Impact of Climate Change on Occurrences and Distributions of Animal Diseases and Deaths in Smallholder Farming Systems: An Investigation of Farm-level Experiences

Centre for Environment and Climate Change Research (CECCR) Project

Ministry of Environment, Forest and Climate Change

September 2023

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Centre for Environment and Climate Change Research (CECCR) Project, Ministry of Environment, Forest and Climate Change Government of the People's Republic of Bangladesh

Year of Publication

September 2023

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Design & Printed by

Fairplay
131, D.I.T Extension Road, Dhaka-1000

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MESSAGE

We, as a nation, recognize the impact of climate change on our smallholder farming systems and the increase in occurrences and distributions of animal diseases and deaths. In our capacity as a developing country, we are committed to addressing this pressing issue and taking proactive measures to safeguard our farming communities.

MoEFCC is working for a sustainable environment, optimum forest coverage and to build a climate resilient community in Bangladesh. CECCR is a government initiative to establish a research centre under MoEFCC and it will be a national knowledge hub for climate change research in Bangladesh CECCR has conducted a research project titled "Impact of Climate Change on Occurrences and Distributions of Animal Diseases and Deaths in Smallholder Farming Systems: An Investigation of Farm-level Experiences" to perceive the challenges posed by climate change on animal diseases and deaths within smallholder farming systems.

The research has assessed the evolving trends in climatic parameters to gain insights into the changing environmental conditions that affect our smallholder farming systems. This study explored the variability in disease occurrence in relation to geographical differences and farm types. We also evaluated the evolution of new diseases affecting farm animals, which may be emerging as a result of climate change.

The outcomes of this research endeavor will play a pivotal role in shaping policies that promote the adoption of best practices and indigenous techniques for safeguarding our livestock. Ultimately, the overarching objective of this study is to shed light on the challenges faced by our smallholder farmers in the wake of climate change and provide actionable recommendations to empower the government and relevant authorities in creating a sustainable and resilient farming ecosystem.

We hope that this report will serve as a valuable resource, highlighting the real struggles faced by our farming communities and inspiring positive change in our nation's approach to addressing the impact of climate change on animal diseases and deaths.

Sanjay Kumar Bhowmik

Acknowledgment

This research report is the outcome of the study titled “Impact of Climate Change on Occurrences and Distributions of Animal Diseases and Deaths in Smallholder Farming Systems: An Investigation of Farm-level Experiences”. This report has been prepared by the research team of the CECCR Project.

We convey our sincere regards and heartfelt gratitude to Mr. Sanjay Kumar Bhowmik (Additional Secretary, MoEFCC), for his exceptional leadership as the Project Director of the CECCR Project. His visionary guidance laid the completion of our study. We also extend our heartfelt thanks to Mr. Md Mazedul Islam, the Deputy Secretary at MoEFCC and Deputy Project Director of CECCR. His meticulous planning and exceptional organizational abilities played a pivotal role in the seamless execution of fieldwork and data collection.

We also wish to acknowledge Mr. Md. Moniruzzaman (Additional Secretary), the Ex-Project Director of CECCR Project and currently working as the Chairman of Bangladesh Steel and Engineering Corporation, for his excellent initiative, ideas and support for the study.

Our heartfelt appreciation goes to Professor Dr. K. B. M. Saiful Islam and Assistant Professor Dr. Sujan Kumar Sarkar from Faculty of Animal Science & Veterinary Medicine, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh who played pivotal roles in the research planning, data collection, analysis and report writing. Their academic guidance and mentorship were instrumental in elevating the quality and rigor of the study.

Furthermore, we extend our sincere gratitude and sincere appreciation to the Upazila Livestock Officers, Upazila Veterinary Surgeons, local veterinary practitioners, and the Union Parishad Chairman in the six study Upazilas.

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Abbreviations Acronyms

BBS	:	Bangladesh Bureau of Statistics
DLS	:	Department of Livestock Services
FGD	:	Focus Group Discussions
FMD	:	Foot and Mouth Disease
GDP	:	Gross Domestic Product
GED	:	General Economic Division
KII	:	Key Informants Interview
LSD	:	Lumpy Skin Disease
MoEFCC	:	Ministry of Environment, Forest and Climate Change
PPR	:	Peste des Petits Ruminants
UNDESA	:	United Nations Department of Economic and Social Affairs

Executive Summary

The livestock sector plays an important role in the total agricultural GDP of Bangladesh. For being one of the most populous countries in the world, the demand for more production of livestock is continuously increasing and will be continuing this trend in the future. Productions of livestock are being affected due to changing of different climate parameters like temperature, rainfall, humidity etc. Climate change has significant effects on the production, disease occurrences and deaths of animals. Keeping those in consideration, this study was conducted to assess the occurrences and distributions of animal diseases and deaths in the changing climate. A mixed-method approach with multistage sampling techniques were applied to obtain data from the respondents. Both qualitative and quantitative data were collected and analyzed for this study. Meteorological data from 30-year periods were analyzed to assess the trend of changes in temperature and rainfall over time. A total of 420 respondents were interviewed with structured questionnaires. Those who had experiences more than 10 years in dealing and managing animal farms were selected as respondents for this study. 30 key informants were interviewed with a semi-structured questionnaire and a total of 10 focus group discussions were conducted. The data gathered was based on the experiences and observations of the respondents, key informants and focus group members. The study found sharp trends for temperature increase in mean annual, pre-monsoon, monsoon, and post-monsoon season in most of the study locations. In the case of rainfall, there were declining trends for mean annual rainfall in most of the study locations except Patharghata and Dowarabazar, while mean monsoon rainfall was found on a declining trend in all the study locations. However, foot and mouth disease, lumpy skin disease, mastitis, ephemeral fever, bloat and repeat breeding were reported as more frequent in the changing climate compared to five to ten years earlier in cattle farms, while foot and mouth disease, bloat, ectoparasitic infection were reported as more frequent from buffalo farms. On the other

hand, bloat, Peste des Petits Ruminants (PPR) and ectoparasitic infection were reported as more frequently occurring diseases compared to five to ten years earlier in goat and sheep farms. Some common symptoms and signs such as anorexia, diarrhea and pneumonia were reported significantly as more frequent by respondents from cattle, buffalo, goat and sheep farms. It was also claimed by the key informants and respondents from focus group discussion that overall diseases occurrences in animals had increased in recent years. There were some mixed observations found regarding the sudden death of animals. Moreover, very few respondents claimed that the sudden death of animals was increased in their farms. It was also revealed from focus group discussions and key informant interviews that due to vaccination and awareness buildup among the animal farmers, sudden death of animals might have been prevented. However, animal disease occurrence in relation to climate change is a complex phenomenon and it would not be wise attempt to simply generalize the concept because there are many more factors related to this phenomenon. In addition, this study assesses the experiences and observations of the respondents which might have some selection and recall bias. More rigorous studies need to be conducted analyzing time series hospital visit data of animals with respect to the climatic parameters for 30-40 years period.

1. Introduction

The global population is expected to increase by 33%, from 7.2 billion to 9.6 billion by 2050 (UNDESA, 2017). By this time, global livestock production is assumed to be doubled due to rapid population growth and improvement in living standards worldwide (Downing, 2017). Meanwhile, livestock sector plays a crucial role in the global agricultural sector as it contributes 17% of global consumption in kilocalories whereas it also provides 33% of all protein sources (Rosegrant et al., 2009). In addition, the sector supports the livelihoods of about one billion poor people and the employment of 1.1 billion people worldwide (Hurst et al., 2005). In case of Bangladesh, the sector contributes 1.90% in Gross Domestic Product (GDP) with a growth rate of 3.10% whereas its contribution in total agricultural GDP is 16.52%. The total share of livestock in GDP of the country is 67,189 Crore Taka which generates 20% employment directly with 50% indirect employment (DLS, 2022). On the other hand, every year a significant amount of money is spent as health expenditure for livestock. In 2020, a total 10,758 million Tk. was estimated as expenditure for treatment of the animals in Bangladesh (BBS, 2022).

It is to be remembered the importance of livestock sector in the economy of Bangladesh. However, it is a matter of concern that climate change has been a threat for survival of many species of livestock and their sustainable production systems (Chauhan, 2014) and also threat to its production, milk production, reproduction, biodiversity, and disease distributions (Downing, 2017). It also evident that climate change has, and will continue to affect the occurrence, distribution and prevalence of livestock diseases in Bangladesh, being one of the most climate vulnerable country. New disease outbreaks could arise within the animal populations as a result of climate change, which could result in significant changes in disease distribution (Thornton et al., 2009). In addition, under conditions of extreme heat stress and salinity, particularly in the coastal regions of Bangladesh, livestock are vulnerable to disease epidemics. (MoEFCC, 2022).

Livestock systems are being rapidly changing due to variation of different climate parameters like temperature, rainfall, humidity etc. (Downing, 2017; Thornton et al., 2009). Climate induced extreme events like heat waves directly affect health and productivity of farm animals (Carabaño et al., 2019). In addition, excessive rainfall, extreme heat, cold stress and increased salinity would cause less livestock production, diseases outbreaks, heat stroke, increased diseases and deaths of animals (MoEFCC, 2022). Heat stress, metabolic disorder, oxidative stress and chronic infection resulting from weak immune function are the direct impact of extreme weather conditions such as high temperatures whereas growth, multiplication, reproduction and distribution of pathogens, parasites and other vectors responsible for occurring diseases are the indirect outcome of extreme weather conditions (Ali et al., 2020). Further, growth of vectors, reservoir hosts and their survival rate are increased with the increasing temperature, which in turn increases the rate of carrying and transmission of parasites and parasitic organisms (Moore et al., 2012; Ostfeld, 2009).

Some of the pathogens or parasites are supposed to get their life cycle longer outside the host and subsequently increases their population in respect to temperature increase while, in contrast, population of some of the temperature sensitive parasites or pathogens would be reduced with increasing temperature (Harvell et al., 2002; Baylis and Githeko, 2006). In addition, immunity of some mammalian species would be suppressed due to exposure of high UV radiation from sun and could have impact on certain disease of livestock and genetic resistance of disease could be affected due to exposure and evolution of new forms of diseases (Baylis and Githeko, 2006). Animals like cow, pigs and poultry may suffer from low reproduction rates while grazing animals may be experienced with high mortality as well as their low immune function may trigger to evolve new form of diseases to various species of animals (Downing, 2017). Moreover, climate change can favor increasing populations of deadly parasites which may lead to the acute infectious diseases and deaths to the farm animals (van Dijk et al., 2009). Farm animals can be directly affected by climate induced extreme weather events. This direct

effect includes heat related mortality and morbidity of the animals (Nardone et al., 2010). In 2020 alone, there were reported 985947, 58999, 1042821, 60793 deaths of cow, buffaloes, goats and sheep respectively in Bangladesh (BBS, 2022).

