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Effect of Rainfall Pattern on the Tea Production in Bangladesh: An Analysis of Socio-economic Perspectives

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Abstract: In Bangladesh, tea is a cash crop that significantly benefits both our economy and food security. Hence, the study aimed to assess the present pattern of tea production and the impacts of rainfall patterns on tea yield and made tea quality. The empirical data was collected from ten tea gardens covering three tea-producing administrative divisions and six districts of Bangladesh. The cost of production and profit-loss were examined to link with rainfall distribution. Likewise, the daily income of permanent workers, the job market of the contractual workers, and the workers' associated welfare were critically analyzed to understand the social impact. The results showed that the *Rangpur* division faces incremental dryness; in contrast, the *Sylhet* division exhibited a steady pattern with a high frequency of continuous heavy rainfall. The rainfall pattern of the *Chottogram* division was highly unpredictable and oscillated. Long spell drought and heavy showers followed by flash floods affect tea yield. According to respondents' perception, the rainfall pattern showed changing behaviours that are not favourable for tea production. The emergence of new pests and deterioration of soil characteristics were reported. Bangladesh enjoyed the most pleasant weather for tea production in 2019. The cost of production increases with the adverse weather, which increases the loss for the growers. Profit loss of growers is a determinant of the welfare of the workers impacting their livelihoods. The organic tea garden is not affected by climatic events. Consequently, the socio-economic conditions of the organic garden are safeguarded. Hence, the study recommends following organic farming to cope with climate change. Differently, it was reported that the intermediaries' hegemony in the market chain is more problematic than climate change. Policy initiatives are warranted to correct the market and to establish gardeners' and consumers' rights.

Keywords: Rainfall; Cost of production; Pest emergence; Daily income; Job market.

INTRODUCTION

Tea, a rainfed plant, grows across a wide range of climates and soils. The tea ecosystem comprises the tea plant, shade trees, the associated crops, and abiotic elements. Tea is a cash crop in Bangladesh, contributing a significant role to our economy and food security. Bangladesh obtained the 8th position in the production area, the 10th position in production, and the 12th position in exporting (ITC, 2020). In 2020, 167 tea estates in Bangladesh produced 86.39 million kg of made tea, out of which 2.17 million kg were exported (BTB, 2021). Tea production largely depends on micro-climatic conditions, notably rainfall. Bangladesh is facing extreme weather and climate events for the last decades. The country encounters extreme weather events like circadian drought, prolonged precipitation, and late winter (Basher *et al*., 2018; Mojid *et al.*, 2015). Bangladesh is one of the worst hits by climate change due to its geographical location (Mishra *et al.*, 2019). Tea is considered one of the most vulnerable crops to climate change (Ochieng *et al*., 2016). Tea leaf production is highly sensitive to both biotic and abiotic stressors (Cheruiyot *et al.* 2010). The drought drastically affects its production (Niinemets, 2015). In recent times, the rainfall distribution in tea-producing areas shows a remarkable variation (Dutta, 2014). The monsoonal rainfall affects the yield and the product's quality (Wijeratne *et al.*, 2007). The various study showed that drought alters the metabolites' concentration (Ahmed et al., 2014; Cai *et al.*, 2013; Eric *et al.*, 2019; Kfoury *et al.*, 2018; Han *et al.*

2017). Few studies measured the rainfall's impact on the tea yield of a single or few tea gardens in *the Sylhet* district (Islam *et al.*, 2021; Rahman *et al.*, 2017; Ali *et al.*, 2014). A study including all tea-producing areas will help better understand the change in rainfall distribution area-wise and the effect on tea yield and the quality of the products.

Chang and Brattlof (2015) reported that climate change has socio-economic impacts on tea production in India. Additional expenses to cope with the challenges cannot be balanced by increasing tea prices. In the market economy, the consumers buy the products by judging the price. Roy (2013) revealed that rainfall has a relationship with rural socio-economic conditions. Rain affects the total agricultural and industrial development of a country. The monsoonal rainfall influences local agricultural productivity and employment generations. In turn, the amount of rainfall determines the availability of water to meet various demands for agriculture, industry, hydroelectricity, and other human activities. Due to the declining rainfall volume in Bangladesh, agricultural crop production has decreased (Roy, 2013). With the decline in rainfall, *Sylhet* districts showed lower agricultural production. Hence, an evaluation of tea's yield and rainfall trend will help predict rainfall variability, changes in the seasonal pattern, and effect on this cash crop's production.

Some tea gardens encounter various problems like erosion of topsoil due to uncharacteristic heavy rainfall patterns, which harms production, increased use of fertilizers to maintain soil fertility, and increased pesticide usage, particularly during the dry season (Chang and Brattlof, 2015). Notably, there are several uncertainties due to climate change impacts that are not yet fully understood but could potentially affect future production levels, employment, and welfare of the growers and workers. These include the frequency of natural disasters, the proliferation of certain pests and diseases, and higher infrastructure costs. Quio *et al.* (2018) reported that tea cultivation is not only for cash earning but also plays a multidimensional benefit for both farmers and industrialists. Differently, organic agriculture has the potential to provide improved livelihood opportunities, increased income, and social benefits for resource-poor small-scale farmers. A comparative analysis between conventional tea cultivation and organic farming can help understand the importance of organic farming to adapt to climate change by ensuring growers' and workers' interests.

Therefore, there is a need to develop an integrated adaptive measure to cope with the changing climate by linking climatic impact with social impact. The fundamental unity of the knowledge ranging from pure science to social science is indispensable for adopting a better policy. Therefore, the study attempts to assess the present pattern of tea production and the impacts of rainfall variations on tea yield and associated socio-economic problems. Finally, the study came up with solutions to cope with climate change.

Conceptual and Theoretical Frameworks

Socio-economic activity persuades climate change; contrarily, climatic variation affects socio-economic activity. Both have a substantial interaction. Climate change impacts the gross domestic product and labour productivity (Matsumoto, 2019). Changing climatic elements causes the reduction of natural resources like water, which affects the people's socio-economic livelihood and health. Agriculture suffers from low productivity and yield, and the prevalence of diseases, which results in increased poverty (Adjei-Mensah and Kusimi, 2020). The impact assessment of climate should consider two interrelated processes: socio-economic impact and climate change. The change in socio-economic activities has not been sufficiently incorporated into impact assessment (Berkhout *et al.* 2002). Hence, the study integrated the difference in socio-economic conditions systems to assess the impact of climate change.

