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IMPACT OF CLIMATE CHANGE ON LEMON (*Citrus limon* L.) PRODUCTION IN EASTERN BANGLADESH

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Abstract

The study was conducted to assess the impact of climate change on lemon production at Sreemangal of eastern Bangladesh as the area is moderately vulnerable to climate change. The study sample consisted of 80 randomly selected lemon growers who were interviewed and the data were collected to identify their perceptions, social characteristics, and the impact of climate change on lemon production. The results of the survey indicated that the grower's perception of climate change was impactful as a majority of growers claimed increased annual precipitation (48.8%), increased summer temperature (48.8%), and reduced winter temperature (46.3%). In the case of extreme events, 56.3% of growers mentioned that the intensity of storms has increased in the last 5 years (2015-2019) and 58.8% of lemon growers said that the intensity of rainfall had increased substantially. However, in terms of environmental hazards, the findings indicate that excess rainfall, pest infestation, cloudy skies, hail storms, and drought are the major problems in lemon production. On the surface, overcast skies cause most of the damage to lemon production. Apart from this, soil fertility, pests, diseases, excess temperature, crop sowing time, maturity period, and drought had a significant impact on lemon production in the study area. From the correlation coefficient table, it appears that many socioeconomic characteristics were also influenced by the impact of climate change on lemon production. In the study area, there is a positive significant relationship between changes in lemon production and changes in environment and risks. The lemon crop requires moderate temperatures and average rainfall for improved production.

Keywords: Citrus fruit, Ecological suitability, Rainfall, Temperature

Introduction

Citrus is mainly grown in tropical and subtropical areas of the world. Lemon production depends on suitable climatic conditions. Climatic factors include temperature, rainfall, and wind. Climate change is one of the foremost serious threats to sustainable development (Khan *et al.*, 2021). Certain human activities have also been identified as significant causes of recent climate change, often referred to as "global warming". The climate of Bangladesh can be characterized by high temperatures, heavy rainfall, high humidity, and fairly marked three seasonal variations hot summer, shrinking winter, and

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medium to heavy rains during the rainy season Khan (2021). In general, maximum summer temperatures range between 38-41°C. April and January is the hottest and coolest month in most parts of the country, and the average coolest temperature is about 16–20°C and around 10°C at night. According to IPCC (2007), climate change affecting the sea level in the coastal region of Bangladesh has been predicted to rise to 80 cm by 2100. Climate change in Bangladesh has become a threat to rural farmers and agricultural workers.

Among the horticultural crops like pineapple, banana, mango, and other fruits, lemon required less cultural practices and hence reduces the labor cost. The area now under the lemon productivity was remaining fallow earlier in lemon cultivation. The environment of Bangladesh is favorable for lemon cultivation. With the globalization of world trade and the establishment of the WTO, the export opportunities for citrus fruits increased significantly. Hence, citrus growers faced increased competition at the world market level. The demand for lemons is increasing day by day, for which it is necessary to know the effect of climate change on the productivity of lemons as well as the current methods of production. In Bangladesh, productivity per unit and overall productivity need to be increased substantially to compete in the international markets. Climate alarm, in the form of unreliable weather patterns, weather excesses, and usual climate variability can potentially affect people's livelihoods adversely, which in turn can induce additional stress and result in vulnerability (Asaduzzman *et al.,* 2005). Bangladesh is a disaster-prone country, despite the fertile land it is subjected to food shortages because of the heavy dependence on agricultural productivity and the vagaries of weather and natural disaster (Paramanik, 1991). Environmental change presents nowadays danger for most agrarian areas and sustenance security among all other influenced divisions. Crop yields are predicted to fall up to 30%, creating a very high risk of hunger and only sustainable climate-resilient agriculture is the key to enabling farmers to adapt and increase food security (World Bank, 2001).