Changes in the temperature, humidity and rainfall spectrum can influence the occurrence of diseases. For instance, rising temperature might favor some pathogens evolve that could cause new forms of diseases to animals. Besides, diseases which are considered as seasonal diseases, might occur all year round. There is very limited research conducted related to the impact of climate change on livestock disease, especially in developing countries like Bangladesh. Most of the studies focus on the impact of climate change on human health and vector-borne disease, but impacts on non-vector borne diseases are lack of sufficient research or study (Thornton et al., 2009). Bangladesh National Adaptation Plan also suggested climate-smart practices, research and strengthened extension services for better livestock management. Some noticeable studies have been conducted regarding the occurrences of diseases of animals in different geographical regions of Bangladesh. Handful of research works were found emphasizing the impact of climate change on the animal diseases. In addition, the impact of climate change on animal diseases is a complex phenomenon and it would not wise attempt to simply generalize the concept because, there are many more factors related to this phenomenon (Thornton et al., 2009). Since climate change is a continuous process and the situation is going toward the adverse scenarios, it should be necessary to understand the above phenomena with diverse information, experience and evidence from the livestock farmers dealing to get deep insights and for better policy formulations. Therefore, the specific objectives of the study might be as follows:

- To assess the trends of the climatic parameters
- To identify the animal diseases which are most prevalent in the changing climate.
- To assess variability in disease occurrence in relation to geographical differences and farm types.
- To evaluate the evolution of new diseases of farm animals.

2. Materials and Methods

2.1 Study Area

The study areas were selected considering the climate vulnerability to different areas of Bangladesh. The coastal region, part of the hilly region, riverine areas, and the haor basin are found highly vulnerable since these regions are more exposed as well as highly sensitive to climate change effects (Azam and Rahman, 2022). Furthermore, General Economic Division (2018) in Bangladesh Delta Plan 2100 identified coastal areas, haor areas, barind areas, hill tracts, major rivers and estuaries and urban areas as the major climate hotspots of the country (Figure 1).

Figure 1. Climate stress hotspots in Bangladesh (Source: General Economic Division, 2018)

Keeping in mind the above discussions, approximately, six different areas were selected in this regard (Figure 2). Firstly, one district was selected for each area and then from each district one sub-district was selected respectively as follows:

1. Coastal Area (Patharghata Sub-district, Barguna District)
2. Hilly Area (Rangamati Sadar Sub-district, Rangamati District)
3. Barind Area (Dinajpur Sadar Sub-district, Dinajpur District)
4. Char Area (Charrajibpur Sub-district, Kurigram District)
5. Haor Area (Dowarabazar Sub-district, Sunamganj District)
6. Urban Area (Savar Sub-district, Dhaka District)

2.2 Data Collection and Management

Both qualitative and quantitative approach were followed to perform the study where quality control was strictly maintained to fulfill the study objectives. For qualitative approach, key informant interviews (KIIs) and focus group discussions (FGDs) were performed. In case of quantitative approach, both Primary and secondary data were collected. Primary data on animal diseases and death including background information of both farmers and farms were collected through questionnaire survey technique. Secondary data for climatic parameters like temperature and rainfall, were collected from Bangladesh Meteorological Department.

For KIIs and FGDs, semi-structured questionnaire was used to collect data where structured questionnaire was applied for questionnaire survey. Field investigators were trained up well to collect information effectively. Pre-test of the questionnaire was performed before going towards the survey work.

2.2.1 Key Informants Interview (KII)

Livestock Officer/Veterinary Surgeon, Freelance Veterinary Quacks, Farm Owner/Manager, Senior Drug Dealer, and Local Leader of the selected study areas were interviewed as key informants. Unstructured questionnaires were used for interviewing. 5 KIIs were taken from the above-mentioned officials in each Sub-district. Therefore, a total 30 KIIs were performed for the study. The experiences and opinions of the key informants were recorded on the climate variability in the designated areas and its impact on occurrences and evolutions of diseases and deaths of farm animals. The key informants were also asked for explaining their difficulties in farm management and their demands and suggestions to overcome the problems.

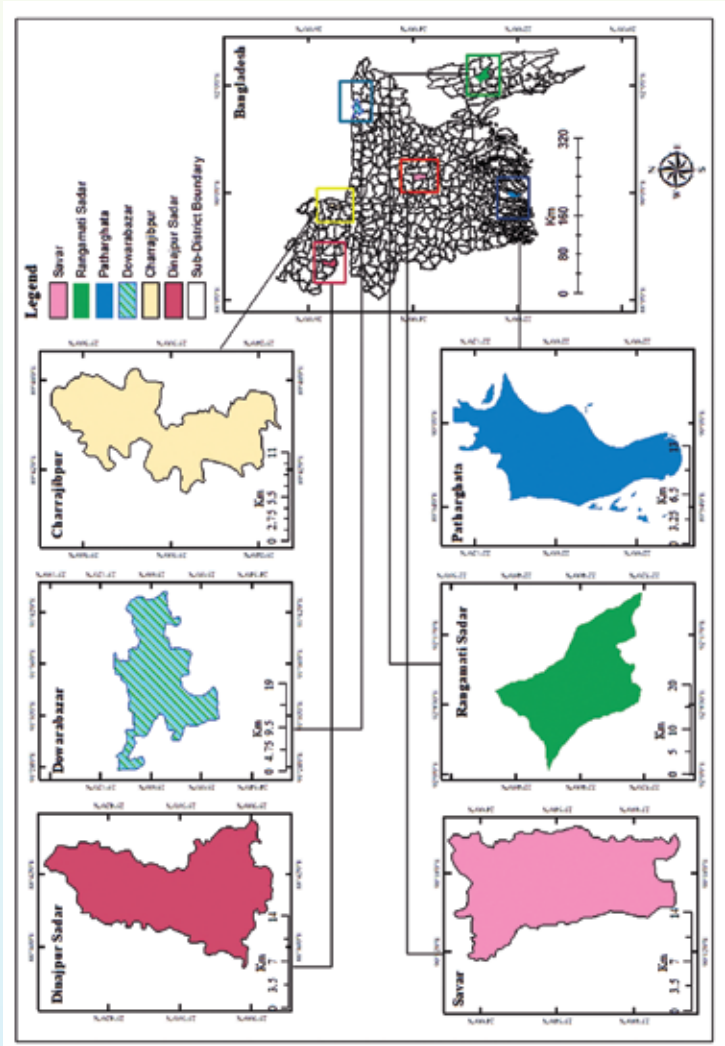

Figure 2. Study area locations representing each Sub-district

2.2.2 Focus Group Discussion (FGD)

A total of 12 FGDs for 06 selected Sub-districts with two (02) FGDs for each Sub-district were conducted. The groups were comprised with respondents from farm owner/manager having experiences more than 12 years. Each group of the FGD was formed with 10-12 respondents following the standard. Similar to the KIIs, the experiences and opinions of the respondents of the focus groups were recorded on the climate variability and its impact on diseases occurrences and evolutions of animals in the study areas. The focus group respondents were also asked for explaining their difficulties in farm management and their suggestions and demands to overcome the problems.

2.2.3 Questionnaire Survey

Non-probability sampling technique was used to conduct the study. In this regard, Quota sampling method was used since the study needs to investigate some specific target population with specific criteria. The animal farms which have been operating more than 10-12 years was selected for survey. Farm owner/manager was interviewed to get their practical experiences and knowledge about occurrences and prevalence of diseases and deaths. The sample size was calculated using the formula set by Fisher et al. (1998) which is as follows:

$$n = \frac{z^2 \times \hat{p}(1-\hat{p})}{\varepsilon^2}$$

Where, z = the z score; ε = the margin of error and p = the population proportions.

Inserting 95% confidence and a 5% margin of error in this equation, it yields a total of 385 sample population. Allocating 70 samples for each Sub-district on quota basis, a total 420 sample was considered convenient to make the sample population more representative. The respondents were asked about the climate variability in their area and its impact on the disease occurrences and deaths to the farm animals. Questions about climate variability were asked in Likert scale questions- “increase”, “no change” and “decrease scale”. Disease occurrences questions were asked about “the diseases that are more frequent in their farms compared to five to ten years ago” and “any cases of newly evolved diseases”. The diseases that had been seen in any single season but that diseases are now seen throughout the season in respective to their farm” were also asked. The respondents were also asked for explaining their difficulties in farm management and their suggestions and demands to overcome the problems.

2.2.4 Management of Climate Data

Meteorological data of study locations were collected from nearby stations of the study area for better representation. Meteoritical stations namely Dhaka, Dinajpur, Rangpur, Sylhet, Rangamati and Khepupara were selected for representing the study locations Savar, Dinajpur Sadar, Charrajibpur, Dowarabazar, Rangamati Sadar and Patharghata respectively. For better representation, climate data was presented using the name of study area locations instead of the station names. Data from the period of 1991 to 2020 was analyzed for this study. Missing data was ignored for the calculation.

2.3 Data Analysis

All data collected through using quantitative and qualitative approaches was processed and analyzed by using conventional methods. Qualitative data was analyzed based on the theme: perceptions of climate variability, diseases and death occurrences, problems facing in farm management and assistances needed. Quantitative data was analyzed through SPSS software whereas crosstab analyses were performed for categorical variables. Chi-square tests were also conducted to identify the relation between two categorical variables and the significance of their relations. The obtained meteorological data were analyzed with Mann Kendall test and Sen’s slop calculation to find out if there are any trends both upward and downward and the magnitude of the trends. Mean annual and seasonal temperature and rainfall were also calculated with standard deviations for the period of 1991-2020. For identifying temporal variations, spatial distributions of the study

area data were analyzed with ArcGIS Desktop software programme. Means of the three (03) decadal period (1991-2000, 2001-2010, 2011-2020) for temperature and rainfall were also analyzed with their corresponding percentage of deviations.

The trends of annual and seasonal temperature and rainfall were examined using the non-parametric Mann-Kendall trend test (Mann, 1945; Kendall, 1975). The Mann-Kendall test was shown to be effective in identifying potential statistically significant trends at various levels of probability. The following equations were applied to perform Mann-Kendall trend test:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\,(x_j - x_i)$$

Where, $x_1, x_2, x_3 \ldots\ldots x_i$ represent n data points where x_j represents the data point at time j and $sign\,(x_j - x_i)$ is defined as-

$$sign\,(x_j - x_i) = \begin{cases} 1, & x_j - x_i > 0 \\ 0, & x_j - x_i = 0 \\ 1, & x_j - x_i < 0 \end{cases}$$

Then, the variance from the data series can be calculated as follows-

$$var = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{i}^{n} t_i(t_i-1)(2t_i+5)\right]$$

Where, n denotes the size of the distributions, t_i represent the number of tied cells for each tie where i is subject to eventually changed based on the number of ties.