Over 80% of the whole population of Bangladesh lives in the rural sectors. As the deltaic floodplain, Bangladesh is highly sensitive to climatic variation. The predominant agricultural economy is interconnected with the monsoonal characteristics, notably the pattern of wet and dry seasons (Ericksen *et al.*, 1996). The changes in climatic variables have severe implications for the local economy and community welfare. Changes in tea yields and quality of made tea may negatively impact the economy and gardeners' and workers' livelihoods (Ahmed *et al.*, 2018). The study explored this theme. The ecology also depends on many anthropogenic and non-anthropogenic perturbations, which impact together (Begum *et al.*, 2022). The study stressed only rainfall distribution as it determines tea production primarily (Wijeratne 1996). Ironically, the tea gardeners do not keep data on maximum temperature, minimum temperature, mean temperature, humidity, day length, light intensity, dew points, soil temperature, soil chemistry and physics, slope, organic matter contents, etc. The study aimed to assess the rainfall's impact on yield and other socio-economic impacts (Figure 1). The main relationships among rainfall, tea yield, and workers' welfare were embraced as climate change's socio-economic impact. This theme was explored through four main questions: What is the trend of tea yield in Bangladesh? How does the rainfall pattern affect the yield and quality of the product? How are the gardeners affected in terms of cost-benefit analysis? What are the consequences for the workers? And what should be the remedies?

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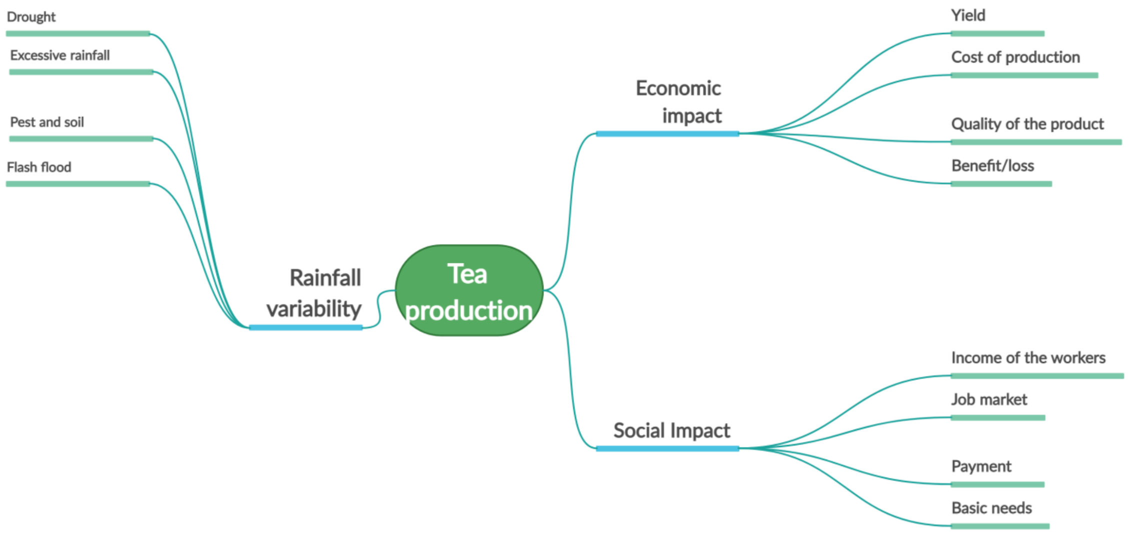

Figure 1. Conceptual framework of the study.

MATERIALS AND METHODS

The study collected both primary and secondary data for the period from November 2020 to March 2021. The existing literature related to the socio-economic impact of climate change was studied to understand the broader picture of the collected data and develop a theoretical framework for this paper. A stepwise systematical research approach was used for a better outcome (Figure 2).

Figure 2. Methodological framework.

Assessing the trend of rainfall and tea yield

Ten tea gardens were taken from three tea-producing administrative divisions: *Sylhe*t, *Chattogram*, and *Rangpur*, which covered 06 administrative districts, namely *Sylhet*, *Moulovibazar*, *Hobiganj*, *Panchagarh*, *Chottogram*, and *Rangamati* (Table 1).

The recorded data on monthly rainfall and tea yield from 2010 to 2020 were collected from each garden. In addition, secondary data on the national yearly tea production of the same duration were collected from Bangladesh Tea Board. For a broader understanding, tea production time in India, Sri Lanka, and China was used from the source of statistica dot com.

Table 1. Locations of the tea gardens.

Name of the garden	Administrative district	Administrative division
Satgaon	Moulvibazar	Sylhet
Ichamoti		
Lackatoorah		
Afifa Nagar	Sylhet	
Lallakhal		
Surma	Habiganj	
Telipara		
Kornafuli	Chottogram	Chottogram
Kodala		
Waggachara	Rangamati	
Kazi and Kazi	Panchagarh	Rangpur

Relating annual rainfall and yield

The annual rainfall was defined as the independent variable and tea yield as the dependent. Pearson correlation coefficient (PCC) determined the nature of the relationship. Eleven years' data (2010-2020) of 10 gardens were used in this calculation. In addition, a simple descriptive analysis was followed to correlate yield with rainfall patterns.

Other economic impact assessment

A comparative assessment of the cost of production and profit/loss per hectare area between the years 2019 and 2020 was done based on the tea gardens' data. A focus group discussion was held in each garden to understand the changing behaviour of rainfall patterns and associated problems like the emergence of new pests and their effects on the products' quality. A total number of 10 FGDs were done.

Social impact assessment

A total number of 30 workers were selected purposively from each garden. Among them, 15 were permanent workers, and the rest was temporary or contractual worker. They were interviewed with a semi-structured questionnaire

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focusing on daily income, monthly employment of the temporary workers, payment regularities, housing facilities, and sanitation status. Based on the collected data, a comparative assessment between the years 2019 and 2020 was accomplished.

Assessing extra-climatic problems

The study analyzed the key actors of tea markets and assessed the profit/loss of the intermediaries based on the data collected from FGDs. In addition, a consultation workshop was held in Chittagong, where the tea growers and representatives from the warehouse, brokers, and buyers were present. Telephonic interviews were done with the senior management of the Bangladesh Tea Board.

RESULTS AND DISCUSSIONS

Yield (made tea) trend from 2010 to 2020

It was found that the average yield in the study area ranged from 1015 kg/ha to 1466 kg/ha. The highest yield was counted in 2019, followed by 2016 and 2020 (Figure 3). Contrastingly the lowest yield was observed in 2011. The annual production per hectare area remained almost symmetrical in 2010-12, 2014-15, 2017-18, and 2020. The trend continues on an upper path.

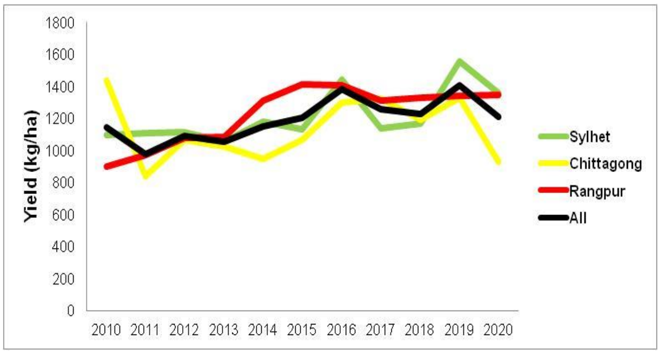

Figure 3. The trend of annual rainfall and tea yield in the study area.

Among the tea-producing administrative divisions, *Chottogram* exhibited a highly choppy trend of yield. The highest yield was enumerated in 2010, and the lowest in 2020. Despite oscillation, *Sylhet* division gradually increased its yield. *Rangpur* division maintained a gentle uptrend, which maximized its yield during 2014-2017.

