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Climate change effects on aquaculture: A case study from north western Bangladesh

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Abstract

The present research was carried out to elucidate the impacts of climate change on aquaculture in north western part of Bangladesh. Primary data including fish farmer's perceptions on climatic change and its impact on their farming practices were collected through face to face interview with 120 fish farmers, 30 from each upazila of Rajshahi district and secondary data of air temperature, rainfall and evaporation were collected from Bangladesh Meteorological Department. Present findings indicated that in last 44 years (1971-2014) mean annual air temperature has been increased by nearly 1.1 °C, while the mean annual rainfall has decreased from 148mm to 112 mm. In addition, mean evaporation showed the increasing trends over the Rajshahi division by 0.50mm/year. As the indicators of the climatic variability, on an average 47% fish farmer mentioned that annual temperature has increased followed by decrease of annual rainfall (about 14%), water quality variability (about 8%) and prolonged drought (7%). Near about 6% of the fish farmer also stated that recently they have experienced with more disease outbreak in fishes as well as lowering groundwater layer. Almost 100% of medium and large scale fish farmer mentioned that they completely depends on groundwater supply to culture fish. Moreover, a substantial percentage of the fish farmer perceived that the growth rate of the cultured fish has decreased and mortality of the fry and fingerlings due to heat shock and disease resulting in decrease in overall total fish production. In addition, farmers also experienced with excessive fish farming cost, most likely to manage the water quality of the ponds (33.33%) and to control diseases outbreaks (25.8%). Majority concluded that they are not interested in involving their family members in fish farming practices because of less marginal profit compared to before and searching for new alternatives to sustain and develop their livelihood status.

Keywords: Climate change, fish farmer's perceptions, fish farming, Rajshahi district

1. Introduction

Aquaculture and fisheries are confronted with challenges posed by numerous natural and anthropogenic causes such as climate change, natural disasters, unbalanced urbanization and industrialization, overfishing and environmental pollution across the world [1]. Bangladesh is one of the world's leading fish producing country with a total production of 36.84 lakh MT in the last financial year 2013-2014, where the contribution of aquaculture to the national production is about 55.92% [2]. At present Bangladesh is ranked 4th in inland aquaculture production all over the world [3]. However, divergent climatic variability listed Bangladesh as one of the most vulnerable countries across the world due to its unique geographic location along with high population density, high levels of poverty, dominance of floodplains, low elevation from the sea, and overwhelming dependence on nature, its resources and services [4]. Though, more than 1.5% of the total population of Bangladesh are directly or indirectly related to fish farming, but their farming practice and livelihood are now vulnerable to the adverse effects of climate changes, whether through changes in physical environments, ecosystems or aquatic stocks, or through impacts on infrastructure, fishing or farming operations, or livelihood options [5].

The fish farmers are rendering unemployed as fish production and fish diversity is reducing gradually due to climate change. Fish farmers are more vulnerable to the climate change impact due to decreasing fisheries resources and their limited adaptive capacity to a changing environment. Literature on impacts of climate change on fish farmer's livelihood and their farming is very limited in Bangladesh. Though it is considered that climate change is one of the most serious problems for aquaculture but unfortunately there is a dearth of research on climate change and their possible impact on aquaculture in Bangladesh.

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Topography and topography and climate make the northern region of Bangladesh ecologically vulnerable to destabilized variations including floods, river erosion, drought spells, and cold waves, all of which occur more frequently and intensely than in other region [6]. Overall, higher temperatures, higher rates of evaporation and changing rainfall patterns are expected to cause drought situation in northern part of Bangladesh. Water is a basic need for aquaculture but water holding capacity of the ponds or many others fish habitat of the northern region of Bangladesh decreasing gradually due to the fact of ground water table fluctuation. Moreover, drought cause disease outbreaks, reduction of fish farming and decline the overall fish production. So, to maintain the flow of benefits to society and the economy from aquaculture it is necessary to assess climate change-induced vulnerability on aquaculture.