Despite promising climatic conditions for year-round citrus production in the country, its production continues to face many difficulties such as insect infestation (Haque *et al*., 2019), postharvest losses, the glut in peak season, and information gap in domestic and export markets (HORTEX Foundation, 2010). The study area is mainly affected by different types of climatic hazards. So, the environmental impact is effective in the agricultural sectors, especially for lemon cultivation. So, in this situation, it is necessary to know the extent of climate change perception and the impact of climate change on lemon productivity. The study aimed to assess the perceived impact of climate change, analyze the selected characteristics, explore the relationship between selected traits and the impact perceived by growers on lemon productivity due to climate change, and ascertain the environmental hazards faced by lemon farmers.

Materials and Methods

The experiment was conducted in an area of 450.74 square kilometers at Sreemangal in Moulvibazar, eastern Bangladesh. This study used both quantitative and qualitative research methods to get a comprehensive view of the perceived impact of climate change on the lemon productivity of Bangladesh. A qualitative method of key

informant interviews was used while a quantitative survey method was used. The key informants were the Agriculture Extension Officers of the unions under model farmers. Keeping the objectives of the study in mind an interview schedule was prepared to collect information. The questions and statements in the schedule were simple and easily understood by the respondents. Both English and Bengali language versions were used with the respondents or the lemon growers.

For this study, researchers prepared an up-to-date list of leguminous growers in the study area with the help of local leaders and concerned SAAOs. The total lemon growers interviewed were 320, among which 72, 64, 60, 48, and 40 were from Sreemangal, Rajghat, Asidron, Sindurkhan, kali-ghat, and Mirzapur respectively. The sample size was determined as 80.

Measurement of the dependent variable

Impact of climate change perceived

The extent of overall lemon productivity in response to climate change is the dependent variable of this study. For this study, we followed the climate change impact index (CCII) developed by Rahman (2005) and the formula was below:

$CCII = I_{no} \times 0 + I_{low} \times 1 + I_{mid} \times 2 + I_{high} \times 3$

Note: II= Impact Index; I_{no}= Frequency of respondents that have no impact; I_{low}= Frequency of respondents that have a low impact; I_{mid}= Frequency of respondents that have a medium impact; I_{high}= Frequency of respondents that have high impact

Measurement of independent variables

The farmers were classified into three categories according to the National Youth Policy, young (18-35 yr), middle (36-50 yr), and old age (above 50 yr).

The education of respondents was classified under Primary education (Grade l-5), Secondary education (Grade 6-10), and higher secondary (Grade 10-12) and graduated as 13 or above.

The occupation was classified (1, 2, 3) as agro-farmer, entrepreneur, and businessman, respectively. The family size was classified as small family (1-7 persons), medium family (7-11 persons), and large family (above 11 persons).

The farm size was classified into four categories marginal (land ownership up to 0.20 ha), small (land ownership 0.201-1.00 ha), medium (land ownership of 1.013.00 ha), and large (land ownership above 3.00 ha). The farm size was measured using the formula below:

Farm Size = A + B + (C + D) + E

Note: A= Own land under own cultivation; B= Land taken from others as a lease; C= Own land given to others as a lease; D= Mortgages; E= Taking mortgages

The method of ascertaining income involved two phases. The actual amount of annual family income of the respondent is calculated by using the formula below:

Total annual income = Agricultural income + Income from the non-agricultural source.

Respondents were classified into three categories as Low income (less than Bangladeshi Taka 1100000), Medium income (Taka 1100000-1700000), and High income (above Taka 1700000). Respondents were classified into three categories of communication levels with the extension personnel or agencies and they are low (score up to 14), Medium (14-21), and high (score above 21).

Environmental hazards faced by the farmers

The **r**espondents were classified into three categories of exposure to environmental hazards such as low hazardous (score up to 6), medium hazardous (6-9), and high hazardous (score above 9). For this study, Rahman (2005) categorization of environmental hazards was followed. An environmental hazard index (EHI) was developed to fulfill this objective using the following formula:

$EHI = EHI_{no} \times 0 + EHI_{low} \times 1 + EHI_{mid} \times 2 + EHI_{high} \times 3$

Note: EHI= Environmental Hazards Index; EHI_{no}= Frequency of respondents that have experienced no hazards; EHI_{low} = Frequency of respondents that have experienced low hazards; EHI_{mid} = Frequency of respondents that have experienced medium hazards; EHI_{high} = Frequency of respondents that have experienced high hazards; The EHI for each of the environmental hazards ranged from 0 to 240.