Finally, test statistic Z_{mk} score is calculated using the formula-

$$Z_{mk} = \begin{cases} \frac{(S-1)}{\sqrt{var}}, & S > 0 \\ 0, & S = 0 \\ \frac{(S-1)}{\sqrt{var}}, & S < 0 \end{cases}$$

Where, Z_{mk} stands for the z score in Mann-Kendall trend test. Confidence interval 90%, 95%, and 99% were taken to distinguish the significance of positive and negative trends. If Z_{mk}>2.575, the null hypothesis of no trend is rejected at 99% significance level; if Z_{mk}>1.96 at 95% significance level; and if Z_{mk}>1.645 at 90% significance level. The positive and negative values for Z_{mk} signify about increasing and decreasing trends respectively.

To determine the magnitude of changes of the events, the Sen's slope method (Sen, 1968) was used and computed as follows-

$$Q = Median\left(\frac{X_{i'} - Xi}{i' - i}\right)$$

Where, Q is a slope estimate. $X_{i'}$ and Xi are the values at times i' and i, where i' is greater than i.

The positive value for Q represents the increasing trend while the negative value for Q represents decreasing trend.

3. Results and Discussion

3.1 Climate Variables and Their Trends

Climate variables- temperature and rainfall, were studied and presented in this study (Table 1). The results showed that mean annual and seasonal temperature in Patharghata and Savar were found higher compared to the other study locations except during monsoon season. In monsoon, the highest temperature was found in Savar (29.0±0.3 ° C) and Dinajpur Sadar (29.0±0.4 ° C) respectively and lowest was found in Rangamati Sadar (27.8±0.3 ° C). The temporal variations of mean decadal temperatures for the decades of 1991-2000, 2001-2010 and 2011-2020 were also found with some noticeable findings which are presented in figure 3. The decadal mean temperatures in Savar, Dinajpur Sadar, Charrajibpur and Dowarabazar were found highest as 26.22±0.24, 24.78±0.24, 24.82±0.26 and 25.01±0.23 °C respectively in the period of 2011-2020 among the periods of 1991-2000 and 2001-2010 while in Patharghata and Rangmati Sadar, highest values were found during the period of 2001-2010 as 26.11±0.23 and 25.30±0.26 °C respectively. The lowest values of decadal mean temperatures were found during the period of 1991-2000 in almost all the study locations Savar (25.78±0.27 °C), Dinajpur Sadar (24.63±0.27 °C), Charrajibpur (24.41±0.28 °C), Dowarabazar (24.62±0.42 °C) and Rangmati Sadar (25.14±0.39 °C) except in Patharghata (26.00±0.26 °C) which showed lowest value of decadal mean temperature during the period of 2011-2020.

From Mann-Kendall test, it was revealed that the mean annual temperature in almost all of the study locations was in increasing trends except Patharghata, while the trends were found significantly increasing at 99% confidence interval in Savar (3.43), Charrajibpur (3.59) and Dowarabazar (3.52) (Table 2). From Sen's slop estimate it was found that the highest increasing rate of mean annual temperature was found in Dowarabazar with 0.024 °C/year. Similar positive trends were found for pre-

Table 1. Annual and seasonal temperature (°C) with mean ($\bar{X}$) and standard deviation (δ) during 1991-2020

Locations	Annual		Pre-monsoon		Monsoon		Post-Monsoon		Winter	
	X	δ	X	δ	X	δ	X	δ	X	δ
Patharghata	26.0	0.2	28.0	1.9	28.8	0.2	25.8	0.4	20.3	0.5
Rangamati Sadar	25.2	0.3	27.2	0.7	27.8	0.3	25.2	0.6	19.7	0.5
Savar	26.0	0.3	28.0	0.7	29.0	0.3	25.8	0.4	20.2	0.7
Dinajpur Sadar	24.7	0.3	26.3	0.6	29.0	0.4	24.4	0.6	17.6	0.6
Charrajibpur	24.6	0.3	25.8	0.5	28.7	0.4	24.5	0.6	18.0	0.6
Dowarabazar	24.8	0.4	25.7	0.6	28.0	0.4	25.0	0.5	19.7	0.7

monsoon season in all the study locations except the study location Dinajpur Sadar. Furthermore, significant positive trends were found in all the study locations during monsoon season whereas, the highest increasing rate of mean temperature was found in Dinajpur Sadar, Charrajibpur and Dowarabazar with a rate of 0.033 °C/year respectively. The trends followed positive direction during post-monsoon season in almost all the locations except the study location Patharghata, while the highest increasing rate of mean temperature was found in Charrajibpur with a rate of 0.033 °C/year. In winter season, mixed trends were found with increasing trends in the study locations Savar, Charrajibpur and Dowarabazar and with decreasing trends in the study locations Patharghata, Rangamati Sadar and Dinajpur Sadar. The highest rate of increasing mean temperature in the winter season was found in the study location Savar with a rate of 0.031 °C/year while the lowest rate of decreasing mean temperature in the winter season was found in the study location Rangamati Sadar at a rate of –0.004°C/year.

On the other hand, the spatial distributions of mean decadal rainfall for the periods of 1991-2000, 2001-2010 and 2011-2020 were also presented in figure 4. There were no sharp trends found for the decadal rainfall except in the location Savar, where it was noticed a clear downfall in decadal rainfall with a 14.4% decrease during the period of 2011-2020 compared to the decadal rainfall during the period of 1991-2000.

However, trends of mean annual rainfall for the period of 1991-2020 was presented in figure 5. The highest mean annual rainfall was calculated from Dowarabazar (400.4±62.9 cm) while the lowest was found in Dinajpur Sadar (193.6±49.3 cm) for the period of 1991-2020 (Table 3). Similarly, highest mean seasonal rainfall for pre-monsoon, monsoon and winter season were found as 109.9±34.1, 262.4±42.2 and 5.5±5.4 cm respectively in Dowarabazar. In contrast, the highest mean rainfall (37.9±20.4 cm) in post-monsoon season was reported in Patharghata.

Table 2. Trend test by Mann-Kendall (Zmk score) and Sen's slope (Q at °C/year) estimate of temperature for annual, pre-monsoon, monsoon, post-monsoon and winter season

	Annual		Pre-monsoon		Monsoon		Post-Monsoon		Winter	
	Z_{mk}	Q	Z_{mk}	Q	Z_{mk}	Q	Z_{mk}	Q	Z_{mk}	Q
Patharghata	-0.12	-0.001	0.52	0.011	3.63***	0.017	-1.54	-0.014	-2.38**	-0.024
Rangamati Sadar	0.95	0.008	0.27	0.004	1.65*	0.010	0.00	0.000	-0.29	-0.004
Savar	3.43***	0.023	0.93	0.013	3.99***	0.027	3.10***	0.028	2.05**	0.031
Dinajpur Sadar	1.68*	0.010	-0.34	-0.006	4.40***	0.033	1.16	0.015	-0.50	-0.006
Charrajibpur	3.59***	0.022	0.84	0.008	4.46***	0.033	2.83***	0.033	1.02	0.016
Dowarabazar	3.52***	0.024	1.27	0.019	4.48***	0.033	2.34***	0.029	1.73*	0.023

* denotes significant trend at 90% confidence interval; ** denotes significant trend at 95% confidence interval; *** denotes significant trend at 99% confidence interval

Table 3. Annual and seasonal rainfall (cm) with mean ($\bar{X}$) and standards deviation (δ) for the period of 1991-2020

Locations	Annual		Pre-monsoon		Monsoon		Post-Monsoon		Winter	
	$\bar{X}$	δ	$\bar{X}$	δ	$\bar{X}$	δ	$\bar{X}$	δ	$\bar{X}$	δ
Patharghata	290.7	39.9	39.1	16.5	209.9	33.8	37.9	20.4	3.8	3.4
Rangamati Sadar	261.5	58.8	51.5	21.4	183.1	50.1	23.1	10.0	3.8	4.0
Savar	198.6	48.7	44.7	17.1	130.7	36.5	19.5	12.9	3.8	3.9
Dinajpur Sadar	193.6	49.3	30.3	13.3	145.4	39.8	15.5	17.2	2.4	2.1
Charrajibpur	219.1	45.6	42.4	13.7	156.7	39.1	17.7	15.0	2.3	1.9
Dowarabazar	400.4	62.9	109.9	34.1	262.4	42.2	22.6	12.2	5.5	5.4

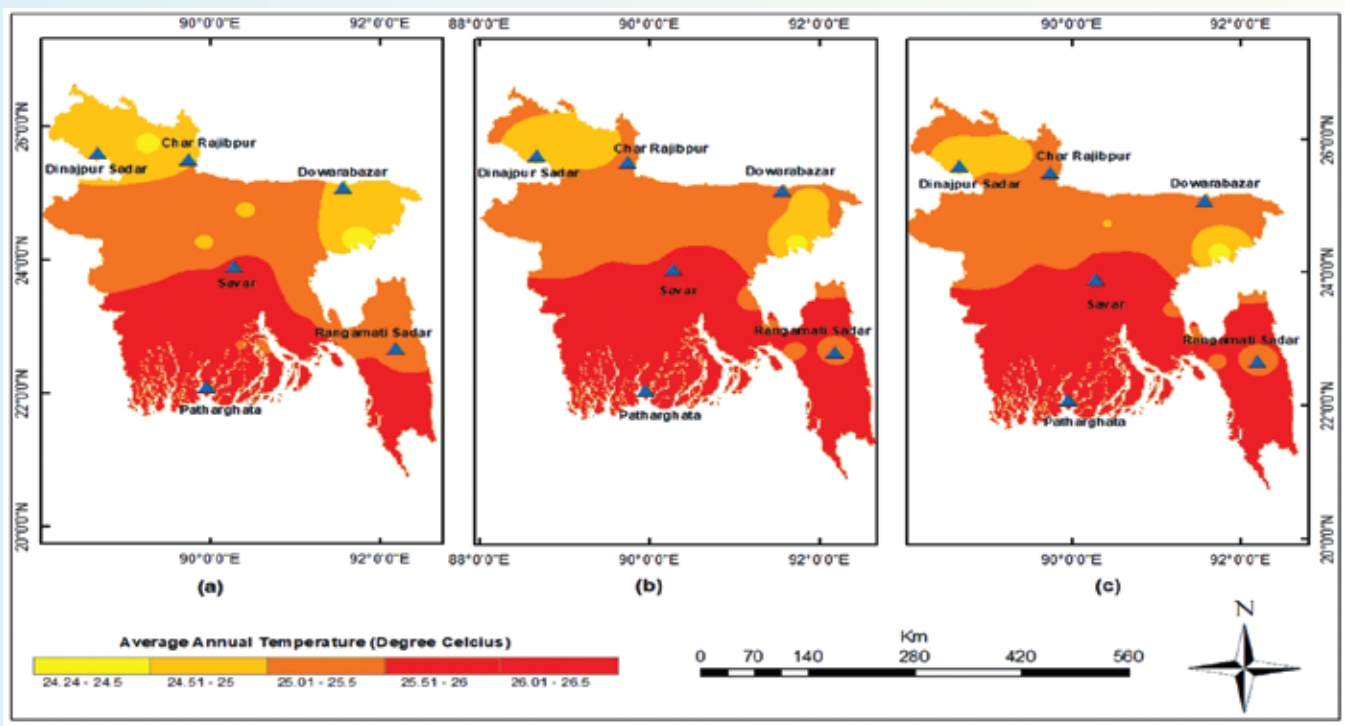

Figure 3. Spatial variation of mean decadal temperature for the time periods (a) 1991-2000 (b) 2001-2010 (c) 2011-2020 in the study areas