The tea yield trend per hectare in the whole study area is mirrored by the national production trend (Figure). The highest annual national production (96.07 million kg) was recorded in 2019, followed by 2020. The lowest national production (59.13 million kg) was found in 2011. In the rest years, the annual national output ranged from 60.04-85.05 million kilograms.

Bangladesh showed an increasing production trend from 2016, and in 2020 the production increased by1.40 times compared to 2010 (Figure 4). The country could not maintain the consistency of 2019's record in 2020. Among other major tea-producing countries in Asia, China doubled its production from 2010 to 2020. India showed a consistent and gradual increase from 2010 to 2020. Tea production in India was 1.5 times in 2020, considering 2010 as a baseline. Sri Lanka exhibited almost a flat trend in annual production.

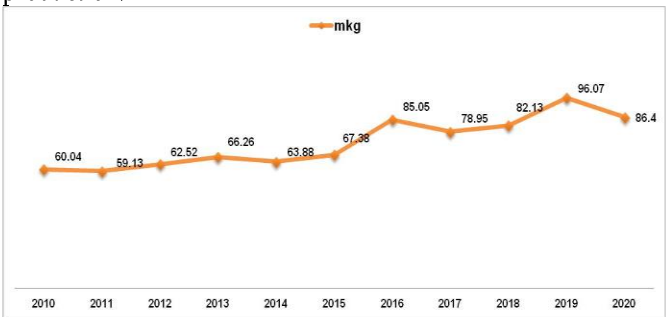

Figure 4. National production trend yearly.

Impact of rainfall on tea yield

Rainfall trend from 2010 to 2020

By taking the monthly average rainfall in the study area from 2010-2020, the highest rainfall was recorded in June, followed by July, August, May, and September. The average rain varied considerably from year to year. The highest rainfall was enumerated in July 2019 and 2020 (Figure 5). The year 2014 faced 03 months-long drought conditions.

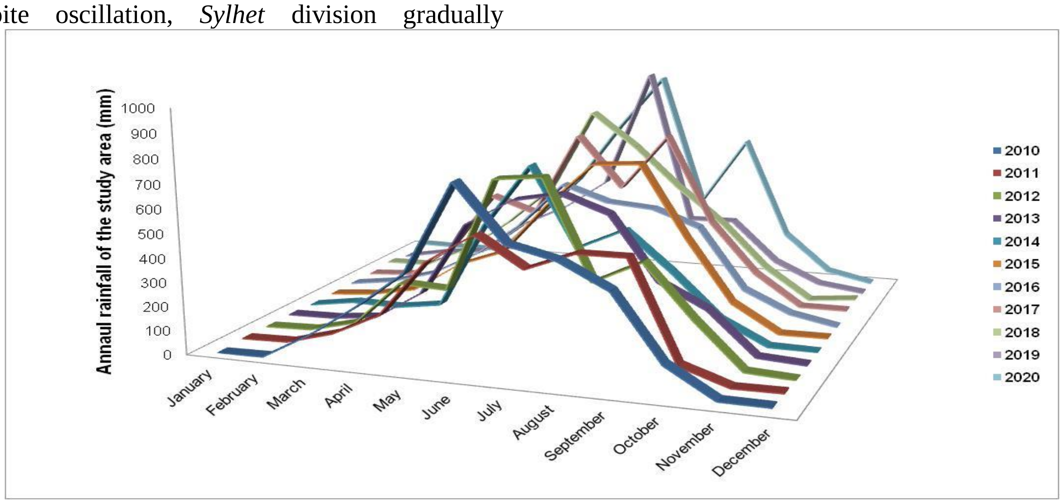

Figure 5. Monthly rainfall pattern during 2010-2020.

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Table 2. Monthly rainfall pattern and yield during 2010-2020 in *Sylhet* division.

Year	**Rainfall (mm)**													**Yield ha/kg**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Σ	
2010		4	269	648	569	751	499	499	574	165		31	4010	1094
2011	14	11	131	227	544	522	545	414	333	130	13	18	2902	1109
2012	11	13	141	311	358	772	496	460	235	116	15	2	2930	1114
2013	3	16	92	342			480	465	275	240	44	8	3282	1055
2014		21	52	141	646	458	385	463	480	174			2819	1177
2015	5	32	42	239	498	503	429	623	551	58	10	2	2994	1135
2016	13	45	116	524	566	582	463	512	423	118	36	1	3397	1444
2017	10	56	288	747	475	713	490	570	416	226	56	54	4101	1136
2018	9	61	282	430	641	883	612	709	461	214	8	66	4375	1168
2019	4	40	100	243	528	790	829	441	341	181	22	11	3531	1556
2020	11	24	49	281	615	994		419	530	288	16		4288	1356

The Sylhet division showed a symmetrical average monthly rainfall pattern. In July 2020, this division enjoyed heavy pouring (1059 mm), the monthly highest record from 2010 to 2020 considering the entire study area. One week-long continuous overweighted downpour caused flooding in the tea gardens. Likewise, 2014 faced 03 months-long droughts. A total number of 06 months was counted from 2010-2020 in this division (Table 2). Except that drought is not a problem there.

The Chottogram division showed a little bit asymmetrical average monthly rainfall pattern. The monthly as well as yearly rainfall average is highly fluctuating. The month of June received the highest average rainfall during July, August, and September during 2011-2020 (Table 3). The year 2013 faced an almost 05 months long consecutive drought. In 2014, the division yielded less because continuous heavy pouring in June caused a short-lived flash flood, and the month of July was comparatively drier. In 2010 and 2019, only January month was rainless. The year 2020 experienced two spells of short-lived drought: February-March and December. The rest years encountered more than 01 month-long dry season.

Table 3. Monthly rainfall pattern and yield during 2010-2020 in the *Chottogram* division.

Year	**Rainfall (mm)**													**Yield ha/kg**
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Σ	
2010		7	70	39	273	658	311	344	156	192	24	15	2089	1437
2011		13	39	113	366	639	313	560	505	70			2619	
2012		14	31	282	136	771	644	309	303	385	20		2895	1068
2013			1	79	566	396	318	326	303	249			2238	1022
2014		34	16	14	352		252	469	284	130	10		2420	950
2015			21	239	132	702	1192	799	547	303	1	16	3954	1066
2016		49	98	18	322	321	554	433	212	129	82		2218	1298
2017			83	436	337	1161	887	641	596	183	10	14	4349	1321
2018	43	2	15	257	424	1053	715	334	197	188	3		3231	1194
2019		54	34	98	239	331	1251	340	329	126	69	3	2874	1328
2020	54	2		179	298	310	474	381	390	323	119		2530	930

Rangpur division showed a decreasing trend of annual rainfall except in 2010 and 2020. A prolonged drought in the dry season is apparent. The month of May received about half of September, which indicates a long spell of drought. Contradictorily, only 2011 enjoyed the year-round shower. The year 2010 and 2016 experienced 04 months long consecutive drought. The division faced 29 months long rainless period during 2010-2020 (Table 4).