However, some studies on climate change threats or impacts, adaptation and mitigation in Bangladesh has been carried out based on the analysis of secondary date of temperature, rainfall, seasonal variability, drought etc. [7-12], but

unfortunately on those studies less or even no concern were given to focus the fish farmers perceptions on climate change, how they experienced and how they cope their culture practice with the changed conditions along with the predicted potential impacts of climate change particularly on aquaculture, though, which are very important for adaptive management [13]. Therefore, the main objectives of the present study was to explore the climate change variability in northwestern part of Bangladesh along with local fish farmers' perception on climate change and its impact on their fish culture practices and livelihood.

2. Materials and Methods

2.1 Study area and fish farmer selection

This research was conducted in the different areas of Rajshahi district (Northwest part) of Bangladesh. A total of four upazilas (ssecond lowest tier of regional administration) under Rajshahi district known as Paba, Durgapur, Mohanpur and Bagmara were studied (Fig. 1).

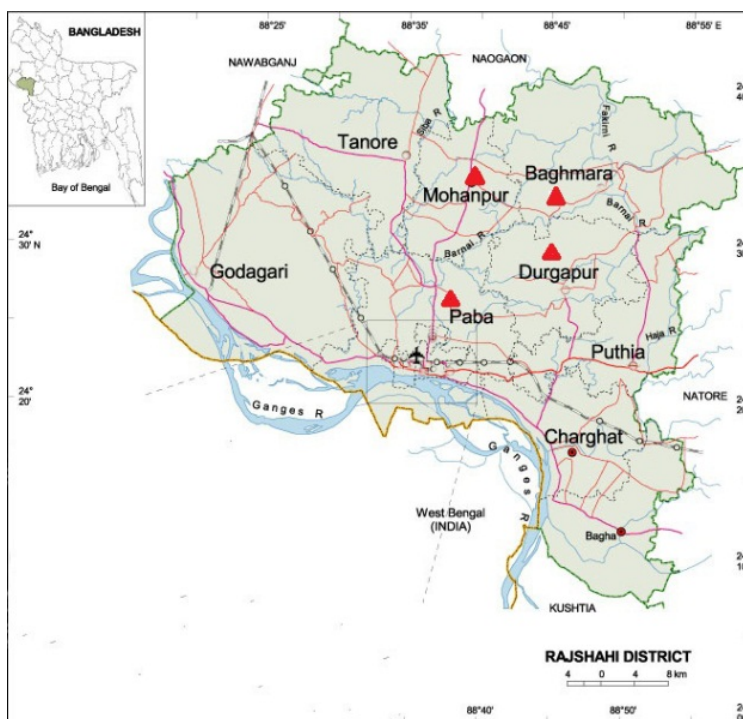


Fig 1: Map showing the study areas

A total number of 120 fish farmers, 30 from each upazila were categorized as small, medium and large scale fish farmer on the basis of the size of their fish farming areas (Table 1)

and selection were done using multi-stage cluster sampling technique [14].

Table 1: Categorizes of fish farmers' found in the study areas

Fish farmer types	No. of fish farmer			
	Paba (n=30)	Durgapur (n=30)	Mohanpur (n=30)	Bagmara (n=30)
Smale scale fish farmer (Farming area: < 1.0 acre)	11	8	11	9
Medium scale fish farmer (Farming area: 1.0-2.0 acre)	13	14	7	12
Large scale fish farmer (Farming area: > 2.0 acre)	6	8	12	9
Total (n)	30	30	30	30

2.2 Data collection technique

This research was based on collection and analysis of both primary and secondary data. Before collecting the primary data, a draft questionnaire was developed which was pre-

tested with a few fish farmers of the study area. In the pre-testing, much attention was given to any new information in the draft questionnaire in order to reach the objectives of the study. According to the experience gained in pre-testing, the

final questionnaire was improved, rearranged and modified. The final questionnaire basically focused the questions relevant to fish farmers' perceptions on climate change as well as climate variability impacts on. In addition, secondary data on annual temperature (1971-2014), rainfall (1971-2014) and water evaporation rate (2001-2014) of Rajshahi district were collected from the Climate division of Bangladesh Meteorological Department (BMD), Dhaka.

2.3 Study period

Face-to-face interview with questionnaire was carried out for a period of 5 months from July 2015 to November 2015 with 120 fish farmers of the study areas.