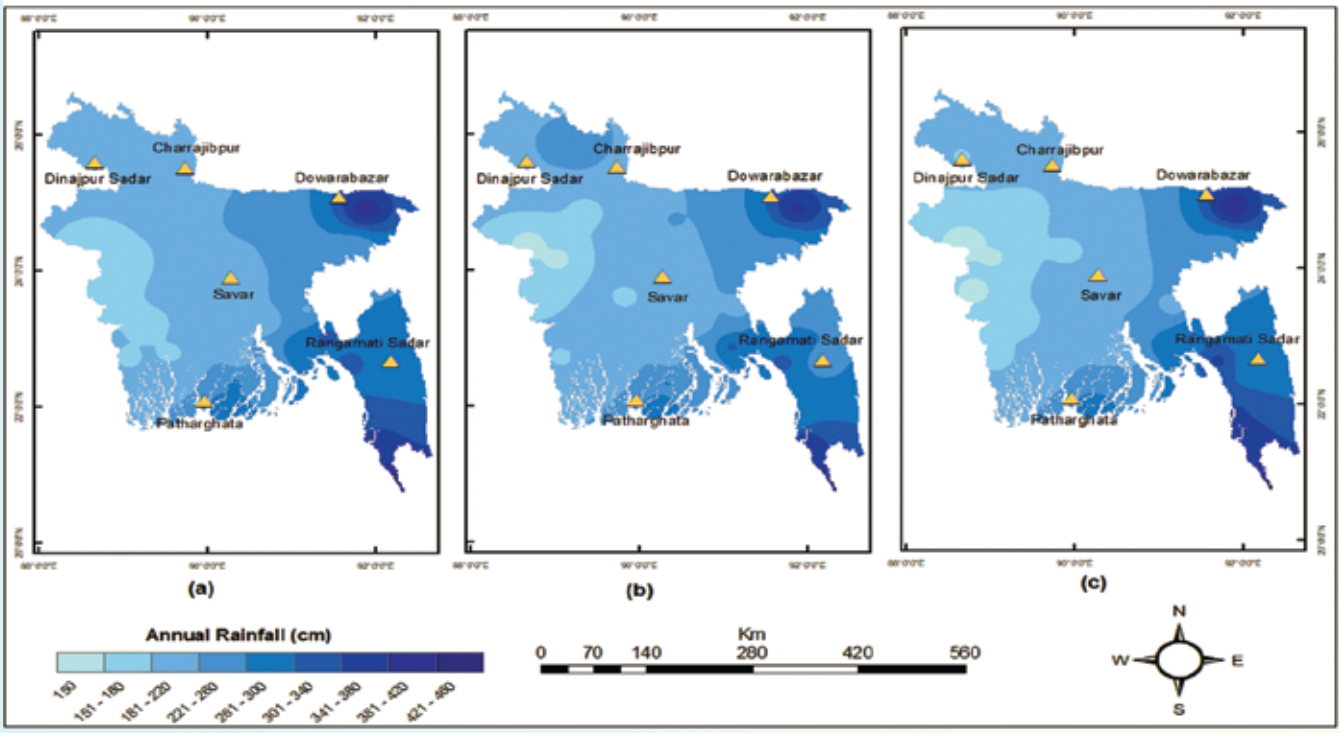

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Figure 4. Spatial variation of mean annual rainfall for the time periods (a) 1991-2000 (b) 2001-2010 (c) 2011-2020 in the study area

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Table 4. Trend test by Mann-Kendall (Zmk score) and Sen's slope (Q at cm/year) estimate of rainfall for annual, pre-monsoon, monsoon, post-monsoon and winter season

Locations	Annual		Pre-monsoon		Monsoon		Post-Monsoon		Winter	
	Z_{mk}	Q	Z_{mk}	Q	Z_{mk}	Q	Z_{mk}	Q	Z_{mk}	Q
Patharghata	0.57	0.57	**-1.87***	-0.81	1.07	0.70	0.41	0.26	-0.55	-0.03
Rangamati Sadar	-0.43	-0.84	-1.18	-0.68	-0.07	-0.15	1.41	0.28	-0.89	-0.05
Savar	-0.89	-1.17	-0.96	-0.36	-0.34	-0.27	-0.86	-0.20	-0.80	-0.06
Dinajpur Sadar	-0.93	-1.14	1.34	0.44	**-2.03****	-1.60	-0.23	-0.04	-1.45	-0.04
Charrajibpur	-0.93	-0.71	**2.44****	0.69	-0.82	-0.81	-0.80	-0.10	-1.13	-0.05
Dowarabazar	0.07	0.17	0.93	0.72	-0.34	-0.33	1.48	0.40	-1.39	-0.10

* denotes significant trend at 90% confidence interval

** denotes significant trend at 95% confidence interval

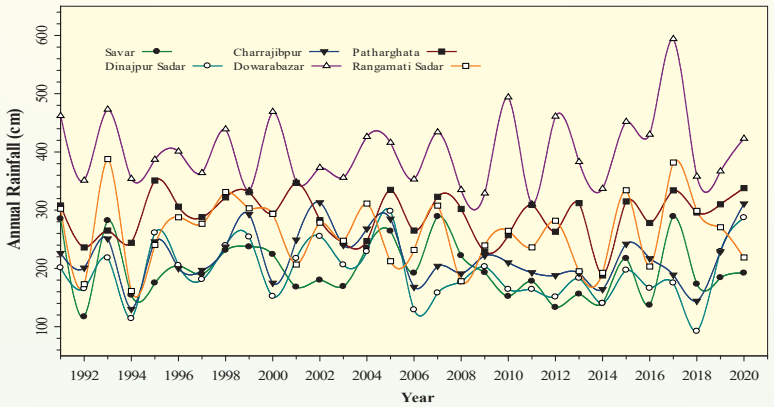

Figure 5. Trends in annual rainfall in the study areas during the time period 1991-2020

From Mann-Kendall test, it was revealed that mean annual rainfall was in negative trends in most of the study locations except Patharghata and Dowarabazar (Table 4). Similarly, most of the locations showed downward trends for the seasonal rainfalls. However, there were mixed results found for pre-monsoon and post-monsoon rainfall where each half of the locations showed either upward or downward trends. In case of winter, all the study locations showed a downward trend. In the meantime, significant positive trend for mean pre-monsoon rainfall was found in charrajibpur (Z_{mk}=2.44) whereas significant negative trends were found in Patharghata (Z_{mk}= -1.87). Another significant positive trend was found in Dinajpur Sadar (Z_{mk}= 2.03) for mean monsoon rainfall. There was no significant trend found for mean annual, post-monsoon and winter rainfall.

From Sen's slope estimate, it was noticed that highest decrease of mean annual rainfall was in Dinajpur Sadar and Savar with a rate of -1.14 and -1.17 cm/year respectively. The highest decrease for pre-monsoon rainfall was found in Patharghata at a rate of -0.81 cm/year while highest rate of increase was found in Dowarabazar with a rate of 0.72 cm/year. Highest rate of decrease for monsoon rainfall was observed in the study location Dinajpur Sadar at rate of -1.60 cm/year while in contrast, monsoon rainfall was found increasing at a rate of 0.70 cm/year in Patharghata. Mixed results were found for post-monsoon rainfall where highest rate of

increasing was calculated in Dowarabazar at a rate of 0.40 cm/year and highest rate of decreasing was calculated in -0.20 cm/year. Decreasing trends for winter rainfall was found all the study locations but the rate of decreasing was not significant.

3.2 Background Information of the Farmers/Farm Managers and Farms

Demographic information of the respondents who are livestock farmers or farm managers having experiences more than ten years was presented in Table 5. The factors included in the table are gender, age, education level, training taken and total land owned by the respondents.

Table 5. Demographic information of the respondents

Factor	Class	Frequency (n=420)	%
Gender	Male	325	77.4
	Female	95	22.6
Age	≤ 30	41	9.8
	31-40	124	29.5
	41-50	134	31.9
	>50	121	28.8
Education	No Formal Education	124	29.6
	Primary Education	143	34.1
	Junior School Certificate	56	13.4
	Secondary School Certificate	53	12.6
	Higher Secondary School Certificate	24	5.7
	Graduation	13	3.1
	Post-Graduation	6	1.4
Total land	≤ 0.5 acre	211	50.2
	0.6 - 1 acre	72	17.1
	1.1 -3 acre	100	23.8
	>3 acre	37	8.8

The majority of the respondents (77.4%) were found male with 22.6% female. The largest percentage (31.9%) of the respondents were fallen within the range of 41-50 years followed by 29.5% in the range of 31-40 years. The lowest percentage of the respondents (9.8%) were found below the age category ≤30 years. The education levels of the respondents were mainly fallen under two classes- "no formal education" and "primary education". The lowest percentage of respondents were reported with graduation and post-graduation level which were collectively 4.5%. However, amount of land owned by the respondents were also asked during the interview. 50.2% of the respondent reported having land property less than or equal to 0.5 acres.

On the other hand, background information of the farms is presented in Table 6. About 75% of the farms were found having land for the farms under two decimals. Only 25% farms were reported to have land greater than two decimals. In addition, about 97.1% of the farms were reported to have no shed over the farms with 49.3% farms having earthen floor. In case of natural light and ventilation, about 88.8% farms were reported to have the availability of the natural light and air supply whereas 35.7% were also found having artificial air supply systems. Since the study focused on the smallholder farms, majority of the farm owners were found to keep their farm animals under the open sky or under only upper shed without sidewalls. That's why, the natural light and ventilation systems are sufficiently available. It was found to have four types of animals in the study among which 383 farms were found having cattle (cow), where 05 having buffalo, 161 having goat and 09 having sheep. It was also found having more than one animal types in a single farm and every animal types were studied.

90.5% of the farmers were found having their own animals in their farm whereas 52.4% was found having purchased animals with 1.9% having leased. Most of the farms were found having both purchased and previously possessed animals. In terms of annual profit from the farms, about 47.9% farms were found

making profit less than BDT 0.5 lac whereas only 5.5% farms were found to have made profit larger than BDT 2 lac. Besides 6.0% farms were reported not having any annual profit while managing the farms. Participants from focus group discussion and key informants reported that the doctor and medicinal costs along with the costs of the feed and fodder had been risen enormously. In that case, small farmers having lower skilled in managing farms and having insufficient land for planting fodder could not gain sufficient profit from animal farming.