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Table 4. Monthly rainfall pattern and yield during 2010-2020 in the *Rangpur* division.

Year	Rainfall (mm)													Yield ha/kg
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Σ	
2010				57	360	903	824	653	469	49	28			
2011	6	11	27	143	290	413	351	470	612	23	9	10	2365	973
2012	4	6	6	147	218	582	1044	192	717	106			3023	1081
2013	18	17	3	39	241	644	1070	867	295	89			3282	1085
2014	4	39	12	11	282	766	425	406	87				2032	1314
2015	4	26	112	84	152	252	406	650	66					
2016			48	31	132	713	406	432	533	142			2438	1405
2017			114	84	265	298	130	1019	105	58			2080	1310
2018			50	94	230	464	638	393	324	3		7	2204	1329
2019		18	37	279	147	206	793	95	219	51			1845	1343
2020		30	15	157	293	722	1218	220	994	8		9		1347

Relationship between rainfall and yield

The study revealed that the annual rainfall volume could not influence tea yield. There was a slight negative relationship between average rainfall and yield (Figure 6). In another study, Rahman *et al.* (2017) found a similar remote negative relationship in *the Malnichara* tea estate of the *Sylhet* division during 2012-2017. The expected average annual rainfall for the excellent tea leaf production in Bangladesh was 4000-4600 mm (Ali *et al.,* 2014). Ochieng *et al.* (2016) revealed that a consistent rainfall pattern is the determinant of high productivity, and any significant deviation affects production. Wijeratne *et al.* (2007) reported that very high rainfall reduces sunlight's availability, which turns down photosynthesis. Similarly, excessive rain causes waterlogging conditions, which affects soil saturation and the plant's absorption capacity.

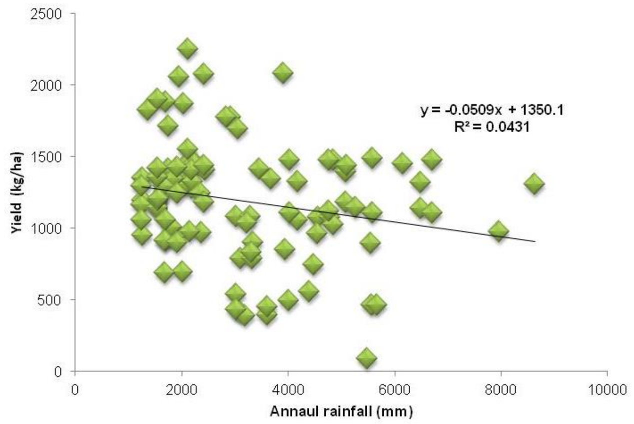

Figure 6. Relationship between average annual yield and annual rainfall of 10 tea gardens.

The study area's average rainfall was the lowest in 2011, though the least amount of rain was recorded in 2014. Despite year-round rain in 2011, *the Sylhet* division produced lower but not the least. The division exhibited high resilience in 2014 though it experienced three months-long droughts and the lowest annual rainfall. The respondents from this division argued that they introduced a sprinkler irrigation system in that year to cope with the drought from the very beginning. Resultantly, the national production and the yield of the study area were not the worst hit. In 2010, the division enjoyed year-round rainfall, and it could not predict 03 months of prolonged drought in advance. Due to a lack of preparedness, not only the study area but also the country produced the least.

Similarly, despite enjoying the highest rainfall in 2017, the maximum production per unit area was in 2019. The *Sylhet* division gained very balance and even rain distribution this year. Consequently, the national production was the highest in that year though national production represents yield and cropped areas. The *Chottogram* division, the second-largest tea-producing division, responded similarly as this division faced minimal dryness in that year.

Sylhet and *Chottogram* division could not maintain their productivity of 2019 in 2020. *Sylhet* division faced dry December and flooded July. The *Chottogram* division's yield sharply fell in 2020 due to unusual dryness in February and March. Despite the incremental dry season, the yield is not affected in the *Rangpur* division as the rainfall distribution does not fluctuate regularly. Only one tea garden, *Kazi and Kazi*, was taken as a sample from that division, which is the only organic tea garden. The respondents opined that *Kazi* and *Kazi* Tea Estate have high resilience capacity, and this tea garden has taken high adaptive measures knowing the distinct micro-climatic pattern. This garden established a modern sprinkler irrigation system. Simultaneously, it uses mulches to conserve soil water and protect the soil from further evaporation. Instead of chemical fertilizer, it adds organic matter to the soil, which has a high water holding capacity. They increased the density of the shade trees to protect against scorching. Neem (*Azadirachta indica*), *Basak* (Malabar Nut), *Bish kanthali* (Knotweed), and *Nishinda* (Chaste Tree) are used as shade trees that are strong repellent against insects and pests. The respondents argued that rainfall distribution could not affect the production of this tea estate.

It is evident that among the 03 tea-producing divisions, *Sylhet* faces occasional flash floods and *Rangpur* encounters drought. In a hilly area, the water of the flash flood cannot stand for a long time. On the other hand, the tea gardens' soil texture in this division is sandy loam, which helps in draining out the water very quickly. Neither a flash flood nor a short-lived drought can hamper the production of this division significantly. On the flip side, *Kazi* and *Kazi* of *the Rangpur* division established tea gardens on the flat terrain comprised of sandy loam soil. This tea garden encounters flash floods on rare occasions. Consequently, the management schemes focus only on the predictable drought. Organic farming systems and strong adaptive measures safeguard the production trend in this division. Ironically *Chottogram* division suffers from unpredictable drought and flash flooding. As a result, the tea growers cannot make dense shade trees to combat drought. The high density of shade trees in case of flooding prolongs the water logging condition. The higher altitude than other divisions cannot help in draining out the water quickly as the soil texture ranges from clayey loam to loam. It can be argued that *Chottogram* is the only affected tea-producing division due to oscillated rainfall pattern.

Short-spelt rainfall is favourable for tea production, and in contrast, long-spelt rain reduces tea yield (Esham and Garforth, 2013; Duncan *et al.*, 2016). Consistent rainfall patterns can boost production (Ochieng et al., 2016). Likewise, the tea-producing areas should enjoy a wet and ora combination of the alternative wet and dry seasons. The rainfall pattern and its distribution determine tea's quality (Boehm 2016). Continuous cloud coverage followed by rainfall hinders bush growth and plucking during peak harvesting time (Boehm *et al.,* 2016). The studies showed that the micro-climatic variables became unpredictable, erratic, and extreme for tea production (Dutta, 2014; Marx et al. 2017). The rainfall determines not only the yield but also the quality of the made tea. Heavy rain dilutes the phytochemicals and changes tea's taste, deteriorating the quality (Han et al. 2017).

Respondents' perceptions about rainfall distribution and associated problems

The respondents of the focus group discussions identified several problems originating from rainfall patterns (Table 5). The tea gardeners from all divisions admitted that they do not receive rainfall in their usual ways. The rain is uneven and does not help the growers. The over-shower in the monsoon cannot help but sometimes creates flood and waterlogging conditions. A minuscule pouring in the dry season, notably from November to February, can boost production. Nighttime rainfall is highly desirable as it does not hamper photosynthesis and plucking. They opined that precipitation occurs in the daytime mainly. It is reported that the soil of the *Chottogram* divisions shows unpredictable behaviours like rainfall and yield. All tea gardeners from the division said that the soil is deteriorating sharply.

