

Socio-hydrological Resilience to Climate-induced Drought: A case of Naogaon, Bangladesh¹

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Abstract

Introduction: Drought poses significant environmental and economic threats in northwestern parts of Bangladesh. The area is characterized by long-dry weather pattern. Climate-change driven uncertainties such as low rainfall, precipitation and water scarcity puts more strain on agriculture and agro-based economy of the region. Farmers and agricultural laborers faces challenge in finding alternative income sources during prolonged drought. To survive, they interact with changing socio-hydrological systems and utilize different absorptive, adaptive and transformative capacities. The country has experienced frequent hydro-climatic disasters including flood, cyclone and drought due to the increased climate change impacts. Drought is a recurring and creeping phenomenon in the Northwest part of Bangladesh. Particularly, the districts such as Chapainawabganj, Rajshahi, Naogaon, Bogra, and Joypurhat face agricultural drought. Intergovernmental Panel on Climate Change (IPCC) has predicted warmer climate and a drastic change in rainfall patterns in the districts. Recent research has also identified the annual maximum temperature increase by 0.16°C in two decades, and the significant decrease of rainfall during 1994-2013 along with the forecast of increase of average minimum temperature by 1.3°C

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Materials and Methods: Taking Sapahar Upazila of Naogaon District as a case, it is aimed to identify and explore the coupled socio-hydrological systems and how farmers of the Upazila deal with the stresses caused by drought. It is also explored the socio-hydrological and social sub-systems that supports livelihood of the villagers to cope with the challenges posed by water scarcity. The research identified increased susceptibility of households to water scarcity, crop failure, food insecurity, and unemployment resulting from recurring drought. Farmers have changed their land use pattern and traditional agricultural practices, cultivating drought-tolerant species, introducing rainwater harvesting systems, and re-excavating pond and canal to store water to cope with draught. They also manage small water systems based on their shared learning, and coordinate with different stakeholders to foster the adaptive system. They also change their conventional occupation and migrate to nearby cities. Long-term transformation in land use and land cover change is identified employing Geographical Information System (GIS) analytical tools.

Results: The change includes gradual decline in the area and coverage of paddy fields and an increase of mango cultivation and fish farming. The study recommends the increased institutional cooperation among relevant stakeholders. It also suggests taking measures like innovating drought tolerant and less water consuming crops and supporting farmers to strengthen the resilience against drought.

Conclusions: Change that occurs at individual level is not transmitted to encourage learning and broaden participation. Besides, strategies need to best utilize the available local knowledge and augment the practices through local government institutions such as Ministry of Disaster Management and Relief. Measures from Ministry of Agriculture is also required to (a) subsidizing farmers to increase their access to water during drought; (b) and promoting drought tolerant species and short-lived crop; (c) capacity building activities for farmers to cope with water related stresses and promote the rainwater harvesting systems. Strong interrelationship between government and non-government organizations and scientists is also prerequisite to facilitate an effective adaptation policy. Integrated approach will help farmers not to leave their traditional agricultural practice. In this backdrop, the study will provide information about the dynamics of the socio-hydrological crisis and opportunities to the policymakers to assist the local people to enhance their resilience.

Keywords: Water scarcity, Land use change, Agriculture, Adaptation, Climate, Resilience.



1. Introduction

Bangladesh is one of the most vulnerable countries to the adverse impact of climate change (Mundial *et al.*, 2013). The country has experienced frequent hydro-climatic disasters including flood, cyclone and drought due to the increased climate change impacts (Islam *et al.*, 2017). Drought is a recurring and creeping phenomenon in the Northwest part of Bangladesh (Habiba, 2011; Shahid, 2008; Umma Habiba, 2011). Particularly, the districts such as Chapainawabganj, Rajshahi, Naogaon, Bogra, and Joypurhat face agricultural drought (Hossain *et al.*, 2016). Intergovernmental Panel on Climate Change (IPCC) has predicted more warmer climate and a drastic change in rainfall patterns in the districts (Parry *et al.*, 2007). Recent research has also identified the annual maximum temperature increase by 0.16°C in two decades (1994 to 2013), and the significant decrease of rainfall during 1994-2013 along with the forecast of increase of average minimum temperature by 1.3°C (Rahaman *et al.* 2016). Some of the moderately drought-affected area may turn into severely drought-prone areas by 2030 (Parry *et al.*, 2007). Drought in the years of 2006, 2009, 2013 and 2015 is already responsible for 20-30 percent reduction of Aman Crop which is widely cultivated variety of rice in Bangladesh (Hossain, 2018).