Statistical analysis

The data collected were analyzed, coded, transferred from the interview schedule to a master sheet, summarized, categorized, and entered into a database using Microsoft Excel 2019. The data were analyzed using SPSS (Version 16.0) which was used to perform all statistical analyses.

Results and Discussion

Personal and socio-economic profile of lemon growers

The observed age of the growers ranged from 29 to 59 Years (Table 1). Among the respondents, the highest proportion was 48.8%, the median 32.4% young, and 18.8% old. Most middle-aged growers are involved with lemon productivity. Mahmood (2011) reported that age is an important factor regarding knowledge because age had a significant negative correlation with horticultural adaptation.

The educational background of the cultivators ranged from 5 to 13 (Table 1). Similar results were also observed by Sarker *et al*., 2017 and the findings where the levels of education were (23.81, 28.57, 19.05, 23.81, and 4.76) % of the respondents were illiterate, don't complete primary education, completed primary education, primary level to SSC, and more than SSC.

The occupation of cultivators were agro-farmer, entrepreneurs, and businessmen (Table 1). The highest 41.2% of people were businessmen, 37.4% were an entrepreneur and 21.2% were agro-farmers. A recent research appraisal of the number of environmental and sustainability degree conceding programs has more than doubled over the last two decades from around 500 in 1990 to over 1200 today, and further, that jobs in these fields between 2008–2018 are projected to increase at a rate of around 28%, which is faster than the average for all occupations (Vincent, 2010).

The family size of the respondents varied from 5 to 13 (Table 1). Medium family size was 55%, followed by small family and large family (32.5 and 12.5) %. Rashid (2014) found similar results and results were marginal, small, and large farm holders 37.5, 30, and 13.7%; respectively in Bagerhat.

The farm size of the growers ranged from 0.31 to 6.25 ha (Table 1). The medium farm holder 78.8% constituted the highest proportion 78.8% and the lowest 7.4% in small farm holders and 13.8% had a large farm. The highest proportion was 78.8% for medium farms, followed by 13.8% for large farms, and the lowest farm size was 7.4% for small farms. Rashid (2014) observed similar results and the farm size ranged from 0.203-4.182 ha in Bagerhat.

Table 1. Distribution of the growers according to their personal profile

Age				
Categories (year)	Number	Percent	Mean	Standard deviation
Young age (18-35)	26	32.4	41.36	8.180
Middle age (36-50)	39	48.8		
Old age (above 50)	15	18.8		
Total	80	100		
Education				
Categories (year)	Number	Percent	Mean	Standard deviation
Primary (1-5)	1	1.2	9.88	2.213
Secondary (6-10)	46	57.5		
Higher Secondary (11-12)	23	28.8		
Graduate (13 above)	10	12.5		
Total	80	100		
Occupation				
Categories (Score)	Number	Percent	Mean	Standard deviation
Agro-Farmer	17	21.2	2.20	0.770
Entrepreneur	30	37.4		
Businessmen	33	41.2		
Total	80	100		
Family size				
Categories (year)	Number	Percent	Mean	Standard deviation
Small (1-7)	26	32.5	8.80	2.016
Medium (7-11)	44	55		
Large (11 or above)	10	12.5		
Total	80	100		

Table 1. Contd.