2.4 Data analysis

The data obtained from the questionnaire survey and BMD were subjected to descriptive statistical analysis in form of frequencies, percentages, and multiple regressions by using SPSS V 20.0 developed by SPSS (mac) and MS Office Excel 2010 developed by Microsoft Corporation.

3. Results and Discussion

3.1 Climate change variability in Rajshahi district

3.1.1 Increase in air and water temperature

It has been observed that in the last 44 years' time scale the annual mean maximum temperature of Rajshahi district is increased by nearly 1.1 °C (Fig. 2).

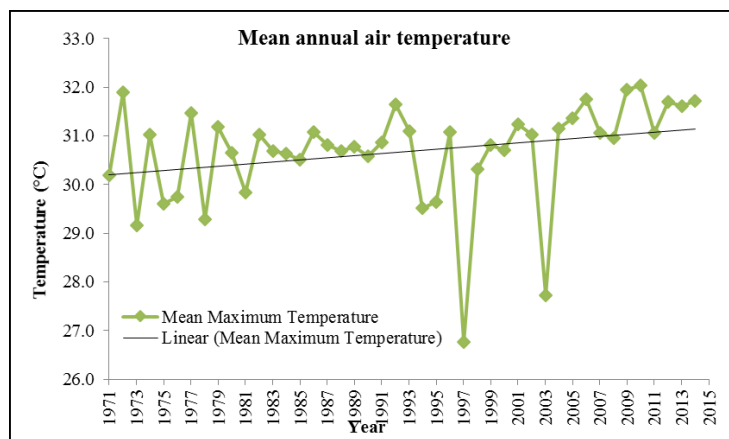


Fig 2: Annual air temperature scenario in the study area

Similar increasing trend were reported by Keka *et al.*, 2013 [15] and Nasher and Uddin, 2015 [16]. Global average air temperature has increased by nearly 1 °C over the past century and a half and it is expected to continue to increase by 1-3 °C by the middle to end of this century [17]. Water temperature is generally changed by the change of air temperature. Most of the fish farmer acknowledged that water temperature in the study area is increasing though there is no time series data on water temperature is available. However, analysis of the secondary data of this study revealed that the mean annual air temperature of Rajshahi district has increased, that perhaps indicated that the surface water temperature of fish habitats has also increased. Morrill *et al.*, 2005 [18] reported an increase in water temperature of about 0.6-0.8 °C for every 1 °C increase in air temperature.

3.1.2 Decrease annual rainfall and increases annual evaporation

Mean annual rainfall in the Rajshahi district has decreased from 148 mm to 112 mm. Lowest total annual rainfall was recorded 792 mm in 2010 and highest rainfall was recorded 2241 mm in 1981. Comparatively high annual (total) rainfall was set in the year 1973, 1977, 1997 and 1999 (Fig. 3). On the other hand, annual evaporation has increased significantly over the period of time and there was a strong positive correlation with the increased annual air temperature (Fig. 2 and 4). This decreased trend of annual rainfall and increased trend of annual evaporation has also been reported by Ferdous and Baten, 2012 [19].