Table 5. The rank of the identified problems in FGDs (Ascending order).

Sylhet	***Chottogram***	***Rangpur***
• Uneven distribution of rainfall in the monsoon • Circadian heavy continuous pouring in the rainy season causes flash floods frequently. • Scarcity of irrigation water due to lowering of the water table • Daytime precipitation is more than nighttime	• Very unpredictable and sporadic rainfall throughout the year • Water scarcity in the dry season and occasional flash floods in the monsoon • Due to erratic rainfall, the soil cannot maintain its usual characteristics • Soil is becoming more acidic	• Predictable prolonged drought • Rare flash flooding • Unnecessary rain in the rainy season • Daytime precipitation is more than nighttime

Economic impacts of rainfall variability

The emergence of pests and their effect on made tea's quality

The *Chottogram* division respondents reported that tea mosquito bugs (*Helopeltis Theivora*) and red spider mite (*Tetranychus urticae*) were minor pest historically. Still, in recent times they have become significant devastating pests (Table 6). Consequently, they have to go for the frequent foliar spray, which increases production cost and decreases the made tea 'quality. A regular foliar spray may be harmful to consumers in terms of health hazards. Al-Mamun *et al.* (2016) revealed that the made tea's physiological and biochemical contents are significantly reduced with the increase of infestation of red spider mites. It was recorded that the nymphs and adults of the tea mosquito bugs suck the sap from the tender leaf, bud, and new shoots, which causes low yield. Roy et al. (2015) reported that the insect's salivation and oviposition damage the plant's tissues, resulting in crop loss. Like *the Chittogram* division, these two insects are the primary pests in the *Rangpur* division. The *Kazi & Kazi* tea gardens planted shade trees that have repellent characteristics. Consequently, this organic tea garden has developed resilience and adaptive capacity to respond to the pests' attacks. Climate change decreases the quality and quantity of tea yield by increasing soil erosion, pests' infestations, and outbreaks of diseases (Wijeratne 1996).

Table 6. Emerging pests in different areas.

Sylhet	Looper Caterpillar, Thrips, Jassid, Crown gall disease
Chottogram & Rangpur	Tea mosquito bug, red spider mite

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Increased/decreased production cost in 2020 associated with rainfall

Afifa Nagar and *Lallakhal* tea estate under *Sylhet* district spent more money in 2020 on purchasing fungicide than in 2019 (Table 7). Record rainfall in July 2020 caused root rot disease in seedlings and younger plants. *Lachatoorah* tea garden of the same district encountered short-lived drought and moderate insect attacks. *Satgaon* and *Ichamoti* tea estate of *Moulvibazar* district suffered from the scarcity of irrigation water in 2020 due to lowered water table. The gardeners paid more incurred in irrigation. *The Surma* tea garden of *Hobiganj* district faced slightly higher acidity in 2020 due to a short spell of drought in January 2020. *Kodela* and *Karnafuli* of the *Chottogram* division had to face both drought and short-lived drought. In addition, *Kodela* experienced a massive attack of tea mosquito bugs and red mites. More expenditure on the *Wagachhara* tea estate of *the Rangamati* district was associated with increasing soil pH and weed control. *Kazi & Kazi* spent huge money to go for organic farming in the initial stage. It did not pay any additional money in 2020.

Table 7. The extra cost involved to cope with rainfall variation.

Tea gardens	*Weedicide*	*Insecticide*	*Fungicide*	*Irrigation*	*Dolomite*	*Total*
Afifa Nagar	0	0	1200	0	0	1200
Lallakhal	0	0	1400	0	0	1400
Lachatoorah	0	800	0	2200	0	3000
Surma	0	0	0	0	800	800
Satgaon	0	0	0	4000	1200	5200
Ichamoti	0	0	0	3600	800	4400
Karnafuli	0	0	1300	2600	0	3900
Kodela	0	1200	1300	3600	0	6100
Wagachhara	500	0	0	0	600	1100
Kazi & Kazi	0	0	0	0	0	0
Mean	50	200	520	1600	340	2710

Profit/loss analysis

The profit/loss was calculated for the year 2020 based on data provided during focus group discussions (Table 8). In 2020, the gardeners pegged massive revenue loss due to mainly pandemic corona 19. Also, the pandemic corona 19 played a crucial role in surging the cost of production and decreasing the market price due to lower consumption. The loss was exaggerated by rainfall-related factors (Table 7). According to respondents' perceptions, the production cost depends on the overhead expenditure, type of ownership, branding, quality of the products, nature of employees, bargaining capacity with the brokers and buyers, and management. Out of the ten tea gardens, *Satgaon, Ichamoti*, and *Kodela* tea gardens experience continued loss. *Satgaon* and *Ichamoti* continuously encounter the lower water table. On the other hand, the *Kodela* tea garden simultaneously faces uneven rainfall and the emergence of devastating pests. *Surma* and *Kazi & Kazi* are running without any losses. *Waggachara* tea estate can minimize the loss as their permanent employees are the minimum. This family-run tea garden does not employ any managerial-level staff. Consequently, its overhead cost is nearly zero. The gardeners surmised that rainfall affects the quality and production cost. In the continuous heavy rain, the permanent workers cannot work, but they are paid. The moisture contents of the leaf increase, and consequently, the drying cost increases. Contrastingly, in case of prolonged drought, the leaf becomes scorched.

Table 8. Profit/loss of the gardeners for the year 2020.

	Production cost (BDT)/kg	Sell (BDT)/kg	Profit (+)/ Loss (-) /kg
Satgaon	200	195	-5
Ichamoti	200	177	-23
Lackatoorah	165	142	-23
Afifa Nagar	200	185	-15
Lallakhal	208	184	-24
Surma	165	192	+27
Telipara	180	165	-15
Kornafuli	220	220	0
Kodala	230	210	-20
Kazi and Kazi	240	240	0
Waggachara	204	185	-19
Average	201.1	190.5	-10.6

Social impact

Reduced income

The workers are categorized as temporary (contractual) and permanent. They are mainly responsible for seedling plantation, leaf plucking, foliar spraying, withering, weeding, cleaning, transporting, cleaning, spraying pesticide, and other intercultural operations. A worker's task is defined by the plucking of 18-24 kg of leaves per day at the cost of 120 Bangladesh Taka. A portion of this wage is deducted to add provident and religious funds and the union membership fee. Besides, the workers enjoy five kilograms of rice or flour as a ration meal per week, free housing, and medical care from the owners. To avail of these facilities, a worker must work 05 days a week. A worker gets 4.5 takas for plucking one kg of the leaf as overtime work out of a task. It is revealed that a worker earned 120-450 taka per day, counting overtime work. The

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average daily income was 240 takas/worker/day in 2019, which decreased to 224 takas in 2020 (Table 9). The workers reported that they could not pluck leaves beyond their tasks in extreme weather and henceforth low yield.