Farm size				
Categories (ha)	Number	Percent	Mean	Standard deviation
Small (>1)	6	7.4	2.2519	0.65156
Medium (1-3)	63	78.8		
Large (3<)	11	13.8		
Total	80	100		
Annual family income				
Categories (ha)	Number	Percent	Mean	Standard deviation
Low income (>1100000)	11	13.8	1702378	612385.705
Medium income (1100000-1700000)	34	42.5		
High income (1700000<)	35	43.7		
Total	80	100		
Communication media exposure				
Categories (Score)	Number	Percent	Mean	Standard deviation
Low contact (>14)	19	23.8	17.54	3.680
Medium contact (14-21)	47	58.7		
High contact (<21)	14	17.5		
Total	80	100		

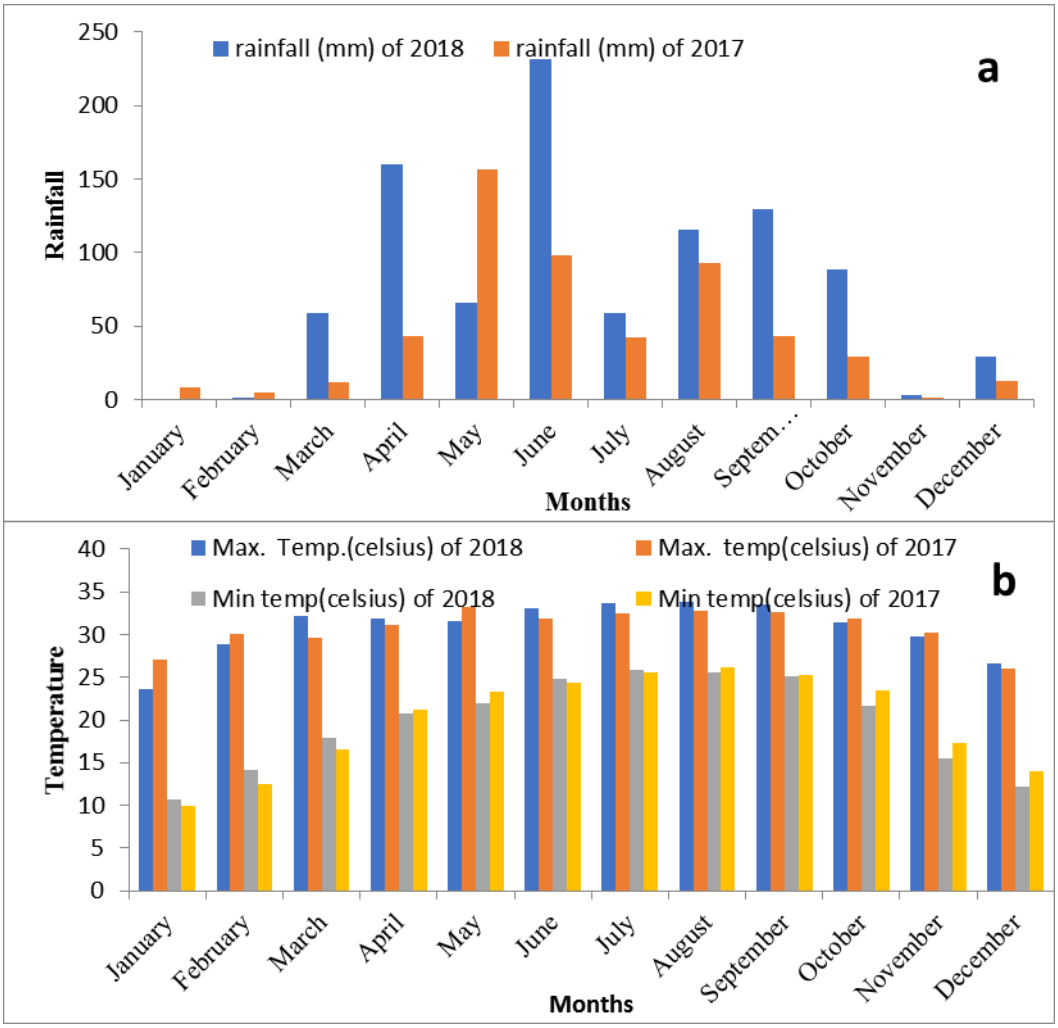
The annual family income of the growers ranged from Taka 456000-3205113 (Table 1). The majority (43.7) % of the respondents was a high annual family income, followed by 42.5% medium annual family and the lowest annual family income was 13.8%. Sarker *et al*., (2017) observed similar results and results were that 56% have their cultivated land where they produce lemon and 44% of farmers have no own land, and earn their livelihood by working on another's land.