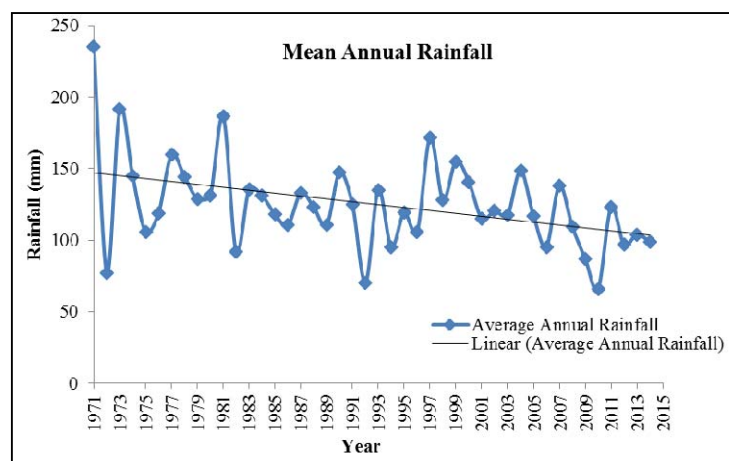


Fig 3: Annual rainfall scenario in the study area

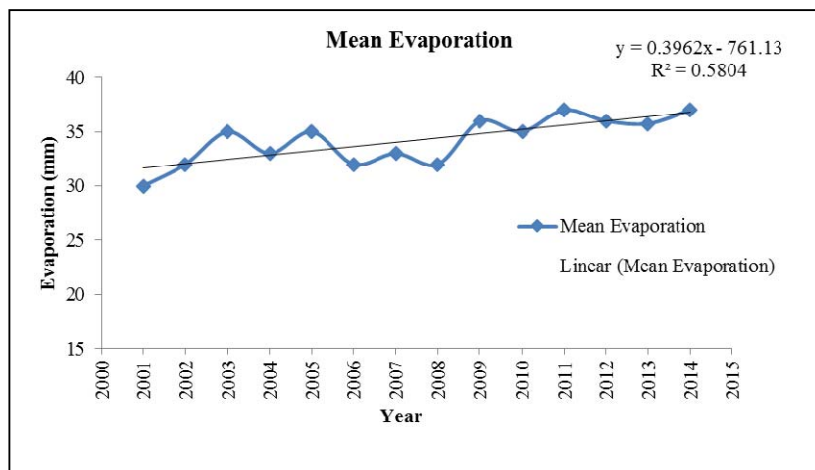


Fig 4: Evaporation scenario in the study area

3.2 Fish farmers’ perceptions on climate variability

All the fish farmer of the study areas perceived that climate has changed and frequently changing in various rate. They have experienced with the changed climate by observing various climate variability parameters as well as gained the experiences from their fish culture practices. As the indicators of the climatic variability, irrespective of different upazila, on an average 47% fish farmer mentioned that annual temperature has increases followed by decreases of annual rainfall (about 14%), water quality variability (about 8%), prolonged drought (7%). Near about 6% of the fish farmer

also stated that recently they have experienced with more disease outbreak in fishes as well as lowering groundwater layer. However, about 5% fish farmer indicated temperature and rainfall fluctuation and seasonal variability as the indicators of climate change in their localities (Fig. 5). More or less similar findings noticed by Jahan *et al.*, 2015^[20]. Ficke *et al.*, 2007^[21] reported that water temperatures, decreased dissolved oxygen levels, and the increased toxicity of pollutants in freshwater systems will likely be increased due to climate change.