The northwestern districts are known as food bowl of the country (Jalilov *et al.*, 2019). More than 48% of the rural workforce are employed in agriculture and their livelihood depends on the agro-based subsectors (Jalilov *et al.*, 2019). The water related stresses have a significant impact on income (Rahaman *et al.*, 2016). The districts experience a dry period every year from November to April when rainfall is low (Shahid, 2008; Kamruzzaman *et al.*, 2017). Sometimes drought prolongs three to six months and all of the rivers and channels dry up making people dependent on groundwater (Shahid, 2011; Bari, 2000). Notably, about 75% of water for irrigation in the region comes from the groundwater resources (Bari, 2000). The proportion of lifting groundwater and surface water is much higher in these areas compared to other parts of the country (Habiba *et al.*, 2014). Hence, 42% of areas in these districts experience the groundwater scarcity every year (Shahid, 2011).

The average annual rainfall in the region is decreasing gradually while the daily use of water for irrigation is increasing day by day. (Shahid, 2011). The average annual rainfall of Bangladesh varies from maximum of 5,690 mm in the northeast to a minimum of 1,110 mm in the west, whereas northwestern region receives an annual average of 1,329 mm (Shahid, 2005). Over-

extraction of groundwater for irrigation in the dry season and frequent droughts are the main causes of groundwater level depletion (Shahid, 2011; Shahid *et al.*, 2015). Drought has not only affected the crop production but also affected the environment and agro-ecosystem with a significant negative impact on livelihoods (Barlow *et al.*, 2006). Some indigenous variety of crops, rice and landraces are in the verge of extinction due to drought (Kamruzzaman *et al.*, 2017). Other negative impacts include the decrease of agricultural production and increase of the price of the food grains at the local markets alongside job and livelihood insecurity (Islam *et al.*, 2014). In severe cases, it increases the chance of seasonal food crises locally known as Monga¹ (Paul *et al.*, 2013). Moreover, hydrological hazards including prolonged drought is the reason for the shortage of food and fodders for livestock.

Among the impacted areas, Sapahar Upazila of Naogaon district is susceptible to the multiple hydrological hazards. Table 1 presents the types of hazards, frequency of hydrological hazards, most impacted unions and number of the impacted peoples. As water becomes scarce, farmers of the Upazila adopted the drought tolerant rice varieties and household stores surface and rainwater in the large reservoirs and excavates canal (Hossain *et al.*, 2016). Some household use Rainwater Harvesting System (BADC, 2005; Butler *et al.*, 2010). However, farmers have a lack of knowledge about managing slow variable and polycentric governance system. Despite, farmers are managing the uncertainties by their own to build resilience. Some places, such as Siranti and Sapahar Unions² have gone through the agriculture and land use change for transformative change. However, the factors of change and the dynamics are less known and undocumented.

Table 1. Hydrological hazards in Sapahar Upazial

Hydrological Hazards	Most impacted Unions	Reasons of hazard	Frequency of Hazard	Impacted populations
Lowering groundwater level	Siranti, Gowala, Tilna, Sapahar	Climate change Unplanned use of ground water Embankments on Waterbodies	Each year since 2000	82550 (approx.)

1. Monga is a Bengali term. It refers to the cyclical times of a year, normally September–November (after the Aman crop is planted) and March–April (after the boro crop is planted), when poverty and hunger remain high in the northwestern districts of Bangladesh. It is also locally known as "Mora Kartik," which means "months of death and disaster." Due to the unavailability of jobs, agricultural workers become migrants and move to nearby towns during this period, and those who cannot migrate face starvation.
2. Union is the smallest rural administrative unit of the local government of Bangladesh.



Hydrological Hazards	Most impacted Unions	Reasons of hazard	Frequency of Hazard	Impacted populations
Flood	Aihai, Patari, Joboi beel area	Bank erosion Agricultural damage Infrastructural damage	2002, 2003, 2006, 2011, 2015, 2019	69960 (approx.)
River bank erosion	Aihai, Patari, Gowala, Sironti, Joboi beel area	Erosion and agricultural Land eaten up by river Loss of agricultural land Loss of fisheries	2000, 2004, 2005, 2006, 2015, 2019	45630 (approx.)
Drought	Aihai, Patari, Sironti, Gowala, Sapahar	Loss of agriculture Loss of livelihood	2000, 2004, 2006, 2008, 2009, 2010, 2013, 2015, 2018	161792 (approx.)
Shortage of rainfall	Patari, Aihai, Sironti, Gowala, Sapahar	Agricultural loss Water related socio-economic stress	Each year since 2000	161792 (approx.)