Table 6. Demographic information of the farms

Factors	Class	Frequency (n=420)	%
Farmland	≤0.5 decimal	69	16.4
	0.5-1 decimal	88	21.0
	1.1-2 decimal	158	37.6
	>2 decimal	105	25.0
Shed on farm	Shed	408	97.1
	No Shed	12	2.9
Floor of the farm	Earthen	207	49.3
	Brick	80	19.0
	Concrete	133	31.7
Natural light and Ventilation	Yes	373	88.8
	No	47	11.2
Artificial air supply	Yes	150	35.7
	No	270	64.3
Farm based on animal types	Cow	383	91.2
	Buffalo	05	1.2
	Goat	161	38.3
	Sheep	09	2.1
Animal source	Own	380	90.5
	Purchased	220	52.4
	Leased	8	1.9
Annual profit	No profit	25	6.0
	≤0.5 lac (BDT)	201	47.9
	0.6-1 lac (BDT)	124	29.5
	1.1-2 lac (BDT)	47	11.2
	>2 lac (BDT)	23	5.5
Helps and Assistances	Yes	41	9.8
	No	379	90.2

3.3 Perceptions of the Farmers about Climate Change in the Study Locations

Perceptions of the farmers/farm mangers about climate change were asked in nine different category questions i.e., the length of hot period, intensity of heat during summer, frequency of heat waves, length of cold period, irregularities in appearing winter, intensity of cold in winter, average rainfall, heavy rainfall events and irregularities in rainfall events (Table 7).

The majority of the respondents (85%) in all the study locations reported an increase in the length of hot period compared to ten to fifteen years earlier, while the highest percentage (16.4%) compared to the total percentage was reported in Savar where 69 out of 70 respondents reported such increase. In addition, 80% respondents reported an increase in intensity of temperature during summer while 68% respondents claimed that the frequency of heat waves was increased compared to ten to fifteenth years ago. Respondents from FGDs and KIIs also reported the similar observations regarding length of hot period, intensity of temperature and frequency of heat waves.

A significant majority of respondents (76%) from all the locations reported a decrease in the length of cold period while 59% respondents reported to decreasing of the intensity of cold during winter and 52% of the respondents reported that irregularities in appearing winter season had been increased.

In case of average rainfall, 59% of the respondents reported that the mean annual rainfall had decreased compared to ten to fifteen years earlier. In contrast, increasing trend was reported by 32% of the total respondents. It should be taken into consideration that most of the respondents who reported increasing trends of average rainfall were from the study locations Patharghata and Dowarabazar. This perception aligns to the data of the meteorological stations located at or near Patharghata and Dowarabazar presented and described above. Similarly, 31% respondents opined increasing trend of heavy rainfall events while most of them were from the study location Dowarabazar also. On the other hand, 48% respondents reported decreasing

Table 7. Perceptions of respondents on climate variability compared to ten to fifteen years ago (n=420)

Perceptions		Locations										Total	
		Patharghata		Dinajpur Sadar		Charrajibpur		Rangamati Sadar		Savar		Dowarabazar			
		f	%	f	%	f	%	f	%	f	%	f	%	f	%
Length of hot period; ***p*<0.001**	Decreased	1	0.2	5	1.2	0	0	3	0.7	0	0.0	21	5.0	30	7
	No Change	5	1.2	8	1.9	2	0.5	5	1.2	1	0.2	12	2.9	33	8
	Increased	64	15.2	57	13.6	68	16	62	14.8	69	16.4	37	8.8	357	85
													Total=	420	100
Intensity of temperature during Summer; ***p*<0.001**	Decreased	0	0.0	4	1.0	1	0.2	2	0.5	9	2.1	17	4.0	33	8
	No Change	7	1.7	3	0.7	4	1	5	1.2	17	4.0	17	4.0	53	13
	Increased	63	15.0	63	15.0	65	15	63	15.0	44	10.5	36	8.6	334	80
													Total=	420	100
Frequency of heat waves; ***p*<0.001**	Decreased	7	1.7	4	1.0	2	0.5	5	1.2	18	4.3	17	4.0	53	13
	No Change	13	3.1	14	3.3	5	1	9	2.1	24	5.7	17	4.0	82	20
	Increased	50	11.9	52	12.4	63	15	56	13.3	28	6.7	36	8.6	285	68
													Total=	420	100
Length of cold period; ***p*<0.001**	Decreased	57	13.6	48	11.4	58	14	57	13.6	67	16.0	33	7.9	320	76
	No Change	5	1.2	17	4.0	8	2	7	1.7	1	0.2	8	1.9	46	11
	Increased	8	1.9	5	1.2	4	1	6	1.4	2	0.5	29	6.9	54	13
													Total=	420	100
Intensity of cold in winter; ***p*<0.001**	Decreased	12	2.9	41	9.8	57	14	53	12.6	53	12.6	31	7.4	247	59
	No Change	2	0.5	17	4.0	4	1	9	2.1	13	3.1	10	2.4	55	13
	Increased	56	13.3	12	2.9	9	2	8	1.9	4	1.0	29	6.9	118	28
													Total=	420	100
Irregularities in appearing Winter; ***p*<0.001**	Decreased	2	0.5	12	2.9	14	3	42	10.0	7	1.7	26	6.2	103	25
	No Change	17	4.0	19	4.5	5	1	12	2.9	20	4.8	26	6.2	99	24
	Increased	51	12.1	39	9.3	51	12	16	3.8	43	10.2	18	4.3	218	52
													Total=	420	100
Average Rainfall; ***p*<0.001**	Decreased	20	4.8	56	13.3	59	14	43	10.2	65	15.5	3	0.7	246	59
	No Change	10	2.4	10	2.4	2	0.5	14	3.3	5	1.2	0	0.0	41	10
	Increased	40	9.5	4	1.0	9	2	13	3.1	0	0.0	67	16.0	133	32
													Total=	420	100

trend of heavy rainfall events. Except Dowarabazar, respondents from all the study locations opined about decreasing trend of heavy rainfall events. In case of irregularities in rainfall events, about 67% respondents reported that the irregularities in rainfall events were at increasing trends compared to ten to fifteen years earlier.

Respondents from FGDs and KIIs also reported mixed opinion about rainfall events. Respondents from the Dowarabazar and Patharghata from FGDs and KIIs reported increased rainfall events while in other study locations decreasing trends were reported. However, it was found from analyzing the perceptions of the respondents of the study locations that changes in the climatic variables are occurring in those locations as observed by the respondents.

3.4 Perceptions of the Farmers about Frequently Occurring Diseases of Animals Due to Climate Change Compared to Five to Ten Years Earlier

More frequently occurring diseases of cattle, buffalo, goat and sheep compared to five to ten years earlier reported by the farm owners in different study locations were presented in Table 8,9,10 and 11 respectively. Levels of significance were also measured with a chi-square test to identify whether there were any relations between disease occurrence frequency and study locations which were implicated by p values. In the case of cattle farming households, foot and mouth disease (FMD), lumpy skin disease (LSD), and bloat were reported by most of the farmers as more frequently occurring diseases compared to five to ten years earlier with 80.9%, 66.8%, and 63.4% respectively of the total cattle farming respondents. There were found significant variations ($p<0.01$) in the more frequent occurrence of LSD and bloat with respect to study locations. LSD was more frequently occurring diseases in all of the study locations except the urban area Savar. Similar results were reported in a study conducted in Chittagong district where less prevalence of LSD was found in the Chittagong metropolitan area compared to the other non-urban sub-districts Shatkania, Karnafully and Anwara (Ghosh et al., 2023). The current study was conducted on the smallholding

Table 8. Frequently occurring diseases reported by the cattle farming households compared to five to ten years earlier (f= frequency)

Diseases	Locations						Total		Significance Level (*p* value)
	Patharghata	Dinajpur Sadar	Charrajibpur	Rangamati Sadar	Savar	Dowarabazar			
	f	f	f	f	f	f	f	%	
Mastitis	42	8	19	10	55	6	140	36.6	<0.01
Anthrax	2	3	3	3	10	1	22	5.7	0.01
Hemorrhagic septicemia	25	9	12	9	15	13	83	21.7	0.02
Black Quarter	4	2	11	13	1	4	35	9.1	<0.01
Foot and mouth disease (FMD)	53	47	51	46	57	56	310	80.9	0.04
Ephemeral Fever	29	47	35	10	20	4	145	37.9	<0.01
Lumpy Skin Disease (LSD)	32	60	50	52	8	54	256	66.8	<0.01
Bloat	50	41	41	24	43	44	243	63.4	<0.01
Milk Fever	17	3	2	12	13	3	50	13.1	<0.01
Heat Stroke	9	18	24	19	26	1	97	25.3	<0.01
Foot Rot	14	7	9	1	2	2	35	9.1	<0.01
Skin disease	8	19	22	15	30	18	112	29.2	<0.01
Repeat Breeding	33	41	23	16	43	31	187	48.8	<0.01
Abortion	19	5	5	11	3	4	47	12.3	<0.01
Ectoparasitic Infection	4	7	17	14	1	25	68	17.8	<0.01
Sudden Death	14	3	7	2	6	6	38	9.9	0.02
Common Symptoms & Signs									
Anorexia	33	34	41	17	26	35	186	48.6	<0.01
Diarrhea	54	44	34	37	39	40	248	64.8	0.08
Pneumonia	32	16	34	47	19	39	187	48.8	<0.01

farmers and more than 80% of them reported LSD as more frequently occurring diseases in recent times. It was also revealed from the study conducted by Ghosh et al., (2023) that LSD was found higher in smallholding farms compared to organized farms. This occurred because organized farms used a zero-grazing management approach to keep their animals free of arthropod vectors, but smallholding farmers kept their cattle in open grazing areas, which might have allowed it to be easier for biting flies to transmit the virus. Bloat was reported more frequent in almost all the climate vulnerable study locations. From KII it was revealed that inundation of grazing areas with saline water from Bay of Bengal in Patharghat sub-district left the pastures moist and lush. When the cattle were grazed within pastures and the animals consumed the moist grass, the animals had in high chance to get affected with bloat. Similar claims were reported from flood prone areas like Charrajibpur and Dowarabzar where frequent flooding left the pastures moist and lush. When drought prone areas like Dinajpur Sadar experienced rain after a long dry period, there might grow forages. When those forages were consumed at early stages by grazing cattle, bloat could have occurred.

However, there was no significant variations found for foot and mouth disease (FMD) with respect to study locations. FMD was reported as more frequently occurring disease compared to five to ten years earlier by most of the farmers from almost all the study locations. Mastitis and ephemeral fever were also reported by a significant number of respondents 36.6% and 37.9% respectively with p value for both cases <0.01 which implicated that there were significant differences in frequently occurrences of mastitis and ephemeral fever in terms of locations. However, mastitis was found higher in Patharghata and Savar compared to the other study locations. Increasing hot and humid weather conditions of these areas might favor occurrences of mastitis. Mastitis of cattle is found higher during the hot and humid conditions and shedding or air conditioning of the farms to reduce heat stress lower the rate of mastitis occurrences in cattle compared to the cattle exposed to the natural environment (Harun et al., 2022; Das, 2017).