Table 9. The average daily wage of a permanent worker in 2019 and 2020.

Year	Range		Average
	Min	Max	
2019	120	450	240
2020	120	430	224

Job loss

The study found that 77% were permanent the rest was temporary or contractual (Figure 7). Hossain et al. (2017) reported that 70.6% of workforces were employed permanently, while 29.4% were used contractually. The respondents opined the employment of temporary workers depends on yield, cost of production, and profit.

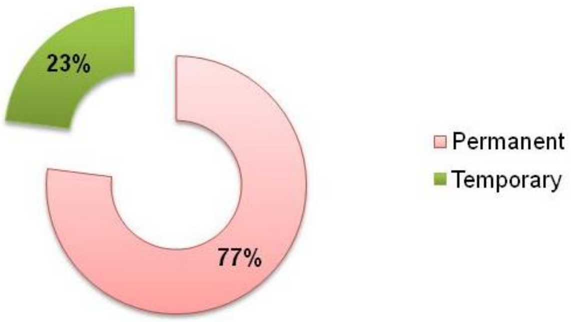

Figure 7. Permanent and temporary worker’s ratio.

Usually, the temporary or contractual workers are employed during the peak plucking season (May-October). In 2019, the temporary worker's average working months was 4.42, which fell off to 3.17 in 2020 (Figure 8). The employment generation and daily income depend on climatic variables like rainfall. The gardeners try to minimize the cost of production in low yield due to climatic variables by contracting the contractual workers' job market. Similarly, the overtime work of the permanent workers is hampered. *Kazi & Kazi* is exceptional as this company runs organic dairy farming along with tea production. Huge cow dung is required for organic fertilizer and for producing biogas. This company has brand organic milk products. The garden owners provide loans to the workers for purchasing dairy cattle, and the workers pay back the loan by selling milk and cow dung at market price. Consequently, their income does not depend on tea leaf plucking only. The workers of this tea estate have enriched their livelihoods.

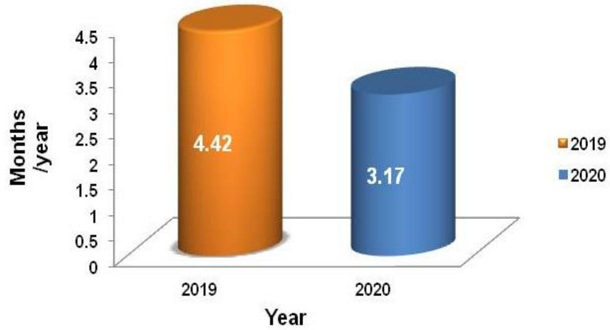

Figure 8. Months of employment of the temporary workers in 2019 and 2020.

Irregularity in wage payment

Irregularity in wage payments was reported in low yield and increased cost of production due to climatic variability. Sometimes, it is tough to pay the workers on the weekend regularly. 79.6% opined that the garden owners could not pay them every weekend due to a shortage of money flow among the permanent workers. By considering the living expenses, periodic payment causes extra challenges in maintaining a decent livelihood. The workers of *Kazi & Kazi* do not encounter such problems.

Inconvenient paying back of provident fund

The permanent workers deposit 7.5% of basic pay as the provident fund starting at 18 years old and ending at 60 years of age. At the time of retirement, they receive double the deposited money plus the bank's interest rate. The respondents except *Kazi & Kazi* opined that the gardeners could not repay the provident fund timely in production loss.

Extra-climatic problems

Profit-making by the intermediaries

The tea gardeners argued that with lower domestic consumption due to corona and lower sell price, the retailer price was steady. The producers were highly affected, and the consumers did not pay less money in purchasing packed tea. The intermediaries, notably buyers, secured the highest return (Table 10). In addition, they have to pay transportation costs to carry the made tea to the warehouses. They have to pay 01% commission to the brokers and 01% of the selling price as *cess* to the government. The brokers also get a 01% commission from the buyers. In total, they earn 02% of the producer's sell price without any investment. The buyers have to pay 15% of the producer's sell price. By purchasing made tea from different gardens, they grade and blend mixed tea. Finally, the tea is dressed with the new packet in the name of the buyers. The buyers' expenditures are also associated with advertisement, marketing, and transportation. The wholesaler buys from the buyers and stores in their godowns. The retailers' prices highly fluctuate as it depends on consumers' bargaining capacity. The respondents argued that the buyers exploited three cases: high production, heavy rainfall, and lower consumption. In the chance of

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high rain, they reduce the producers' price in the name of high moisture content. In anticipation of increased production and lower consumption, they sharply contract the price mentioning the demand and supply relationship. It was also reported that few buyers are highly united and syndicated, and they determine the fate of the producers (Alam *et al.* 2021; Rahman 2021 a, b, c, d; Rahman 2022 a, b).

Table 10. Profit/loss of the market players.

	Items	Mean (BDT)
Producer	*Expenditure (production cost, transportation, warehouse charge. Broker's cost, and cess)*	196.9
	Sell	186.7
	Loss	***10.2***
Broker	Expenditure	0
	Profit	***3.74***
Warehouse	Expenditure (maintenance)	0.94
	Profit	***2.8***
Buyer	Buy	186.7
	Expenditure (VAT, Broker's commission, grading, blending, processing, packaging, transportation)	70
	Sell	300
	Profit	***43.3***
Wholesaler	Buy	300
	Expenditure (Transportation, storage)	12
	Sell	325
	Profit	***13***
Retailer	Buy	325
	Transportation	7
	Sell	350
	Profit	***18***
Consumer	Buy	350

Other regulatory problems

Bangladesh Tea Board (BTB) is an autonomous body responsible for drafting laws, rules, and public policies regarding tea production and the management of the tea sector (Figure 9). The gardeners believe that BTB always upholds the buyers' interests and rarely cares about the producers' welfare. The buyers have benefitted from the existing regulatory framework. Other farmers buy agricultural inputs like fertilizers, pesticides, and machinery at a subsidized rate, except the tea growers. On the other hand, the rest agricultural sectors pay electricity charges for irrigation purposes at a household rate, but the tea growers are charged a high commercial rate. The government helps the farmers in various ways and provides various incentives to boost agricultural production. Contrarily, the government imposes a 1% *cess* and 15% VAT on tea products despite being an agricultural crop.

Figure 9. Regulatory problems.

Recommendations

Following *Kazi & Kazi* model: *Kazi & Kazi*, the only organic tea garden in Bangladesh, has developed a highly resilient farming system against any adverse effect of climatic variables like drought. As it produces premium quality organic tea, it makes a profit under any circumstances. It has developed associated organic dairy entrepreneurship, which boosted the workers' socio-economic conditions and the company. The other tea estates can follow organic farming to avoid gradual tea production loss and improve the workers' living standards. On the other hand, this is essential for ensuring pure, safe, and health hazard beverages. A*lbizia odoratissima*, *A. Chinensis*, and *A. lebbek* are commonly used in other tea gardens among the shade trees. These shade trees should be gradually replaced by Neem (*Azadirachta indica*), *Basak* (Malabar Nut), *Bish kanthali* (Knotweed), and *Nishinda* (Chaste Tree) to combat emerging pests.