(Source: Ministry of Disaster Management and Relief, 2017)

It is also important to understand the mechanism of interaction with nature, particularly the management aspects of drought alongside their capacities to foster the adaptive system. In understanding the resilience of a system and the attributes that govern the system's dynamics, it is imperative to understand the capacity of the system to absorb disturbance, capacity of actors of the system to adapt and influence the resilience, and capacity to transform and create a new system (Walker *et al.*, 2009). Therefore, resilience can be understood from a set of systemic absorptive, adaptive and transformative capacities of a society or a system (Walker *et al.*, 2004).

The major objectives of this study are to (i) identify the water related stresses of framers and households and their coping mechanisms; (ii) assess the capacities of the socio-hydrological subsystems to absorb, adapt and develop new systems and (iii) to identify the challenges to achieve the socio-hydrological resilience. The major research questions are- what are the capacities that are fostering the complex adaptive system; encouraging the shared learning and; promoting polycentric governance for transformative change.

2. Materials and Methods

Considering the three capacities, the study was conducted in Siranti and Sapahar Unions (Figure 1), of Sapahar Upazila in the Naogoan district. The field study and data collection were done in 2019. Two Unions (Siranti and Sapahar Unions) were selected considering (i) frequency of hydrological hazard, prevalence and the most impacted unions; (ii) depletion of groundwater and (iii) review of electronic and print media news on the drought impacts (iv) review of secondary literatures on the water-related

stresses and local adaptation practices. Based on the available information, Siranti and Sapahar Unions were identified as most susceptible to the frequent drought and most dynamic in terms of the water related stresses and transformative changes in terms of the water management and agricultural practices. Using purposive sample, sixty households were interviewed from two Unions. Purposive sample was used to identify the families that area exposed to the water related stresses both in the agriculture and household levels and to know the socio-hydrological resilience of the households against the prolonged drought. Households were interviewed using qualitative tools such as Ken Informant Interview (KII) and Focus Group Discussion (FGD) following the indicators identified under different capacities (Table-1).

Table 2. Indicators to assess the socio-hydrological resilience

Absorptive capacities	Adaptive capacities	Transformative capacities
(i) Early warning systems (ii) Timely availability of information (iii) Physical capital (water system, road) (iv) Social capital (family, neighbors, friends, community groups) (v) Social protection scheme (insurance, microfinance) (vi) Human capital (health and education system, social wellbeing) (vii) Policy framework (laws, policies, contingency plans, cooperation and collaboration among public and private sectors)	(i) Natural resources (land, soil and water) (ii) Knowledge and information (iii) access to resources (credit, market, livestock, linkage to input supplies) (iv) accessibility to social networks (self-help, groups) (v) access to technology and innovation (new seed varieties, agricultural practices, enterprise development, ICTs) (vi) legal and policy frameworks to support adaptation	(i) conscious changes in household, community and institution level (ii) engagement of CSOs, NGOs and institutions for inclusive change (iii) shared management of resources (iv) adopting new ways of organizing and sharing power (v) collectively working to reduce vulnerabilities (vii) inclusive decision making process to form new laws and practices (viii) live experience of generating knowledge and shaping new ways of thinking and acting) (ix) inclusive form of governance

Semi-structured questionnaire and case study were deployed to extract the socio-economic and socio-hydrological practices, its changing pattern, coping mechanism, and challenges. A checklist was prepared to conducted KII and FGDs with farmers and households to understand the resilience capacities, best practices and challenges. All of the discussions were recorded and transcribed for further analysis.

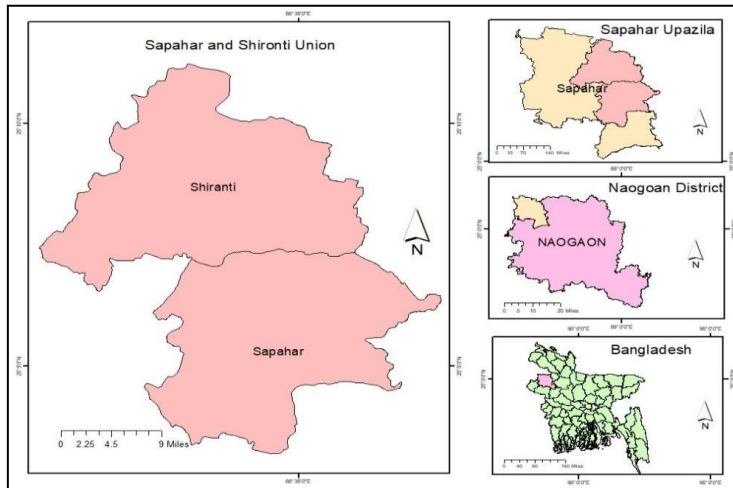


Figure 1. Study area, Siranti and Sapahar Unions of Sapahar Upazila, Naogaon

Temperature and precipitation data from BMD were used for analyzing the hydrological aspects. Satellite images were used to identify the land use pattern and detect the changes during 2000-2020. To calculate Land Use and Land Cover (LULC) changes, a 30m resolution LANDSAT satellite imagery was acquired from United States Geological Survey (USGS) (Table 2). Relevant vector data were also collected from Local Government Engineering Department offices.