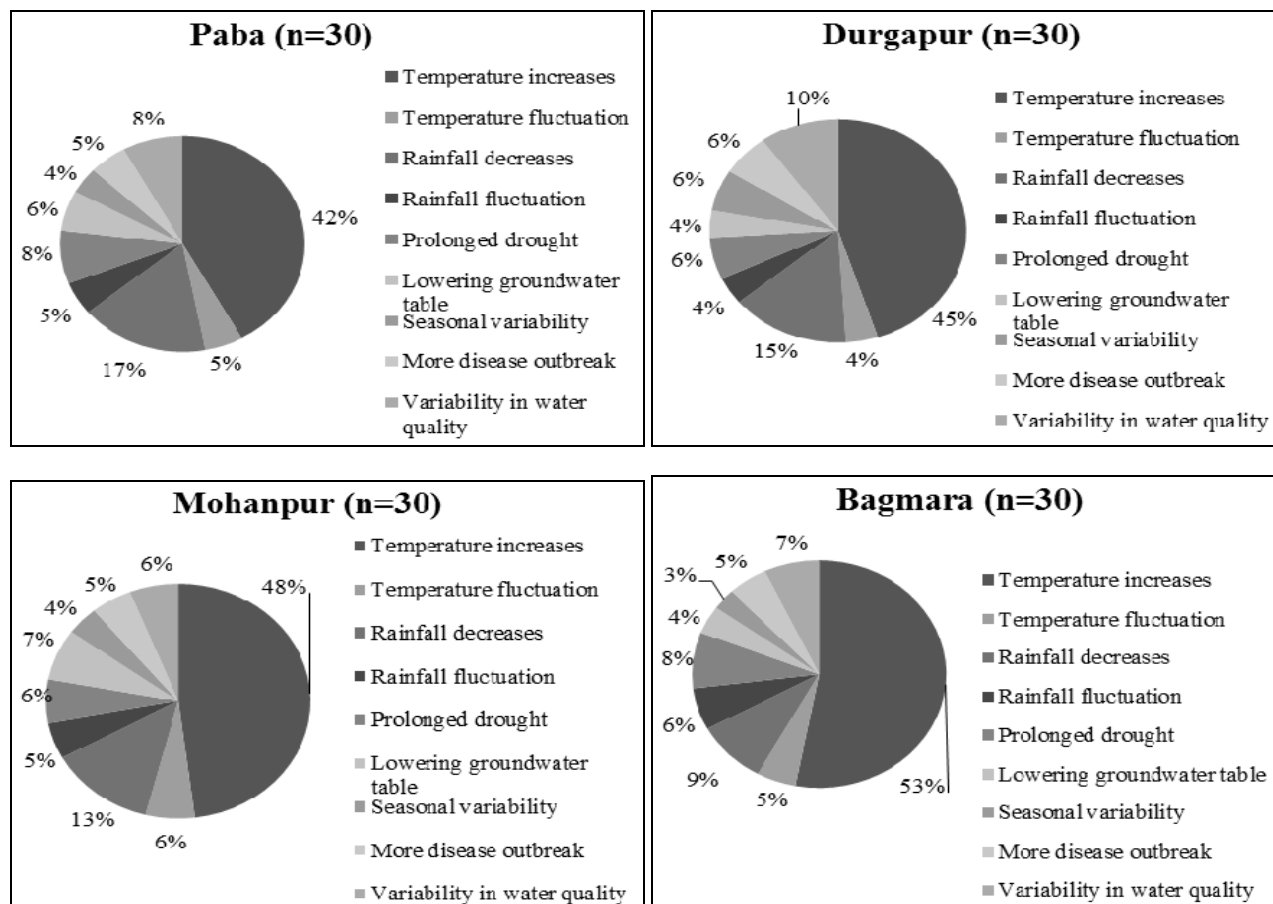


Fig 5: Climate variability indicators perceived by the local fish farmers of the study area.

3.3 Climate change impacts on aquaculture

3.3.1 Water supply

Climate change has both direct and indirect impacts on water supply to the fish farming ponds, direct impact due to decreased annual rainfall and indirect impact due to the fluctuations of the groundwater tables. Most of the fish farmer irrespective of the upazila remarked that natural water supply has been drastically changed in their fish farming ponds, now depends on the deep tube well or pump for water supply, though there found some small fish farmers who are still

depends on rain water for aquaculture, range varies from 11.11-36.43%. But almost 100% of medium scale and large scale fish farmers stated that they are completely depends on the mechanical pump to supply water to culture fish (Table 2). They also stated that ground water table has likely to be lowered day by day. Dey *et al.*, 2013 [22] found the declining trend of groundwater table over the last 30 years and the magnitude of the decline in groundwater table has been found between -2.3 to -11.5m in the northwest Bangladesh.

Table 2: Water supply scenario in the study areas

Water supply	Smale scale fish farmer				Medium scale fish farmer				Large scale fish farmer			
	P* n=11	D* n=8	M* n=11	B* n=9	P n=13	D n=14	M n=7	B n=12	P n=6	D n=8	M n=12	B n=9
Natural	17.28% (3)	25% (2)	36.34% (4)	11.11% (1)	7.7% (1)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)
Pump	72.72% (8)	75% (6)	63.64% (7)	88.89% (8)	92.3% (12)	100% (14)	100% (7)	100% (12)	100% (6)	100% (8)	100% (12)	100% (9)

* P=Paba, D=Durgapur, M=Mohanpur, B=Bagmara

3.3.2 Fish habitat

On an average 83% of the fish farmers of the study areas has remarked that small sized fish culture pond has gradually declined and becomes derelict due to shortage of natural water along with manmade causes, like construction of buildings, conversion of ponds to irrigation field etc.