Considering tea as an agricultural crop: Like other crops, tea growers should enjoy government subsidies in purchasing agricultural inputs, including fertilizers, pesticides, electricity, and different types of machinery. Government should exclude this sector from paying *cess* money and VAT. This stimulus will help the growers to restore their confidence level and to minimize the losses.

Clearing intermediaries from the market chain: According to the growers' perception, the intermediaries' incremental hegemony in the market chain is causing more problems than climate change. Neither the head (the growers) nor the tail (the consumers) benefitted from the existing market systems. Most of the farmers face loss in most of the years, but the intermediaries, notably the buyers, make huge profits. SDG target 2.b. stresses correcting the market chain and clearing all obstacles to ensure food security. Therefore, it is recommended that the government intervene to remove those intermediaries from the market chain or limit their profits to save both producers and consumers.

Crop insurance: Tea producers should be obliged to bring under the umbrella of risk insurance to transfer the production loss into monetary compensations.

Integrated adaptive measures: The drainage and irrigation systems should be modernized to protect the

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plants from waterlogging and drought, respectively. Establishing a sprinkler irrigation system may ensure efficient water resources use and minimize the adverse effect of drought. Applications of indigenous knowledge can be encouraged. Bangladesh Tea Research Institute should work intensively to develop drought-resistant varieties. Integrated nutrient management can combat nutrient deficiency and drought simultaneously. The pruning litter and shade tree droppings should be preserved and added to the soil to increase the soil's organic matter and water holding capacity.

Worker's floor protection: The workers should be considered part of society's mainstream and left-behind group. The government should incorporate them into all safety net programs administered by various public departments. Only the tea growers cannot ensure their wellness and meet basic needs. Besides, the government can encourage local, national, and international Non-Government Organizations to improve the workers' socioeconomic conditions.

CONCLUSION

The tea sector of Bangladesh has multidimensional importance in earning foreign currency, employment generations, food security, green coverage, sustainable land use, and biodiversity conservation. The land of most of the tea gardens is *Khas* (government-owned land) in nature. Each garden is a chunk of land which the government can use for many purposes. If the tea plantation is stopped, the land is grabbed overnight. On the other hand, Bangladesh's natural forest habitats have become lost, degraded, and fragmented, creating remnants. Consequently, the tea gardens are gradually being turned into a wildlife sanctuary. Therefore, this sector should be survived at least, for nature conservation. This study used a dataset of monthly rainfall, which is only available in the tea gardens. The data on various climatic variables should be recorded to understand to assess the impacts of multiple stressors. Future research should focus on the causal factors of emerging new pests and the remedies for avoiding chemical pesticides to ensure safe and pure beverages. Bangladesh may witness more extreme climate events in the future. Hence, the tea sector warrants policy initiatives to achieve SDGs. Tea should enjoy government stimulus like other crops. On the other hand, the policy should be producer and consumer-friendly. The obstacles should be cleared to protect the gardens from the adverse effect of climatic events and to ensure the welfare of the growers and workers.

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Conflict of Interest

The author declares is no conflict of interests or conflicting issues in this research paper. The author declares that a preprint version of this manuscript is available at Research Square (https://doi.org/10.21203/rs.3.rs-1172844/v1).

REFERENCES

Adjei-Mensah, K. and Kusimi, J.M. 2020. Dwindling water supply and its socio-economic impact in Sekyere Kumawu District in Ashanti Region of Ghana: public opinion on the role of climate change. GeoJournal, 85: 1355–1372. https://doi.org/10.1007/s10708-019-10026-0.

Ahmed, S. et al. 2018. Global Climate Change, Ecological Stress, and Tea Production. In: Han WY., Li X., Ahammed G. (eds.) Stress Physiology of Tea in the Face of Climate Change. Springer, Singapore. https://doi.org/10.1007/978-981-13-2140-5_1.

Alam, S., Rahman, M.M. and Arif, A.A. 2021. Challenges and opportunities in artisanal fisheries (Sonadia Island, Bangladesh): The role of legislative, policy and institutional frameworks. Ocean & Coastal Management, 201, 105424. https://doi.org/10.1016/j.ocecoaman.2020.105424.

Ali, M., Uddin, M.N., Mobin, M.N. and Saha,, N. 2014. Effects of Microclimatic Parameter on Tea Leaf Production in Different Tea Estates, Bangladesh. *Journal of Environmental Science and Natural Resources*, 7(1): 183-188.

Al-Mamun, M. S., Hoque, M. M., Mainuddin, A. and Yasin, M. 2016. Physiological and Biochemical Changes in Tea Leaves and Made Tea Due to Red Spider Mite Infestation. Asian Journal of Plant Sciences, 15: 16-25.

Basher, M., Stiller-Reeve, M.A., Saiful Islam, A.K.M. et al. 2018. Assessing climatic trends of extreme rainfall indices over northeast Bangladesh. Theor Appl Climatol, 134: 441–452. https://doi.org/10.1007/s00704-017-2285-4.

Begum, A., Uddin, M.K., Rahman, M.M., Shamsuzzaman, M.M. and Islam, M.M. 2022. Assessing policy, legal and institutional frameworks of marine megafauna conservation in Bangladesh. Marine Policy, Volume 143. https://doi.org/10.1016/j.marpol.2022.105187.

Berkhout, F, Hertin, J and Jordan, A. 2002. Socio-economic futures in climate change impact assessment: using scenarios as 'learning machines', Global Environmental Change, 12(2): 83-95.

Boehm, R., Cash, S.B., Anderson, B.T., Ahmed, S., Griffin, T.S., Robbat, A., Stepp, J.R., Han, W.Y., Hazel, M. and Orians, C.M. 2016. Association between empirically estimated monsoon dynamics and other weather factors and historical tea yields in China: Results from a yield response model, *Climate*, 4: 20.

BTB. 2021. *Monthly Bulletin of Statistics on tea. January 2021*. Bangladesh Tea Board, Nasirabad, Chittagong.

Cai, X.M., Sun, X.L.L., Dong, W.X.X., Wang, G.C.C. and Chen, Z.M.M. 2013. Herbivore species, infestation time, and herbivore density affect induced volatiles in tea plants. *Chemoecology*, 24: 1–14.

Chang, K. and Brattlof, M. 2015. Socio-economic implications of climate change for tea producing countries, Market and Policy Analyses of Raw Materials, Horticulture and Tropical (RAMHOT) Products Team, Food and Agriculture Organization of the United Nations (FAO).

Cheruiyot, E.K., Mumera, L.M., Ng'Etich, W.K., Hassanali, A. and Wachira, F. 2010. High fertilizer rates increase susceptibility of tea to water stress. *Journal of Plant Nutritio*, 33:115–129.

Duncan, J.M.A., Saikia, S.D., Gupta, N. and Biggs, E.M. 2016. Observing climate impacts on tea yield in Assam, India. *Applied Geography*, 77: 64–71.

Dutta, R. 2014. Climate change and its impact on tea in Northeast India. *Journal of Water and Climate Change*, 5 (4): 625-632.