The agricultural extension contact score of the growers ranged from 10 to 23 against the possible range from 0 to 33 (Table 1). The highest proportion of respondents was medium media exposure (58.7%), followed by 23.8% for low media exposure and the lowest was 17.5% for high media exposure.

Meteorological data (rainfall and temperature)

Total rainfall at Sreemangal was 2420 mm in 2018-19, as per the records of the meteorological department. Approximately 86% of the annual average rainfall occurs between April and September (Fig. 1). The maximum and minimum rainfall were 231.2 mm and 0 mm in April and January in 2018 and 156.25 and 1 mm in May and November in 2017. The maximum and minimum temperature was 33.8 and 10.70^0c respectively in August and January of 2018 and the maximum and minimum temperature was 33.1 and 9.90 ^{0}c respectively in May and January of 2017. Sarker *et al*., (2017) found that 2030-

2290 mm annual rainfall humidity was between 60 and 86%, the duration of sunshine from 5-9 hours, and this study also found annual temperature from 10-37°C where the minimum and maximum temperature prevail in January and May in Muktagacha.



Source: Bangladesh Meteorological Department (year 2017-2018)

Fig. 1. a). Annual rainfall, b) Annual temperature of 2017-2018

Grower's perception of climate change

Farmers' perception of climate change has been studied (Table 2). The data showed that farmers revealed information on average annual rainfall patterns, from 2015-2019. However, the lemon growers revealed the monsoon length as shown in Table 2 for the period 2015-2019. Most of the farmers (52.5%) said that the annual mean temperature has not changed since the previous 5 years and only 13.75% of farmers said that the annual average temperature has decreased since the previous 5 years.

Farmers (46.25%) said that the annual average winter temperature has decreased, and only 11.25% of farmers mentioned that the winter temperature increased 5 years ago. Farmers (48.75%) said summer temperature increased 5 years ago and only farmers (16.25%) said summer temperature decreased. Most of the farmers (56.25%) said that storm intensity has increased and farmers (10%) said that storm intensity has decreased over the previous 5 years. Martínez *et al.*, (2020) noted that climate change was influencing the citrus management practices of the producers.

Table 2. Distribution of the respondents based on their perception of climate change

Sl. No.	Name of the statement		The extent of perception (No=Number)							
			Increased		Decreased		No changed		Don't know	
			No	%	No	%	No	%	No	%
1.	Precipitation	Annual	39.00	48.75	6.00	7.50	25.00	31.25	10.00	12.50
		In rainy season	16.00	20.00	18.00	22.50	34.00	42.50	12.00	15.00
		In dry season	32.00	40.00	10.00	12.50	24.00	30.00	14.00	17.50
		Rainy season length	21.00	26.25	13.00	16.25	36.00	45.00	10.00	12.50
		Summer season length	11.00	13.75	38.00	47.50	24.00	30.00	7.00	8.75
2.	Temperature	Annual	15.00	18.75	11.00	13.75	42.00	52.50	12.00	15.00
		Winter season	9.00	11.25	37.00	46.25	21.00	26.25	13.00	16.25
		Summer season	39.00	48.75	13.00	16.25	18.00	22.50	10.00	12.50
3.	Extreme events	Intensity of storms	45.00	56.25	8.00	10.00	16.00	20.00	11.00	13.75
		Intensity of hotness	13.00	16.25	36.00	45.00	25.00	31.25	6.00	7.50
		Intensity of rainfall	47.00	58.75	9.00	11.25	13.00	16.25	11.00	13.75

Environmental hazards faced by lemon growers

Environmental hazard scores faced by the growers ranged from 5 to 12 against the possible range from 0 to 15. The distribution of Environmental hazards faced by growers was depicted according to their experience (Table 3). The majority (43.8%) of the growers in Sreemangal had medium environment hazard scores while 37.5% had low environment hazard scores and 18.8% had high environmental hazards. Ahmed *et al*., (2020) observed similar results and the farmers perceived Nor'wester (77.9 %) as the most frequent hazard causing crop damage followed by heavy rainfall, hailstorm, heavy wind, flashflood, heavy fog, and floods.