Table 3. Data Source and Type

Satellite and Sensor	Year/ Acquisition Date	Datum & Scale in Meter	Land Cloud Cover (%)	Data Type
LANDSAT 8	12/02/2020	WGS_1984,30	0.02	Level 1
LANDSAT 5	06/02/2010	WGS_1984,30	0.00	Level 1
LANDSAT 5	11/2/2000	WGS_1984,30	0.00	Level 1

Source: USGS, 2020

Necessary secondary data were incorporated for analysis. Satellite images were analyzed using ArcGIS. Primary data were processed and statistical analysis was done by the MS Excel.

3. Results and Discussions

Agriculture is one of the most critical sectors and highly vulnerable to drought. During dry season, the perennial water bodies such as rivers, natural canals,

and ponds completely dry up in the study area. As a result, the farmers are dependent on groundwater for irrigation and the household activities. In the study area, farmers pump groundwater and use the diesel and electric pumps, and shallow tube-wells for irrigation (Table 3). Load-shedding, infestation of insect, high cost of diesel, fertilizer, insecticide are the main challenges of agriculture.

During drought, marginal farmers and small share croppers cannot irrigate their paddy field due to the heavy demand of water and unavailability of the irrigation schedule. Particularly, the water schemes are controlled by local elites, wealthy farmers, and influential people who have the power over water. Such power dynamics are the cause of local disputes and quarrel. Late irrigation in the critical phases of cultivation reduces the crop productivity. As a result, production loss occurs which ranges from \$12-\$175 in 0.25 hectare. Farmers also experience the harmful pests and infestation of insect due to drought. It decreases the crop production and increases the economic loss.

Increased production cost is another challenge due to the water shortage. Fifty-one percent farmer reported that their production costs increased by \$80-\$100/per 0.25 hectare to that of nearly a decade ago. Drought is also responsible for the reduced soil moisture and nutrients. To retain soil fertility, farmers apply the fertilizer and organic composts that increase the economic burden. To reduce expenses, farmers convert their traditional agricultural land into the mango gardens.

Table 4. Water stress and their consequences and coping strategy

Impacts of drought	% of HHs reported	Impacted Groups	Context/cases of impact	Consequences	Coping Strategy taken by the HHs
Decrease of Rainfall	100	All groups	Scarcity of irrigation; dry up natural water bodies; decrease perennial water bodies;	Reduce food production	Pumping groundwater, Re-excavation of pond and channels;
Depletion of groundwater	100	All groups	Scarcity of irrigation water and drinking water; crop failure	Severe and prolonged water scarcity	RWHS
Increase of temperature	100	All groups	Infestation of pests and insects on crops, health problem; loss of soil moisture and fertility	Crop failure and uncertainty in agriculture	Borrow money/take loan from NGOs and money launderers.
Decrease of natural water body	100	All groups	Reduction of open water sources for irrigation; reduction of subsisting economic activities in open water bodies; reduction of fishing opportunity	Decrease of indigenous fish species; reduction of livelihood opportunity and subsistence activities for poor and marginal households	Excavating new ponds



Impacts of drought	% of HHs reported	Impacted Groups	Context/cases of impact	Consequences	Coping Strategy taken by the HHs
Decrease of agricultural productivity	77	Poor and subsistence farmers	Shortage of food; malnutrition; low income; spend most of the money to purchase food	Economic loss and decrease of resilience to cope with upcoming disasters	Mixed Farming; mango cultivation; fish farming
Increase of production cost	100	Poor and subsistence farmers	Spend most the money to buy irrigation water; reduction of profit and low earning from agriculture	Economic loss and decrease of resilience to cope with upcoming disasters	Take loan
Increase of water price	100	Poor and subsistence farmers	spend most of the money to purchase water; fail to irrigate crop land timely and crop failure	Decrease income from agriculture; reduced access to water for irrigation	Carrying water from open waterbodies other than pumping; introduce drought tolerant species
Decrease of household income	76	Poor and subsistence farmers	High cost of agriculture and low earning	Economic loss and decrease of resilience to cope with upcoming disasters; less investment in education and nutritious food	Alternative livelihood option such as migration to nearby cities, rickshaw and van pulling
Travel distances to fetch water	40	Women	Reduced access to water and sanitation facilities; and sexual harassment	Health impact and social insecurity	Use deep tube well and nearby dug wells
Change traditional cropping/agricultural practices	45	Farmer	Decrease agricultural land perennial water bodies	Loss of traditional agricultural practice and species and crops	Increase homestead vegetation and mango cultivation
Social unrest	10	All groups	Political or undue influence to get irrigation schedule during drought;	Loss of social cohesion	N/A
Reduced soil moisture	80	Farmer	Increase water demand for irrigation; increased use of fertilizer	reduce economic capacity/resilience of farmers	Changing crop type (from rice to mango)
Other crisis	30	Poor and subsistence farmers	Less income	Economic stress	Migration