Eric, R.S., Li, X., Kfoury, N., Morimoto, J., Han, W.Y., Ahmed, S., Sean, B.C., Griffin, T.S., Stepp, J.R., Robbat, and Orians, C.M. 2019. Interactive effects of drought severity and simulated herbivory on tea (Camellia sinensis) volatile and non-volatile metabolites. *Environmental and Experimental Botany*, 157: 283-292.

Ericksen, N.J., Ahmad, Q.K. and Chowdhury, A.R. 1996. Socio-economic Implications of Climate Change for Bangladesh. In: Warrick, R.A., Ahmad, Q.K. (eds.) The Implications of Climate and Sea–Level Change for Bangladesh. Springer, Dordrecht. https://doi.org/10.1007/978-94-009-0241-1_5

Esham, M. and Garforth, C. 2013. Climate change and agricultural adaptation in Sri Lanka: A review. *Climate and Development*, 5: 66–76.

Han, W.Y., Huang, J.G., Li, X., Li, Z.X., Ahammed, G.J., Yan, P. and Stepp, J.R. 2017. Altitudinal effects on the quality of green tea in east China: a climate change perspective. *European Food Research Technology*, 243: 323–330.

Hossain, S.M.S., Khan, A.R., Islam, M.Z. and Khandaker, S. 2017. Socio-economic situational analysis of tea plantation workers: a case study from Lubachhara Tea Garden, Sylhet. Bangladesh Journal of Public Administration, 25(2): 75-83.

Islam, M.N., Tamanna, S., Rahman, M.M., Ali, M.A. and Mia, I. 2021. Climatic and Environmental Challenges of Tea Cultivation at Sylhet Area in Bangladesh. In: Jakariya M., Islam, M.N. (eds,) Climate Change in Bangladesh, Springer, Cham. pp. 93-118. https://doi.org/10.1007/978-3-030-75825-7_6

ITC. 2015. *Annual Bulletin of Statistics (September 2015)*. International Tea Committee (ITC), London, UK. p. 158.

Kfoury, N., Morimoto, J., Kern, A., Scott, E.R., Orians, C.M., Ahmed, S., Griffin, T., Cash, S.B., Stepp, J.R., Xue, D, Long, C. and Robbat, A. 2018. Striking changes in tea metabolites due to elevational effects. *Food Chemistry*, 264: 334–341.

Marx, W., Haunschild, R. and Bornmann, L. 2017. Global warming and tea production—the bibliometric view on a newly emerging research topic. *Climate*, 5 (3): 46.

Matsumoto, K. 2019. Climate change impacts on socio-economic activities through labor productivity changes considering interactions between socio-economic and climate systems. *Journal of Cleaner Production*, 216: 528-541.

Mishra, A. et al. 2019. Adaptation to Climate Change in the Hindu Kush Himalaya: Stronger Action Urgently Needed. In: Wester, P., Mishra, A., Mukherji. A., and Shrestha, A. (eds.) *The Hindu Kush Himalaya Assessment*, Springer, Cham. pp. 457–490,

Mojid, M., Rannu, R. and Karim, N. 2015. Climate change impacts on reference crop evapotranspiration in North-West hydrological region of Bangladesh. *International Journal of Climatology*, 35: 4041-4046.

Niinemets, Ü. 2015. Uncovering the hidden facets of drought stress: secondary metabolites make the difference. *Tree Physiology*, 36: 129–132.

Ochieng, J., Kirimi, L. and Mathnge, M. 2016. Effects of Climate variability and change on agriculture production: The case of small-scale farming in Kenya. *NJAS-Wagenngen Journal of life Science*, 77: 71-78.

Qiao,Y.. Niels, Halberg, Saminathan, V. and Steffanie, S. 2018. Assessing the social and economic benefits of organic and fair-trade tea production for small-scale farmers in Asia: a comparative case study of China and Sri Lanka. *Journal of Renewable Agriculture and Food Systems,* 2 (12): 1- 12. doi:10.1017/S1742170515000162.

Rahman, M. R., Islam, N. Hossain, R. and Ali, M. A. 2017. Statistical Association between Temperature-Rainfall and Tea Yield at Sylhet *Malnicherra* Tea Estate: An Empirical Analysis. The Jahangirnagar Review, Part II, Social Sciences, Vol. XLI: 1-13.

Rahman, M.M. 2021a. The rhetorical blue economy in Bangladesh: Analyzing the inborn regulatory bottlenecks, Acta Aquatica. *Aquatic Sciences Journal*, 8 (2): 66-73.

Rahman, M.M. 2021b. Achieving Sustainable Development Goals of Agenda 2030 in Bangladesh: the crossroad of the governance and performance, Public Administration and Policy: *An Asia-Pacific Journal*, 24 (2): 195-211. https://doi.org/10.1108/PAP-12-2020-0056

Rahman, M.M. 2021c. Biologia Futura: can co-management protect Saint Martin's corals of Bangladesh? BIOLOGIA FUTURA **72,** 517–527. https://doi.org/10.1007/s42977-021-00101-4

Rahman M.M. 2021d. Analyzing the institutional and regulatory framework for operationalizing the blue economy in Bangladesh: Lessons from Australia, 13 December 2021, PREPRINT, Research Square, DOI: 10.21203/rs.3.rs-1163138/v2

Rahman, M.M. 2022a. Is co-management a double-edged sword in the protected areas of Sundarbans mangrove? *Biology and Philosophy* 37: 4. https://doi.org/10.1007/s10539-022-09836-3

Rahman, M.M. 2022b. Effectiveness of the coastal and marine conservation initiatives in Bangladesh: Analyzing the drawbacks of the legal, policy, and institutional framework. *Journal of the Indian Ocean Region* (forthcoming).

Roy, M. 2013. Time Series, Factors and Impacts Analysis of Rainfall in North-Eastern Part in Bangladesh. *International Journal of Scientific and Research Publications*, 3(8): 1.

Roy, S., Muraleedharan, N., Mukhopadhyay, A. and Handique, G. 2015. The tea mosquito bug, *Helopeltis theivora* Waterhouse (Heteroptera: Miridae): its status, biology, ecology and management in tea plantations. *International Journal of Pest Management*, 61(3): 179-197. DOI: 10.1080/09670874.2015.1030002.

Statistica. 2021. Production of tea by main producing countries since 2006. Available at: https://www.statista.com/statistics/264188/production-of-tea-by-main-producing-countries-since-2006/ (Accessed on 20 November 2020).

Wijeratne, M.A., Anandacoomaraswamy, A., Amarathunga, M.K.S.L.D., Ratnasiri, J., Basnayake, B.R.S.B. and Kalra, N. 2007. Assessment of impact of climate change on productivity of tea (Camellia sinensis L.) plantations in Sri Lanka. *Journal of the National Science Foundation of Sri Lanka*, 35: 119-126.

Wijeratne, M.A. 1996. Vulnerability of Sri Lanka tea production to global climate change. *Water Air Soil Pollut*, 92: 87–94. doi https://doi.org/10.1007/BF00175555.

DOI: https://doi.org/10.55706/jae1507