Impact of climatic change as perceived by lemon growers

The data in Table 3 indicated the impact of climatic change on the growers in Sreemangal with an average of 30.25. The majority (53.7%) of the growers in Sreemangal observed high impact towards climate change while about 32.5% observed low impact and 13.8% observed medium impact was found in the study area. During 2003-2013, the total damage and losses to the crop subsector amounted to about 13$ billion. Almost 60% of this damage and losses were caused by floods, followed by storms with 23% (FAO, 2015).

Table 3. Distribution of environmental hazards and impacts of climate change

Environmental hazards faced				
Categories	Number	Percent	Mean	Standard deviation
Low hazardous (>6)	30	37.5	7.50	1.909
Medium hazardous (6-9)	35	43.7		
High hazardous (9<)	15	18.8		
Total	80	100		
Impacts of climate change				
Categories (Days)	Number	Percent	Mean	Standard deviation
Low impact (>28)	26	32.5	30.25	2.698
Medium impact (28-30)	11	13.8		
High impact (30<)	43	53.7		
Total	80	100		

The overall rank order of hazardous events experienced by growers

The percentage of distribution of the growers in Sreemangal according to environmental hazards is provided in Table 4. Along with the EHI and rank order of each environmental hazard, the environmental hazards index of the respondents of the 5 items ranged from 0 to 240. The problems identified by the growers in Sreemangal were listed according to their importance. Most of the growers of the study area experienced excess precipitation to a considerable extent rather than other environmental hazards. The highest hazard index (180) was found in the case of precipitation. The next index was found in the case of the cloudy sky (168). During the period 2003-2013, 3.4% of all humanitarian aid went to agriculture, while this sector absorbed about 22% of total damage and losses caused by natural hazards (FAO, 2015).

Table 4. Overall rank order of hazardous events experienced by growers

Problems	Growers (N=80)				EHI	Rank order
	High	Medium	Low	Not at all		
Drought	0	7	31	42	45	4th
Spread of pest	25	42	10	3	169	2nd
Hail storm	2	5	18	55	18	5th
Cloudy sky	28	38	8	6	168	3rd
Excess precipitation	33	34	13	0	180	1st

The rank order of climate change on lemon productivity

The impact of climate change on lemon productivity score ranged from 85 to 176 against the possible score of 0 to 240 (Table 5). The growers marked extra cloudy sky mostly affected lemon productivity and scored highest to 176, while the lowest ranked drought on citrus growth and productivity scored 85. The study of OĞUZ *et al*., (2017) supported this study.

Table 5. The rank order of climate change of lemon productivity

Impacts	Growers (N=80)				CCII	Rank Order
	High	Medium	Low	Not at all		
Due to excess temperature, the amount of lemon productivity increased before	25	28	16	11	147	4th
The fertility of the soil has decreased compared to before	35	28	10	7	171	2nd
The sowing time of lemon has changed	26	22	18	14	140	5th
Crop productivity takes longer than before	20	30	15	15	135	6th
Extra cloudy sky cause damage to lemon productivity	38	25	12	5	176	1st
Drought on citrus growth and productivity	10	15	25	30	85	7th
New pests and diseases are seen in lemon fields	30	23	13	14	149	3rd

Relationship between selected socio-economic characteristics and their impact of climate change on lemon production

From Table 6 it was found that education and communication media exposure of the lemon growers had a negatively significant relationship with the impact of climate change. Similarly, age, occupation, family size, farm size, and annual family income had

a positively significant relationship with the impact of climate change on lemon productivity in the study area. In the country bean, the insect of aphid and pod borer showed a significant positive relationship with temperature and pod numbers in Sylhet (Khan *et al*., 2020).

The calculated value of (r=0.516) was found greater than both the tabulated value of 0.05 and 0.01 levels (Table 6). It was concluded that there was a positive significant relationship between the age of the lemon growers and the impact of climate change on lemon productivity. Age had a positive significant relationship with agricultural adaptation to climate change (Santa, 2013).