(Source: Field Survey, 2019)

Households face severe drinking water crisis during November-April. Thirty-one percent of respondents collect their drinking water from wells, and nine percent collect from nearby tube-wells. Households use pond water for other daily needs. Female members fetch water from nearby available sources. Households also faces difficulties to maintain healthy hygiene practice due to water scarcity and often exposes to water-borne diseases. Cattle and domestic animal face the food shortage and suffers the drought-infested diseases. To cope with the situation, farmers sell their livestock as their last resort of livelihood. Due to unavailability of water, other household income generating activities such as fishing, duckling, livestock rearing has become challenging.



To cope with the situation, farmers adopt the various strategies, including adopting drought-tolerant rice varieties, shifted their traditional agricultural practice. However, socio-hydrological capacities have supported their resilience to cope with recurring drought (Eslamian *et al.*, 2019).

3-1. Adaptive capacities that support resilience

Physiography: Clay-clayey loam is the most dominant soil category which compares 98% of Sapahar Upazila. The soil characteristics support the increased production of Rabi crops (grows during October to March) such as wheat, mustard, barley, oats, potato; Bengal gram, peas, linseed, lentil, berseem, cabbage and cauliflower. The area of Sapahar Upazila is 24462 hectare and constituted of two major physiography: Barind Tract¹ and Teesta Floodplain. Barind Tract covers 74.6% of the Upazila and is generally 1 to 2 meter higher than floodplain areas. The elevation protects the Unions from seasonal flooding caused by rainfall in the upstream. The mean annual total rainfall is 1477 mm which is 45 percent less than the national average of 2550 mm. However, the rainfall during monsoon plays critical role in groundwater recharge and drought mitigation.

Roads and Infrastructures: 217 km. metalled, 6.61 km. semi metalled and 165 km unmetalled roads are connected with two major growth centers, nine bazars and nearby urban areas. The road connectivity supports farmer to sell their agricultural products in nearby growth centers and cities. Improved transportation and communication support the communities to connect with major cities, hospitals, community clinics, educational institutions, growth centers, bazars and banks and financial institutions.

Land holding characteristics: Agriculture is the major source of income of the household and access to resources. Particularly access to agricultural land plays a critical role in their resilience. Total number of agricultural holders in the study area is 22,548. Out of which owner holder is 19,850, owners cum tenant are 10,766 and tenant holder is 2,461. Out of 24,462 hectares, 19,890 hectares is agricultural land which is 81% of the total land. Land utilization scenario represents those 3190 hectares is single cropped, 9540 hectares is double cropped and 7160 hectares is triple cropped area. As the number of double and triple cropped area has increased, the production has also increased in last twenty years despite the water related stresses.

1. Barind Tract is the largest Pleistocene physiographic unit of the Bay of Bengal and recognized as a unit of old alluvium, different from floodplain.



3-2. Absorptive capacities that support resilience

Socio-economic Characteristics: The majority of the respondents are engaged in agriculture with an experience of more than 20 years. Diversification of earning such as business, agriculture, service and opportunity to migration to urban areas play a critical role to cope with drought and crop failure. About 57% of farmers have monthly earning between \$60 and 100\$. As is observed in Figure 2, only 5% respondents earn above \$230. Thirty-six percent of households reported higher spending than their income, interestingly, belonged to the low-income group. They take a loan from their relatives or relies on the money lending non-profit and microfinance organizations. Sometimes, crop failure attributes to the low production of grains and vegetables. The yield of the crop cannot fulfill the household needs, let alone remaining any surplus to sell in the market. Those who still cultivate their agricultural land during drought possess either a deep tube well or spend the most of their savings for purchasing water for irrigation alongside spending for fertilizer and daily food. It reduces their economic solvency and capacity to cope with any upcoming disasters.

It is found that farmers with multiple experiences of drought events possess a better understanding of socio-hydrological consequences of drought and can make the better decisions to cope with. They explore other means of livelihood, such as selling stocked agricultural commodities and cattle in the local markets and cultivating mango to earn extra money to survive. On the other hand, low-income groups with low education have less capacity to explore the new livelihood opportunities and unable to make informed decisions.