3.3.3 Fish species

Climate change has both direct and indirect impacts on fish stocks which are exploited commercially as well as on the small indigenous fish species (SIS) which are not commercially cultured. All interviewed fish farmers denoted that they are now culturing only 12-13 species of fishes (*Labeo rohita*, *Catla catla*, *Cirrhinus cirrhosus*, *Hypophthalmichthys molitrix*, *Hypophthalmichthys nobilis*, *Ctenopharyngodon idella*, *Cyprinus carpio*, *Puntius sarana*, *Labeo calbasu*, *Oreochromis mossambicus*, *Anabas*

testudineus and *Pangasius hypophthalmus*), which has faster growth rate rather than culturing the small indigenous fishes. Therefore, small native fishes have likely to be threatened day by day. IUCN, 2000 [23] listed 54 native fishes as threatened species of Bangladesh. This reduction in the number of fish species is a common trend in Bangladesh due to anthropogenic impacts along with the adverse effects of climate change [24, 25].

3.3.4 Fish production

A substantial percentage of the fish farmer in the study areas perceived that growth rate of the cultured fish has decreased and mortality of the fry and fingerlings due to heat shock and disease has also increased thus decreased the overall total fish production (Fig. 6). They also conceded that there is a scarcity of having genetically pure fish fingerling, as a result fish production per decimal has severely hampered.

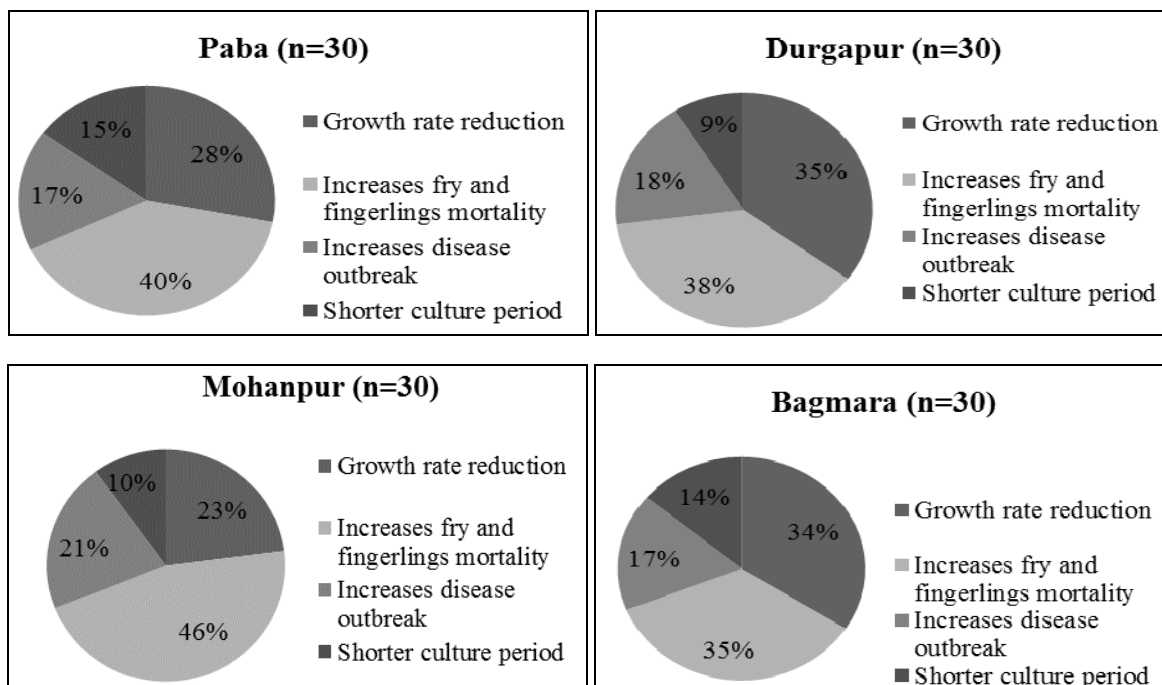


Fig 6: Climate change induced causes of fish production loss in the study areas

Climate change, particularly increased temperature has direct effects the physiology and behaviour of the cultured species, thus alter growth, reproductive capacity, mortality and distribution of that species. Indirect effects alter the productivity, structure and composition of the open water ecosystems on which fish depend for food [26].