Some common symptoms and signs reported by the respondents as more frequent in recent times compared to earlier are anorexia (48.6%), diarrhea (64.8%) and pneumonia (48.8%). These conditions are not considered as diseases, but these are the signs and symptoms of various diseases which could not be clearly diagnosed. These could be symptoms of diseases presented in table 8 and if these symptoms were properly diagnosed by the respondents, percentages of some diseases could be increased as more frequently occurring diseases. Considerable percentages of farmers reported repeat breeding (48.8%) as more frequent disease in their farms. Heat stress resulted from the climate change adversely affect the reproductive functions of the animals. It also reduces the fertility of the cattle and decreases the length and intensity of estrous period and thereby, conception rate is reduced (Bekele, 2017). Heat stroke was reported as more frequent by 25.3% respondents of the total cattle farmers with a significance level ($p<0.01$) in respect with study locations. Temperature increase at significant rate in recent years might be the causing factor of the heat stroke. From KII with local veterinary practitioner and livestock officer, it was revealed that heat stroke had been increasing at an alarming rate in recent years especially in hybrid cattle. They also said that most of the time farmers even did not understand that either cattle of their farms were heat stroked. The diseases reported as more frequent by the lowest percentages of respondents were anthrax (5.7%), foot rot (9.1%), and abortion (12.3%). However, the significance levels of the reported diseases in respect to study locations were found significant, with p-values less than 0.01. Only 9.9% of the total respondents of the cattle farming households reported sudden death as becoming more frequent compared to five to ten years earlier. From FGDs and KIIs, it was claimed that due to awareness buildup among the farmers and the rate of vaccination was increased, the rate of disease incidents such as anthrax, black quarter etc. was reduced. As a result, sudden deaths might have been prevented by those diseases that occurred frequently earlier.

Table 9. Frequently occurring diseases reported by the buffalo farming households compared to five to ten years earlier (f= frequency)

Diseases	Locations			Total		Significance Level (*p* value)
	Patharghata	Savar	Dowarabazar			
	f	f	f	f	%	
Mastitis	1	0	0	1	20.0	0.39
Hemorrhagic septicemia	1	0	0	1	20.0	0.39
Foot and mouth disease (FMD)	2	1	0	3	60.0	0.23
Ephemeral Fever	2	0	0	2	40.0	0.08
Lumpy Skin Disease (LSD)	0	1	1	2	40.0	0.23
Bloat	2	1	1	4	80.0	0.39
Milk Fever	1	0	0	1	20.0	0.39
Foot Rot	2	0	0	2	40.0	0.08
Repeat Breeding	0	0	1	1	20.0	0.08
Abortion	2	0	1	3	60.0	0.08
Ectoparasitic Infection	1	2	0	3	60.0	0.23
Sudden Death	0	0	0	0	0.0	-
Common Symptoms & Signs						
Anorexia	2	0	1	3	60.0	0.08
Diarrhea	2	2	0	4	80.0	0.08
Pneumonia	0	2	1	3	60.0	0.08

In case of buffalo farming household, the more frequent diseases in the respective farms compared to five to ten years earlier were presented in table 9. Farms with buffalo were found only in three different locations Patharghata, Savar, and Dowarabazar. The significance level (p value) was also presented for each disease. The most frequently occurred diseases as reported by the buffalo farming households were bloat (80%) and ectoparasitic infection (60%). Foot and mouth disease (FMD) and abortion were reported as frequently occurring diseases compared to five to ten years earlier each by 60% of the respondents of the total buffalo farmers. Ephemeral fever, lumpy skin disease, milk fever, foot rot, repeat breeding, and hemorrhagic septicemia were reported by a smaller percentage of households (20-40%). In case of common symptoms and signs, anorexia, diarrhea and pneumonia were reported as more frequent occurring diseases as 60%, 80%

and 60% respectively by the respondents. From the buffalo famrs However, only 9.9% respondents reported sudden death as frequently occurring event in their farms. From KII interviews, it was revealed that due to vaccine and some sort of awareness among the farmers, sudden death events might have been prevented.

In the case of disease occurrence frequency in buffalo compared to five to ten years earlier as reported by the buffalo farmers, no statistically significant association with the locations and diseases occurrences were found (all p values > 0.05).

The diseases of goats which became more frequent compared to five to ten years earlier as reported by the respondents from goat farming households were presented in Table 10. The statistical significance level (p-value) was also provided for each disease. More frequently occurring diseases were reported as bloat (62.1%), peste des petits ruminants (PPR) (80.7%), foot and mouth disease (15.5%), and heat stroke (6.2%). Mastitis was reported by only 6.2% of the households.

Anthrax, hemorrhagic septicemia, black quarter, lumpy skin disease, milk fever, ectoparasitic infection, and skin disease were also reported as frequently occurring diseases by quite small percentage of respondents from goat farming households. In the case of common symptoms and signs, diarrhea, pneumonia and anorexia were reported as frequently occurring diseases with 75.8%, 68.3% and 46.0% respectively.

The statistical significance level (p-value) was less than 0.05 for most of the diseases, indicating that there were significant differences in the prevalence of these diseases in respect with the study locations. For example, foot and mouth disease was reported as more frequently occurring in Patharghata, Dinajpur Sadar, Charrajibpur, and Savar, but not in Rangamati Sadar and Dowarabazar. Similarly, heat stroke was reported more frequently in Charrajibpur and Savar, but not in Patharghata, Dinajpur Sadar, Rangamati Sadar, and Dowarabazar. In addition, Peste des Petits Ruminants (PPR) was found more frequent in Dinajpur Sadar,

Charrajibpur and Rangamati Sadar compared to the other study locations.

Lower amount of diseases for goats were reported to be more frequent compared to cattle in the case of five to ten years earlier. Only PPR and bloat are the diseases which were reported by considerable goat farmers as frequently occurring diseases compared to five to ten years earlier.

Table 10. Frequently occurring diseases reported by the goat farming households compared to five to ten years earlier (f= frequency)

Diseases	Locations						Total		Significance Level (*p* value)
	Patharghata	Dinajpur Sadar	Charrajibpur	Rangamati Sadar	Savar	Dowarabazar			
	f	f	f	f	f	f	f	%	
Mastitis	1	0	1	8	0	0	10	6.2	<0.01
Anthrax	0	1	1	1	0	0	3	1.9	0.94
Hemorrhagic septicemia	1	1	2	0	0	1	5	3.1	0.36
Black Quarter	0	0	2	0	0	0	2	1.2	0.33
Foot and mouth disease (FMD)	3	12	9	0	1	0	25	15.5	<0.01
Bloat	3	23	32	14	3	25	100	62.1	<0.01
Milk Fever	2	0	2	0	0	1	5	3.1	<0.01
Heat Stroke	0	1	7	2	0	0	10	6.2	0.04
Skin disease	0	2	9	8	2	5	26	16.1	0.29
Peste des Petits Ruminants (PPR)	5	30	37	33	6	19	130	80.7	0.04
Repeat Breeding	0	8	14	4	4	11	41	25.5	0.02
Abortion	2	7	1	4	0	3	17	10.6	0.06
Ectoparasitic Infection	0	7	8	14	0	16	45	28.0	0.01
Sudden Death	1	4	8	10	1	3	27	16.8	0.56
Common Symptoms & Signs									
Anorexia	4	17	29	7	2	15	74	46.0	<0.01
Diarrhea	6	20	36	32	7	21	122	75.8	0.01
Pneumonia	3	10	31	36	5	25	110	68.3	<0.01

Table 11. Frequently occurring diseases reported by the sheep farming households compared to five to ten years earlier (f= frequency)

Diseases	Locations			Total		Significance Level (*p* value)
	Rangamati Sadar	Savar	Dowarabazar			
	f	f	f	f	%	
Anthrax	1	0	0	1	11.1	0.01
Bloat	1	3	3	7	77.8	0.85
Milk Fever	1	0	0	1	11.1	0.01
Heat Stroke	1	0	0	1	11.1	0.01
Skin disease	0	2	0	2	22.2	0.20
Peste des Petits Ruminants (PPR)	0	1	2	3	33.3	0.57
Repeat Breeding	0	2	1	3	33.3	0.57
Abortion	0	0	1	1	11.1	0.50
Ectoparasitic Infection	0	4	3	7	77.8	0.10
Sudden Death	1	1	0	2	22.2	0.10
Common Symptoms & Signs						
Anorexia	1	0	1	2	22.2	0.10
Diarrhea	0	4	4	8	88.9	0.01
Pneumonia	1	2	4	7	77.8	0.20

More frequently occurring diseases for sheep compared to five to ten years earlier reported by the sheep farmers were presented in table 11. The diseases listed in the table include anthrax, bloat, anorexia, diarrhea, pneumonia, milk fever, heat stroke, skin disease, peste des petits ruminants (PPR), repeat breeding, and ectoparasitic infection. Only three locations out of six study locations where the diseases were reported include Rangamati Sadar, Savar, and Dowarabazar. Bloat, diarrhea, and pneumonia were the most frequently reported diseases as 77.8%, 88.9% and 77.8% respectively. Anthrax, milk fever, heat stroke, and skin disease were reported by the respondents with percentages ranging from 11.1% to 22.2%. The p-values for most of the diseases were above 0.05 indicated that the relation between the prevalence of the diseases with study locations was statistically insignificant except for the diseases anthrax, milk fever and heat stroke. For instance, the p-values for PPR and repeat breeding were relatively high, indicating that these diseases had not much variations in occurrences in respect with the locations. Considerable respondents reported diarrhea and pneumonia as

more frequently occurring symptoms with 88.9 and 77.8% respectively.

Beside theses, the diseases presented in the above tables were then further categorized according to their causal factors (Table 12). Mastitis, anthrax, black quarter, hemorrhagic septicemia and foot rot were categorized as bacterial disease/symptoms whereas foot and mouth disease (FMD), lumpy skin disease (LSD), peste des petits ruminants (PPR) and ephemeral fever were categorized as viral disease symptoms. In addition, ectoparasitic infection was categorized as parasitic infection while diarrhea, pneumonia, skin disease and abortion were categorized as diseases/symptoms occurred by multiple causes. Again, bacterial, viral, parasitic and disease/symptoms occurred by multiple causes were further categorized as infectious disease. In addition, bloat, anorexia, milk fever, heat stroke and repeat breeding were categorized as non-infectious diseases. Cattle were reported to get more exposed to bacterial, viral and diseases/symptoms occurred by multiple causes whereas goats were reported more susceptible to viral and diseases/symptoms occurred by multiple causes. It was found that almost all the animal farming households reported infectious diseases to be more frequent to their farm animals compared to five to ten years earlier. However, non-infectious diseases were also reported in quite noticeable proportions.