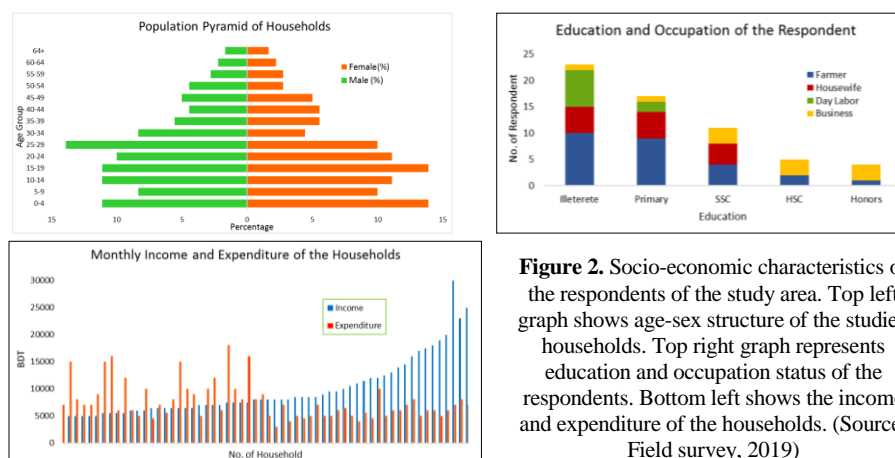


Figure 2. Socio-economic characteristics of the respondents of the study area. Top left graph shows age-sex structure of the studied households. Top right graph represents education and occupation status of the respondents. Bottom left shows the income and expenditure of the households. (Source: Field survey, 2019)



Diversifying Agriculture: About 63% households are farmer and produce the variety of crops such as paddy, wheat, pulses, mustard, potato and different kinds of vegetables. Agro-based tertiary activities such as rice, flour, oil and husking craft mill are found in the study areas (Local Government Division, 2019). Respondents suggested that wheat and potato production declined due to increase of temperature and decrease of rainfall. Besides, mango cultivation has recently flourished and has become a major source of seasonal income. Farmers are more willing to grow mango, maize and corn rather than paddy (UNDP, 2019). Farmers prepare their land for mango and maize as it requires very little amount of water. Besides, mango cultivation provides inter-cropping facilities such as growing mango, wheat, corn and maize in the same land. Mixed cultivation decreases the cost of agriculture and increased their income compared to the traditional crops. Therefore, it has become popular among farmers. Farmers also reported to experiment drought-tolerant fruits, such as date, coconut, Jackfruit. Around 5% of households reported to use the rainwater harvesting technology for meeting their water needs.

Poultry: There are fifty poultry and eighty-three dairy farms in the study area. A survey identified that each household has cattle and livestock species ranging the number from 1 to 15. They include cow, buffalo, goat, sheep. The livestock provides important support to the households during prolonged drought. They sell it in the market which provides them the subsisting income.

Fishing: Livelihood of a large number of households depends on fishing in the river and nearby Jabai Beel¹. Punorbhaba River is also a major source of surface water. Farmers depend on the river and adjacent Jabai Beel for irrigation during monsoon particularly during June to October.

Other social capital (Banks, Non-profit organization and communications): There are seven government and private commercial banks. Commercial farmers acquainted with financial system have access to bank. Besides, farmers reported borrowing money from nationalized and private commercial banks for agricultural to offset the financial crisis. Three major telecommunication companies (Grameen phone, Banglalink and Robi) operate in the Upazila. Expansion of mobile banking has made day to day commercial activities easy for farmers. It saves their time and money for communication as they had to travel to Upazila and District headquarters for financial

1. A Beel is a lake like wet land with static water. Typically, beels are formed by inundation of low lying lands during flooding.



transaction. There are five insurance companies and 19 Non-Government Organizations (NGOs) where farmers save money in small schemes and takes various types of microfinance loans when necessary. Particularly, NGOs help them providing small loans, trainings and information on drought and alternative livelihood generation activities to cope with difficult situation. They provide crucial social protection as well.

Excavation of small water bodies: Apart from the Punarbhaba river and Jabai Beel, there are 3390 pond (126 re excavated) 52 big water bodies and 30 canal (length is 97.325 km of which 8.7 km has been re-excavated) that provides surface water necessary for small household work and agriculture. There are 12995 power pumps, including 632 deep tube wells for irrigation. However, due to over exploitation and climate induced drought, local people listed numerous waters related stresses which are presented in the Table 3. Farmers have also re-excavated their ponds and nearby canals to store water, while some of the well-off households use the electric pump for extracting groundwater.