3.3.5 Fish farm operation cost

Table 3 shows the excessive fish farming cost experienced by the fish farmer of the study areas due to the adverse effects of climate changes. Most of the fish farmer of the study areas

Table 3: Fish farming cost experienced by fish farmers due to climate variability

Fish farm operation cost	Study areas (Upazila)				Overall (%)
	Paba (n=30)	Durgapur (n=30)	Mohanpur (n=30)	Bagmara (n=30)	
Maintaining water quality parameters	33.33 (10)	30 (9)	40 (12)	30 (9)	33.33
Management of fish diseases	26.67 (8)	30 (9)	23.33 (7)	23.33 (7)	25.83
Marinating water level by artificial means	20 (6)	16.67 (5)	13.33 (4)	16.67 (5)	16.67
Pond management during flooding	3.33 (1)	3.33 (1)	6.67 (2)	6.67 (2)	5.00
Fish feed	16.67 (5)	20 (6)	16.67 (5)	23.33 (7)	19.17

This result agrees well with the findings of Silva and Soto, 2009 [27]. Climate change lowers water quality causing more disease outbreak and increases competition with other water users which altered and reduced freshwater supplies with greater risk of drought which ends up with higher costs of maintaining pond water levels [28].

3.3.6 Profit

About 80-93.3% of the fish farmers of the study areas specified that marginal profit comes from fish culture has decreased gradually year by year as they needs to spent certain amount of money for managing climate induced negative events most noticeably diseases of fish followed by maintaining water level in fish culture ponds by artificial means like pumps. However, 6.7-20% fish farmer stated that their profit has increased in recent years due to getting good sealing prices than before (Fig. 7). Aquaculture profit is strongly influenced by the climate variables, including extreme weather events and long term climate changes [29, 30].

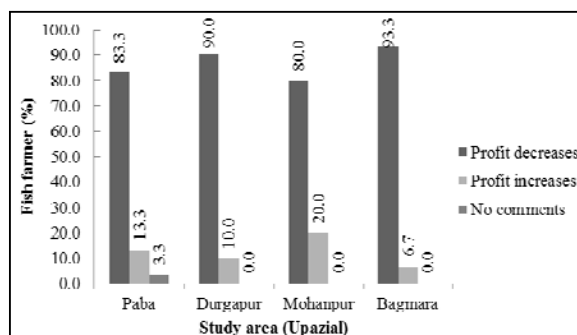


Fig 7: Fish farmers' perceptions on profit made through fish farming

3.3.7 Social mobility and socio-economic condition

Anthropogenic global warming has significantly influenced physical and biological processes at global and regional scales. The observed and anticipated changes in global climate present significant opportunities and challenges for societies and economies. Most of the fish farmers of the study areas who are involved on aquaculture for over 10 years stated that they are not interested in involving their family

perceived that the fish farming operation cost has increased several folds due to climate variability, particularly to manage the water quality of the ponds (33.33%) and to control diseases outbreaks (33.33%) (Table 3). About 17 percent of the fish farmer irrespective of fish farmer categories, mentioned that price of fish feed has increased upto 20% than the previous purchase price. Fish farmers also acknowledged that they needed certain amount of money to maintain water level in their culture pond by artificial means like water pump as well as to control the escaping of fish when occasionally heavy rainfall over flooded their culture areas.

members in fish farming practices because of less profit compared to before and are interested in high education for their child to find other job opportunity, develop their socio-economic condition.

4. Conclusion

There is increasing concern over the consequences of climate change for aquaculture and fisheries production all over the world. The production and distribution of fish depends strongly on environmental conditions. Changes in hydro-graphic and meteorological variables such as temperature, rainfall, storminess and cloudiness have all been shown to affect fish life history. Bangladesh is widely recognized to be one of the most climate vulnerable countries in the world. It experiences frequent natural disasters, which cause of life, damage of infrastructure and economic assets, and adversely impacts on fish farming. Pond fish farmers are the poorest of poor in the country who are seriously affected by the climate change. Fish farmers were mentioned that amount of fish productions has decreased because climate variability. Most of the fish farmers also cited that high temperature, decreased rainfall, seasonal variability, prolonged drought affected the fish production. Due to climate change fish are susceptible to disease and could not recover from disease. As because fish farming becoming less profitable venture due to climate induced factors along with anthropogenic causes in the Rajshahi district, so that fish farmers changes their occupation and that made the fish farmers socio-economic condition more vulnerable. The changing environment put the fish farmers in great challenge as they have to shift their main occupation to alternative employment opportunities on which they are not adopted.

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