Table 12. Frequently occurring infectious and non-infectious diseases reported by the respondents compared to five to ten years earlier

Animal Types	Infectious				Total Infectious (%)	Non-infectious (%)
	Bacterial (%)	Viral (%)	Parasitic (%)	Disease by Multiple Causes (%)		
Cattle	56	96	18	87	100	88
Buffalo	40	10	60	100	100	80
Goat	9	84	28	90	98.8	74
Sheep	11	33	78	100	100	100

However, the study found that the diseases/symptoms like foot and mouth disease (FMD), lumpy skin disease (LSD), diarrhea, bloat, anorexia and repeat breeding were reported with higher frequency of occurrences compared to five to ten years earlier in cattle and buffalo farms. On the other hand, bloat, peste des petits ruminants (PPR), diarrhea and pneumonia were reported more frequent in recent years compared to five to ten years earlier within goat and sheep farms respectively. Respondents from FGD and KII, it was claimed that overall disease occurrences in animals had been increased within the last five to ten years. It was also reported that diarrhea, bloat, anorexia, repeat breeding and LSD were more frequent in recent years. They also revealed that prevalence of some kind of diseases like anthrax, black quarter, hemorrhagic septicemia etc. were decreased due to effective awareness building activities and vaccination programs by the government and other non-government organizations. Sarker et al. (2013) reported the most common infectious causes of cattle disease was mastitis (78.02%) followed by FMD (7.02%) but the current study found FMD (80.9%) as the highest percentage in frequency in cattle followed by LSD (66.8%). Sarker et al. (2013) studied particularly in Sirajganj district which is one kind of hub for animal farming in Bangladesh. Most of the locations in the current study were found farmers who collected animals from different parts of the country even from the outside of the country. It was reported from KIIs that when farmers brought any animals outside the respective territory, the risks for spreading diseases were increased. Because, in most cases farmers were not found conscious about separating the outsiders animals from their farm animals at least for one week after they had purchased or collected. This was reported as one of the most common causes for FMD cases.

3.5 Perceptions of Farmers about Frequently Occurring Diseases of Animals Due to Climate Change within Different Farm Types

Frequently occurring diseases were cross tabulated with farm types for all the four animals cattle, buffalo, goat and sheep (Table 13). The farms having animals of local species were considered as

Table 13. Frequently occurring diseases in terms of farm types reported by the farmers compared to five to ten years earlier

Diseases	Farm types															
	Cattle				Buffalo				Goat				Sheep			
	Local	Hybrid	Mixed	*p*-value	Local	Hybrid	Mixed	*p*-value	Local	Hybrid	Mixed	*p*-value	Local (n=9)	Hybrid (n=0)	Mixed (n=0)	*p*-value
Mastitis	19.1	74.7	41.8	<0.01	20.0	-	-	-	7.2	-	0.0	0.41	0.0	-	-	-
Anthrax	3.4	10.8	6.6	0.04	0.0	-	-	-	2.2	-	0.0	0.78	11.1	-	-	-
Hemorrhagic septicemia	21.5	26.5	17.6	0.36	20.0	-	-	-	3.6	-	0.0	0.65	0.0	-	-	-
Black Quarter	11.5	6.0	6.6	0.22	0.0	-	-	-	1.4	-	0.0	0.85	0.0	-	-	-
Foot and mouth disease (FMD)	77.0	86.8	84.6	0.10	60.0	-	-	-	14.5	-	45.5	0.01	0.0	-	-	-
Ephemeral Fever	32.1	37.4	51.7	0.01	40.0	-	-	-	23.2	-	36.4	0.62	0.0	-	-	-
Lumpy Skin Disease (LSD)	79.4	39.8	62.6	<0.01	40.0	-	-	-	0.0	-	0.0	-	0.0	-	-	-
Bloat	59.8	67.5	68.1	0.27	80.0	-	-	-	63.0	-	72.7	0.26	77.8	-	-	-
Milk Fever	9.1	22.9	13.2	0.01	20.0	-	-	-	3.6	-	0.0	0.65	11.1	-	-	-
Heat Stroke	18.2	38.6	29.7	<0.01	0.0	-	-	-	6.5	-	9.1	0.61	11.1	-	-	-
Foot Rot	8.6	9.6	9.9	0.92	40.0	-	-	-	0.0	-	0.0	-	0.0	-	-	-
Skin disease	28.7	36.1	24.2	0.22	0.0	-	-	-	15.9	-	9.1	0.58	22.2	-	-	-
Peste des Petits Ruminants (PPR)	0.0	0.0	0.0	-	0.0	-	-	-	79.7	-	90.9	0.65	33.3	-	-	-
Repeat Breeding	37.8	60.2	63.7	<0.01	20.0	-	-	-	24.6	-	36.4	0.69	33.3	-	-	-
Abortion	10.5	10.8	17.6	0.21	60.0	-	-	-	10.9	-	18.2	0.35	11.1	-	-	-
Ectoparasitic Infection	24.4	4.8	14.3	<0.01	60.0	-	-	-	30.4	-	9.1	0.21	77.8	-	-	-
Sudden Death	12.0	8.4	6.6	0.32	0	-	-	-	18.8	-	9.1	0.19	22.2	-	-	-
Common Symptoms & Signs																
Anorexia	46.9	53.0	48.4	0.64	60.0	-	-	-	46.4	-	36.4	0.78	22.2	-	-	-
Diarrhea	66.0	68.7	58.2	0.30	80.0	-	-	-	74.6	-	90.9	0.48	88.9	-	-	-
Pneumonia	56.9	34.9	42.9	<0.01	60.0	-	-	-	69.6	-	63.6	0.68	77.8	-	-	-

local farms whereas the farms having cross breed animals were considered as hybrid animals. Those farms having both local and cross breed animals were considered as mixed type farms. In case of buffalo and sheep farming households, only local species were found and in the case of cattle, local, hybrid and mixed types of farms were identified. In case of goat, local and mixed type farms were identified. Almost all types of diseases were found to be more frequent in farms with hybrid cattle compared to the farms with local species except for the diseases black quarter, LSD, Pneumonia and ectoparasitic infection. The diseases which spreads by the insects or mosquitos might be effectively controlled in farms with hybrid cattle because farmers primarily were found to take care of these species for their high prices. In most cases, hybrid cattle were found rearing in organized farms whereas local species were found rearing exposed to natural environments. It was also revealed from the FGD and KII respondents that the farmer usually constructed farms with concrete floor fencing with net and applying other preventive measures in organized farms rather than traditional farms with local species. Ghosh et al., (2023) reported that lower frequency of exposure and restricted rearing in a better-protected environment in organized farms kept animals away from the access of flies and other vectors. This might be the cause that LSD was reported more frequent in local farms rather than hybrid farms. In case of goat farms, bloat, pneumonia, diarrhea and anorexia were found higher in both the local and hybrid farms. Almost all the mentioned diseases were found as more frequently occurring in hybrid farms rather than local farms as reported by the respondents compared to five to ten years earlier. Skin disease, ectoparasitic infections and sudden death were reported as more frequent within local farms compared to hybrid farms. It might be the cause that local species were found rearing exposed to the natural environments even with less care. As these species exposed to natural pastures, there might have been chances to get infected with different types of bacterial, viral and parasitic infections.

3.6 Perception of Farmers about Frequently Occurring Diseases in Terms of Hot, Cold and Wet Periods

The respondents were asked about frequently occurring diseases in terms of hot, wet and cold periods compared to five to ten years earlier (Table 14). FMD, LSD, bloat, diarrhea, anorexia, and heat stroke were reported more frequent by the respondents from cattle farming households during hot period whereas FMD, pneumonia, diarrhea and skin disease were reported to be more frequent in cold period. Ayal et al. (2018) reported that the severity of all livestock diseases was found higher during the hot season. Further, FMD and Diarrhea were reported more frequent during wet period in cattle farming households. Similarly, FMD was reported to occur frequently during cold and wet season by Ayal et al. (2018). In buffalo farming households, FMD, Ephemeral Fever and LSD were reported more frequent in hot period. In addition, Pneumonia, diarrhea and milk fever were reported more frequent during cold period. Further, FMD, ephemeral fever, bloat, diarrhea, foot rot and skin disease were reported as more frequent during wet period. In case of goat farms, bloat, anorexia and diarrhea were reported more frequent during hot periods, while pneumonia and PPR during cold period and diarrhea and PPR during wet period. It was revealed from the study of Ayal et al. (2018) that the rate of prevalence of PPR would become more frequent during cold and dry period. On the other hand, bloat, anorexia and diarrhea were found more frequently occurring diseases during hot period within sheep farms as reported by the respondents. In addition, pneumonia and ectoparasitic infection were found as more frequent during cold period whereas diarrhea and pneumonia were reported as more frequent in wet period as opined by the respondents from sheep farming households.

3.7 Emerging of New Diseases within the Last Five to Ten Years

The respondents were asked whether there had been an evolution of any new diseases within the last five to ten years in their farms. Emergence of new disease was only reported from the cattle and buffalo farms as reported by the respondents. There were no observation on emergence of new diseases in goat and sheep farms. About 63% of the respondents of the total respondents

Table 14. Frequently occurring diseases reported by the farmers in terms of hot, cold and wet periods compared to five to ten years earlier

Diseases	Cattle			Buffalo			Goat			Sheep		
	Hot period	Cold Period	Wet period	Hot period	Cold Period	Wet period	Hot period	Cold Period	Wet period	Hot period	Cold Period	Wet period
Mastitis	18	9	6	0	0	0	8	1	0	0	0	0
Anthrax	2	1	1	0	0	0	1	0	1	0	0	11
Hemorrhagic septicemia	7	2	2	20	0	0	1	1	1	0	0	0
Black Quarter	2	1	14	0	0	40	1	0	1	0	0	0
Foot and mouth disease (FMD)	20	24	56	40	0	60	1	3	14	0	0	0
Ephemeral Fever	17	13	5	40	0	0	-	-	-	-	-	-
Lumpy Skin Disease (LSD)	53	5	12	60	0	20	0	0	0	0	0	0
Bloat	42	9	8	80	0	40	39	6	7	78	11	11
Milk Fever	5	6	3	0	40	0	0	0	0	0	0	0
Heat Stroke	21	1	0	0	0	0	7	0	0	11	0	0
Foot Rot	1	0	7	0	0	40	0	0	0	0	0	0
Skin disease	3	23	5	0	40	40	2	6	2	0	22	0
Peste des Petits Ruminants (PPR)	-	-	-	-	-	-	10	58	31	0	11	33
Repeat Breeding	7	7	6	0	0	40	0	0	0	0	0	0
Abortion	2	1	3	0	20	20	4	1	4	0	0	0
Ectoparasitic Infection	1	6	3	0	20	20	2	6	5	11	78	11
Common Symptoms & Signs												
Anorexia	21	8	5	20	0	0	20	5	4	33	0	0
Diarrhea	24	20	25	20	60	40	40	18	25	56	22	33
Pneumonia	2	52	5	0	100	0	4	64	8	11	44	33

having cattle farms told that they had encountered emerging of new diseases in their farms within the last five to ten years (Figure 6). In addition, 40% respondents from buffalo farms noticed LSD as new emerging disease in their farms (Figure 7). LSD was first identified in South-eastern part of Bangladesh in 2019 among the cattle population (Hasib et al., 2021; Talukdar et al., 2020). None of the susceptible animals, including cattle, have ever had an LSD outbreak in Bangladesh and there might have been a number of causes contributing to the present outbreak and its nationwide spread (Hasib et al., 2021). Later, reports of the same clinical onset pattern came from several regions of the country (Giasuddin et al., 2020; Khalil et al., 2021).