Institutional support: Early forecast of drought is not available to the farmers in the study area. Survey identified that 70% of the respondent do not know how to adapt effectively with drought. Available Service-oriented infrastructures, such as non-government organization (NGO) and vocational and technical institutes supports in capacity building to cope with drought. There are 31 non-government organization (NGO) operated schools and two vocational and technical institutes enrolling eighteen thousand students that plays a crucial role in generating new ideas for business and income generating activities. Survey identified that 63.33% respondents who are middle-aged, are familiar with previous drought events and the impacts. Despite not having any formal education, they take informed decisions from their past experience. They diversify their agricultural activities such as produce drought tolerant corn varieties instead of paddy. Families having formal education are involved in tertiary activities such as services and business. They also grow increase paddy and mango through adopting new varieties and agricultural techniques. They use ponds and excavate canals for surface water augmentation, use header tanks and buried pipelines for reducing water loss, and irrigate using solar energy.

3-3. Transformative Capacity

3-3-1. Land use Land cover changing pattern of the study area (2000-2020)

During dry season, shallow tube wells become dysfunctional as groundwater level goes down due to over-extraction of water. Therefore, many of the

farmers have changed their traditional agricultural practice. Mixed agriculture has been popular, for example, growing rice and cereals in mango garden. Some of the farmers have converted the land for fish farming by excavating ponds. Changing vegetation cover is identified from the satellite images of 2000-2020 (Figure 3). The maps portray several features such as (a) water bodies, (b) homestead vegetation, (c) cultivated land, (d) settlements, and fallow land in 2000, 2010, and 2020.

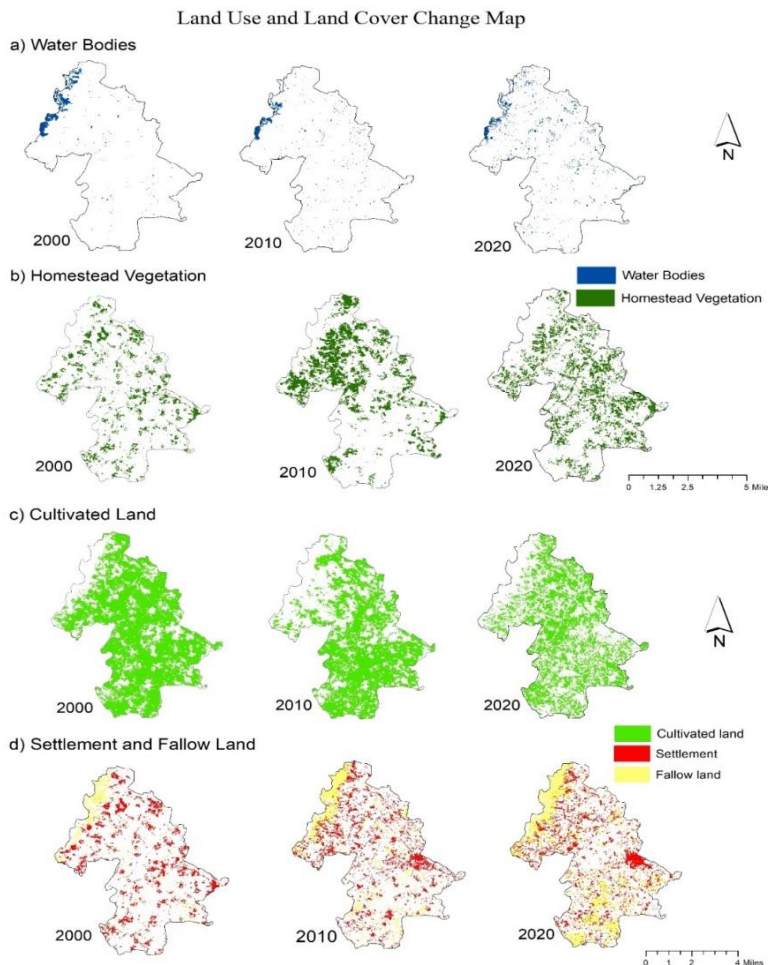


Figure 3. Land Use and Land Cover map of the study area. It shows changes in (a) water bodies, (b) homestead vegetation cover, (c) cultivated land, (d) settlement and fallow land in 2000, 2010 & 2020 (Source: Authors, 2020).