The calculated value of (r=-0.627) was found smaller than both the tabulated value of 0.05 and 0.01 levels (Table 6). It was concluded that a negative significant relationship between education level and the impact of climate change on lemon productivity. Education had a positive significant relationship with "Perception of the positive effect of climate change" as well as higher education may be ensured a higher perception of a positive effect of climate change (Santa, 2013).

Table 6. Correlation Co-efficient between Selected Characteristics of Respondents and their Impact of Climate Change on Lemon Production

Dependent variable	Independent variable	Correlation coefficient (r) values with 98 d.f	Tabulated value of 'r'	
			0.05 level	0.01 level
Impact of Climate Change on Lemon Productivity	Age	0.516**	0.197	0.257
	Level of education	-0.627**		
	Occupation	0.408**		
	Family size	0.570**		
	Annual Family Income	0.567**		
	Farm size	0.440**		
	Communication Media Exposure	-0.450**		

Note: ** = Correlation is significant at 0.01 level of probability
* = Correlation is significant at 0.05 level of probability

The calculated value of (r=0.408) was found greater than both the tabulated value of 0.05 and 0.01 levels (Table 6). It was concluded that there was a positive significant relationship between the occupation of the lemon growers and the impact of climate change on lemon productivity. Occupation of the household head, gender of household age, and family type had a negative relation to an adaptation of climate change strategies (Dahal *et al*., 2019).

The computed Correlation coefficient value of (r=0.570) was found greater than both the tabulated value of 0.05 and 0.01 levels and was statistically positively significant (Table 6). It was concluded that family size had a positive significant relationship

between family size and the impact of climate change on lemon productivity. When the family size was large, most of the family members did not find the minimum facilities to lead a life. Most of the members had less education and communication facilities. The study of Shafqat *et al*., (2021) supported this study for the farm size and lemon production.

The calculated value of (r = 0.440) was found greater than both the tabulated value of 0.05 and 0.01 levels (Table 6). Growers having large farm sizes are expected to have higher productivity of lemon. It was concluded that there was a positive significant relationship between the farm size of the lemon growers and the impact of climate change on lemon productivity. The farm size had a positive significant relationship with the agricultural adaptation to climate change (Santa, 2013).

Indicate that the computed Correlation coefficient value of (r = 0.567) was found greater than both the tabulated value 0.05 and 0.01 level was statistically positively significant (Table 6). It was concluded that annual family income could vary positively with the variation of climate change impact. The annual family income had a positive significant relationship with the agricultural adaptation to climate change Santa (2013).

The calculated value of (r = -0.450) was found smaller than both the tabulated value of 0.05 and 0.01 levels (Table 6). It was concluded that a negative significant relationship between communication media exposure and the impact of climate change on lemon productivity. A study was conducted on the participation of rural women in income-generating activities on the agricultural farm and found that communication media exposure had no significant relationship with the extent of participation in activities (Haque, 2008).

Conclusion

Lemon (*Citrus limon*) needs average temperature and adequate rainfall for maximum productivity. However, excess precipitation and cloudy sky were the main climatic factors affecting the lemon quality and spreading pests respectively. It is found from the study that the climatic parameters have changed within the study period. The temperature is found to increase in the summer season, whereas decreasing in the winter season. On the other hand, the trend of annual rainfall and the number of storm occurrences has increased in the last 5 years. Growers of the study area are more or less concerned about the impact of climate change on lemon productivity in Sreemangal Upazila. For the last few years, lemon has been growing vastly as a consequence of adopting strategies to cope up with climate change. However, most of the growers rely mostly on applying chemical fertilizers for high productivity and ignore environmental sustainability. Cooperation and coordination of DAE and NGOs are required for the success of good agricultural practice (GAP) in lemon production. A balance is to be maintained among the quality and supply of planting materials, maintaining the sustainability of the environment and natural resources to cope up with climate change.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this manuscript.

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