The current study found respondents from all the study locations experiencing this new disease LSD in their farms. It indicated that the newly emerging disease LSD was spread over the country. From FGDs and KIIs, it was revealed that there was no specific treatment they could offer to their animals if LSD attacked. Some local traditional measures were performed by the local farmers that the infected animals were cleaned regularly with warm water mixing with turmeric and leaves of medicinal tree Neem (Azadirachta indica). Some told about applying antibiotics to lessen the effects of the diseases. No vaccine or effective treatment were available for treating this disease as described by the key informants.

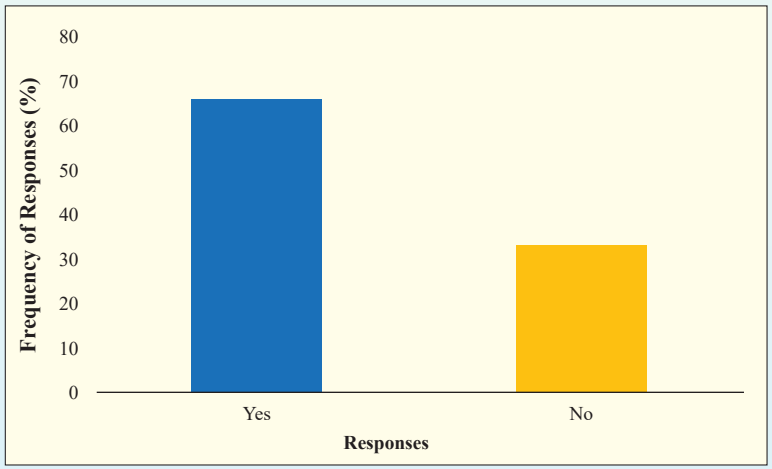

Figure 6. Responses of cattle farming households about emerging of new diseases

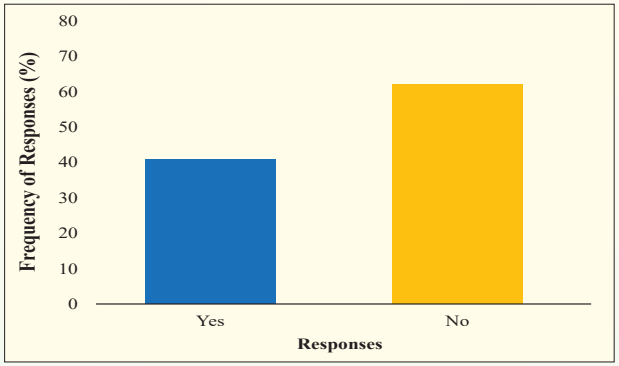

Figure 7. Responses of buffalo farming households about emerging of new diseases

3.8 Difficulties Facing by the Farmers and Their Suggestions and Demands

A variety of difficulties were reported by the respondents in managing their animal farms (Figure 8). Among them the most noticeable issues were found as lack of registered veterinary practitioner, inadequate knowledge about the modern farming systems, increasing rate of feed and fodder prices, feed and fodder crisis, shortage of capital, inadequate supply of vaccines and lack of improved treatment facilities.

The study mainly focused on the smallholding farmers who are the most sufferer of these problems. Similar kind of results were also drawn from the KIIs and FGDs where key informants and FGD respondents alarmingly manifested these problems.

Lack of Registered Veterinarians were seemed to be the most serious problems in the study areas especially in remote areas like Patharghata, Rangamati Sadar, Charrajibpur and Dowarabazar. The poor and unprivileged animal farmers often went to the local veterinary practitioners who are incapable of offering the right treatment in many cases. Most often, local farmers get them to the local veterinary practitioners for not having enough money or could not find any registered veterinarians available. In addition, farmers from the remote areas of the study locations were found going through damaged road infrastructures and poor transportation systems. Transportation of animals to the distant places for

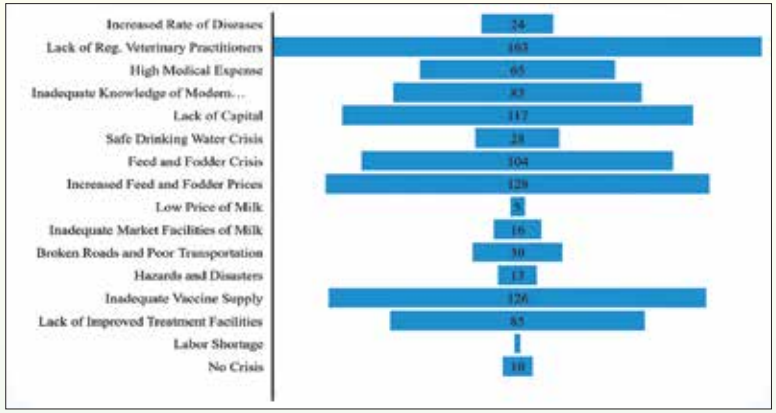

Figure 8. Problems and difficulties facing by the respondents with frequency

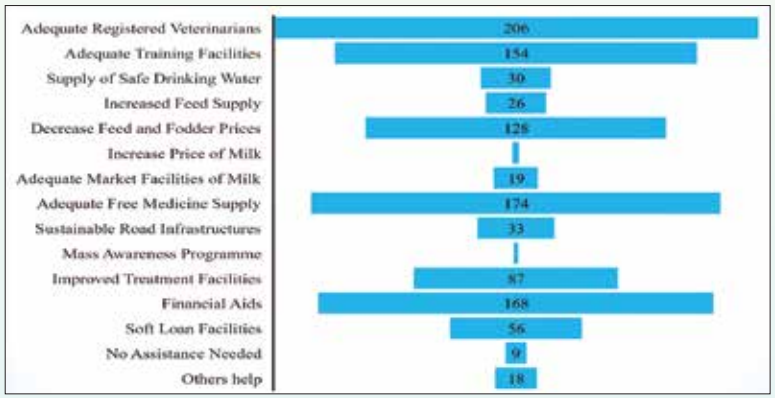

Figure 9. Helps and assistances demanded by the respondents with frequency

treatment was also found very troublesome for them and this might get them deprived of the better treatment.

However, some very essential and necessary suggestions and demands came from the survey respondents and also from focus group discussion participants and interviewee as key informants. They suggested some key points like availability adequate registered veterinarians, decreasing food and fodder prices, adequate training facilities, free medicine supplies including vaccines, improved treatment facilities, financial aids etc. (Figure 9) and each demand encountering the specific issues was presented in table 15.

Table 15. Demands by the respondents against the problems they are facing

Problems Facing by the Respondents	Helps and Assistances They Need
Lack of Registered Veterinary Practitioners	Adequate Registered Veterinary Practitioners
High Medical Expense	Adequate Free Medicine and vaccine Supply
Inadequate Vaccine Supply	
Increased Rate of Diseases	Improved Treatment Facilities
Lack of Improved Treatment Facilities	
Inadequate Knowledge of Modern Farming Systems	Adequate Training Facilities
Lack of Capital	Financial Aids & Soft Loan Facilities
Safe Drinking Water Crisis	Supply of Safe Drinking Water
Feed and Fodder Crisis	Decrease Feed and Fodder Prices
Increased Feed and Fodder Prices	
Low Price of Milk	Increase Price of Milk
Inadequate Market Facilities of Milk	Adequate Market Facilities of Milk
Broken Road Infrastructures and Poor Transportations	Sustainable Road Infrastructures
Hazards and Disasters	

Those who are visionary farmers demanded soft loan facilities to grow their business. Adequate free vaccine supplies to the remote places were demanded. They also suggested to provide necessary helps and supports to the smallholding farmers in managing the lethal diseases like FMD, LSD, anthrax etc. The poor farmers demanded necessary arrangements to make them and their farms maintaining proper hygiene. It was further suggested from the key informants that farmers should be made aware enough about the disease occurrences and necessary hygiene practices. To make it practical, it was advised to arrange enough training, mass awareness programs, rally with festoons, placards etc. In addition, more

training arrangements for the Government field staffs and the local veterinary practitioner were also advised.

4. Recommendations

The study focused on the experiences of the smallholding farm owners about more frequently occurring diseases of their farm animals compared to five to ten years earlier in the changing climate. The results revealed some recommendations as follows:

- The outbreak of lumpy skin disease (LSD) should be taken into priority consideration, especially for traditional farmers and vaccine of the disease needs to be developed soon.
- More training programs need to be provided to the local unregistered veterinary practitioners with monitoring their services effectively.
- Vaccines and medicines needs to be available enough through community pharmacy/mobile veterinary clinic services of Department of Livestock Services in remote places of the country where the farmers usually could not avail better treatment facilities.
- Heat-tolerant animal breeds could be developed as the temperature of the country would be in significantly increasing trends.

5. Conclusions

Most of the respondents were found with minimum formal education but their perceptions and awareness of changing the climate variability and its impacts on diseases occurrences of animals were significant. Most of the respondents opined about increasing summer length, increasing trend of temperature, irregularities in winter appearing and irregular rainfall events. Most of the farms with cattle reported more frequently occurring diseases compared to five to ten years earlier as mastitis, ephemeral fever, FMD, LSD, bloat, diarrhea and repeat breeding. In addition, FMD, bloat, diarrhea, LSD and heat stroke were reported to be more frequent during hot period. On the other hand, FMD, bloat, anorexia, diarrhea, pneumonia, abortion and ectoparasitic infection were reported to be frequent by most of the respondents having buffalo farms. Bloat, anorexia, diarrhea, pneumonia and PPR were found as more frequent as opined by most of the goat farming households whereas bloat, diarrhea and pneumonia were reported as more frequent by most of the sheep farming households. Cattle were found more susceptible to diseases compared to goats. On the other hand, very limited number of respondents reported sudden death as frequent for the farms of all types. The study was conducted in climate stress areas of Bangladesh. To be more precise and or generalization about disease occurrence in each climate stress area it is needed to conduct the study extensively in each of the climate stress areas. Due to lack of long-term recorded data on hospital visit of the animals, we had to go for recall method in which the respondents were asked about their experiences on these issues which might have some bias such as selection bias and recall bias. Besides, the diseases were reported from the farmers where clinical confirmation of the particular diseases could not be possible. And, farmers opined based on their observation. Farmers having more than 10 years of experiences in management of farms were selected as respondents and thus tried to minimize some sort of recall bias. However, long term hospital visit data is very crucial to draw substantial relation in terms of geographical locations and climate variability. Bangladesh Animal Health Intelligence System (BAHIS) has already started to keep record of hospital visit data with enough importance. This approach should be effectively running in future to get future disease spectrum with concrete evidence and information. This study might pave the way for new research on long-term changes in disease occurrence patterns for livestock which is essential for the formulation of plans and to set the priorities for what should be the first action in a more precise way.

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