Table 2 shows the LULC changing pattern of the Sapahar and Shironti

union from 2000 to 2020. Positive (+) and Negative (-) sign presents an increase and decrease of particular features respectively. The total area of the study unions is measured as 84.2391 km². As is presented in the Table 2 and Figure 3, the areas of water bodies, homestead vegetation, cultivated land, settlements, and fallow land were 2.2437, 10.989, 57.1527, and 13.8537 km², respectively, in 2000. Due to low rainfall and prolonged drought, the water bodies have been decreased by 0.67% from 2000 to 2010, while the areas increased by 1.36% from 2010 to 2020.

Table 5. Land use Land cover changing pattern of the study area from 2000 to 2020

Land use and land cover categories	2000 Area (sq. km)	2010 Area (sq. km)	2020 Area (sq. km)	2000-2010		2010-2020	
				Changes in area (Sq. km)	Change in area (%)	Changes in area (Sq. km)	Change in area (%)
Water bodies	2.2437	1.6632	2.7972	-0.5805	-0.67%	+1.134	+1.36%
Settlement	9.8901	11.6946	11.9988	+1.8045	+2.26%	+0.3042	+0.36%
Homestead Vegetation	10.989	17.9136	21.2467	+6.9246	+8.23%	+3.3331	+4.18%
Cultivated land	57.1527	43.7499	35.0127	-13.4028	-15.189%	-8.7372	-10.75%
Fallow land	3.9636	8.4852	12.4511	+4.5216	+5.36%	+3.9659	+4.85%

(Source: Author, 2020)

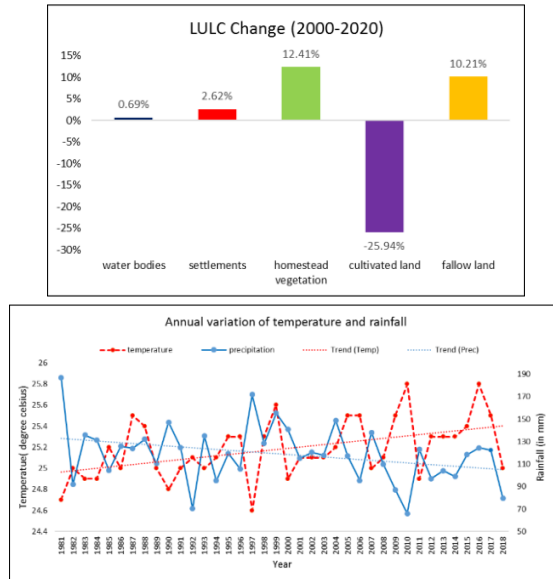


Figure 4. (left) Land use and land cover change from 2000 to 2020 (Source: Author, 2020). (right) Temperature and precipitation in northwest region of Bangladesh from 1981 to 2018 (Source: BMD, 2018).

Figure 4 depicts the spatial changing pattern of land use and land cover in 2020 compared with that in 2000 in a period of 20 years. Overall, homestead vegetation, fallow land, settlement, and water body have been increased by 12.41%, 10.21%, 2.62% and 0.69% over the last two decades respectively. The places have been converted for mango gardening. However, the amount of cultivable land has decreased by 25.94% from 2000 to 2020. Arable crop land has been converted into mango garden. Participants of FGDs informed that a portion of their arable land often remains uncultivated due to drought and water related stresses. The recurrence of drought incidents increased after 2010, therefore, many of the households have altered their traditional crop production into mango cultivation. Mango gardens yield higher than any other traditional crops with better market price that also require less water for cultivation. Overall, four significant changes in land use and land cover have been observed due to drought: (i) a large portion of perennial and natural water bodies has disappeared, (ii) much of the natural water bodies have been converted to ponds that are used for commercial fish farming, (iii) traditional agricultural lands, such as paddy fields, have been decreased, and (iv) agricultural lands have been converted into homestead vegetation cover. Furthermore, a range of impacts of drought in different contexts and their coping strategies are briefly described in Table 3.

4. Conclusions

The study area experiences drought every year from October to April. Major economic sectors are impacted by water-related stresses. No significant government activities are available to address the challenges posed by drought and water-related stresses. Change that occurs at individual level is not transmitted to encourage learning and broaden participation. Besides, strategies need to best utilize the available local knowledge and augment the practices through local government institutions such as Ministry of Disaster Management and Relief. Measures from Ministry of Agriculture is also required to (a) subsidizing farmers to increase their access to water during drought; (b) and promoting drought tolerant species and short-lived crop; (c) capacity building activities for farmers to cope with water related stresses and promote the rainwater harvesting systems. Strong interrelationship between government and non-government organizations and scientists is also prerequisite to facilitate an effective adaptation policy. Integrated approach will help farmers not to leave their traditional agricultural practice. In this backdrop, the study will provide information about the dynamics of the socio-

hydrological crisis and opportunities to the policymakers to assist the local people to enhance their resilience.

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