogenesis, folliculogenesis, and ovulation. Furthermore, buffalo reproduction is negatively impacted by heat stress (Tailor and Nagda, 2005; Kabir *et al.* 2021). Buffalo exhibits silent heat by itself, while excessive heat may cause it to behave abnormally. Therefore, it may be said that increasing heat has a detrimental effect on animal reproduction and mating behaviour.

***Biodiversity***

Environmental issues and animal genetic resources are inextricably linked. Climate change poses a serious threat to genetic resources. Animal biological diversity and utilization must be protected in order to adapt to climate change. Conserving and utilizing a diverse range of genetic variations is critical for enhancing shock resistance, decreasing production cycles, and improving output. By and large, several species' distributions, population densities, group composition, the scheduling of biochemical pathways, and their behavior are anticipated to be altered (FAO, 2021). There had already been a 16% decrease in livestock species by the year 2000 (Thornton *et al.* 2009). Rischkowsky and Pilling, (2007) also revealed that 20 percent of the studied animals were considered endangered, with an average of one variety going extinct every month. There was a total of 209 extinct breeds of cattle in that study. Among the animal species, the chicken, pigs, and cattle possess the greatest risk of breed extinction that were 33%, 18%, and 16%, respectively according to Rojas-Downing *et al.* (2017). Sustainable livestock production is aided by animal genetic resources, which also offer options for adjusting to climate change. Conserving and utilizing genetic resources sustainably will be crucial for developing climate-smart livestock systems (FAO, 2017). The production of local breeds of Bangladesh such as Red Chittagong Cattle, Pabna Cattle, Black Bengal goat, and so on should be focused on to flourish a sustainable animal production system that can adapt to the changing climate more efficiently. Animal gene banks should be developed and animal conservation by both ex-situ and in-situ methods should be emphasized to build a resilient animal production system and security for animal protein for the future generation.

***Adaptation and mitigation strategies of the climate change effects on livestock production***

Adaptation strategies are some practices that can help our animals to cope with the growing temperature and natural hazards. In addition, mitigation strategies are some prevention techniques for hazards through that the impact of hazards can be reduced. Since the global temperature rise is not easy to control, we can follow some strategies to overcome the threat of climate change impacts. Table 2 illustrated some adaptation and mitigation strategies for the betterment of our livestock sector.

## Conclusion

Bangladesh is geographically located in the subtropical monsoon zone, surrounded by multiple rivers and the Bay of Bengal. Due to this location of our country, the effect of climate change may exacerbate the livelihood and income of our people. This study found that the temperature is raising and rainfall is fluctuating in our country consequently the drought, flood, salinity, and natural disasters' intensity is enhancing. In addition, heat stress is observed to be the most harmful impact on livestock due to global warming. It reduces the growth, production of milk and meat, and reproductive capabilities of the animals. On contrary, adopting local breeds and integrated farming systems, building hazard-proof housing, and altering feeding practices are found the most effective adaptation and mitigation strategies for livestock to climate change. Policies should be implemented on selection of breed and livestock management strategies according to the different climatic regions. Also, the livestock insurance should be provided to the farmers so that they can focus on this sector without worrying about hazards.

Bangladesh has conducted several studies on climate change simultaneously on the livestock and agricultural fields; however, a lot of information gaps need to be filled by further research. Firstly, climate change has a diverse impact on Bangladesh's seven climatic regions. There was little research into the specific problems and mitigating measures associated with climate change on livestock production in these areas. Secondly, few studies have examined how global warming would affect the well-being and output of poultry and non-ruminant animals. Thirdly, some research on farmers' views and awareness about climate change are available in our nation but that are not enough. Fourth, there is a research deficit on the effects of changing weather on local grass and water quality. Fifth, no comprehensive research has been done here on livestock diseases and climate change, the probability of new diseases appearing, the impact of such diseases on farm animals, or how farm animals react to them. Sixth, a few research have estimated climate change's effect on declining domestic livestock populations. Therefore, more research, mitigation and adaptation techniques, and new technologies should be implemented to address the developing climate change challenges.

***Author's Contribution***

All authors have equally contributed to this manuscript.

***Conflict of Interest***

There are no conflicts of interest in this article.

***Data Availability***

The data of the research are available from the first author upon logical request by contacting zan.naim01@gmail.com

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