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The impact of climate change on ecosystem services and socio-economic conditions of Char Dwellers in Northern Regions of Bangladesh

Mst. Amena Khatun[1*], Md. Abdul Baten[2], Murad Ahmed Farukh[3], Md. Omar Faruk[4]
Bangladesh Rural Development Board, Dhaka, Bangladesh[1*]
Department of Environmental Science, Bangladesh Meteorological Department, Dhaka[2,3]
Assistant Communication Engineer, Bangladesh Meteorological Department, Dhaka[4]
amena.khatun592@gmail.com[1], baten_envsc@yahoo.com[2], farukh_envsc@bau.edu.bd[3], omarfaruk_1864@yahoo.com[4]*

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Abstract
Purpose: The proposed livelihood framework approach facilitates an understanding of the linkages between char livelihood strategies, asset status, and the way of using available natural resources.
Research methodology: The study was conducted by a Questionnaire interview, Focus Group Discussion, Key Informant Interviews, and secondary data. Climatic factors like varying temperature, rainfall, sunshine, and wind speed were detailed studied.
Results: In this study, we identified several indicators viz., five livelihood capitals (human, natural, social, physical, and financial) that are vulnerable now but have a prospectus, climatic disaster, and threat that faced with char dwellers are floods, riverbank erosion, thunder, heatwave, cold wave, and erratic rainfall. Finally, the present status of the Ecosystem Services negatively impacts livelihood and agricultural practices.
Limitations: Sustainable livelihoods do not support analysis of political economy factors and the future difficulties of climate change are a significant worry for the reasonable development of the locale are the major limitations of the research.
Contribution: This study will be contributing achievement of ecosystem management the executives in agricultural nations like Bangladesh e.g. subject to Good Governance and the current strength of biodiversity and environment elements.
Keywords: Bangladesh, Char land, Climate change, Climatic factors, Ecosystem services, Livelihoods
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1. Introduction

The char lands in Bangladesh are regularly perceived as an area of multiple vulnerabilities (Paul & Islam, 2015). Among the various agro-ecological zones and hydrological regions of the country, the chars are particularly susceptible to natural hazards, like floods, erosion and drought, low and volatile land, remoteness from the mainland areas, and lack of extension and support services (Mondal *et al.*, 2015). In the Char area vulnerability to global climate change is non-climatic factors (endemic poverty, hunger, high prevalence of disease, chronic conflicts, low levels of development, and low adaptive capacity) the foremost vulnerable sectors agriculture, biodiversity, water, health, forests, and energy (FAO, 2005).

The ecosystem is defined due to the fact of complexity of living communities & non-living components of their surroundings interacting as a functional unit to interchanged during a largely cyclical manner and providing a diversity of blessings to humans (Tansley, 1935; Molles, 1999; Chapin *et al*., 2002; Schulze *et al*., 2005; Gurevitch *et al*., 2006; Smith & Smith, 2012). Ecosystem Services (ES) are described due to the blessings received from the surroundings for the person (Daily, 1997; Costanza *et al*., 1997; Groot *et al*., 2002; MEA, 2005). Nature provides four types of ecosystem services (TEEB, 2010; MEA, 2005) e.g. provisioning, regulating, cultural, and supporting that directly influence human and supporting services which are wished to attend to different services (Finlayson *et al*., 2005). The first one is that the provisioning as direct services, extracted from ecosystem processes e.g. food, timber, woods, etc. Secondly, the regulatory as indirect services e.g. climate regulation, disaster risk reduction, erosion prevention, etc. Thirdly, cultural services such as aesthetic like spiritual, education, recreation, eco-tourism & sense of place, etc. and eventually supporting services as partially e.g. soil formation and retention, nutrient cycling, water cycling and habitats for species, etc. (Wang *et al*., 2014; Groot *et al*., 2002; Lette and Boo, 2002).

Now a day's these services are highly vulnerable tanks to natural and anthropogenic causes and are decreasing day by day (MEA, 2005; TEEB, 2010; Nahar, 2013; Morshed, 2013). To make sure a balanced understanding of the complex link between global climate change, ES, and livelihoods we should be a clear concept about a) Human Ecological Approach (HEA), b) social traits in their environment and consequently the biosphere (Lawrence RJ, 2003). Global climate change scenarios suggest that there'll be considerable impacts on ecosystems and their associated ES with extreme effects for the livelihoods of communities, particularly within the most economically challenged components of the planet (IPCC, 2001; Agrawal & Perrin, 2008; Van de Sand, 2012).

The northern region of Bangladesh, a rather slopped plain area may be a food surplus production area, where agriculture is the principal source of employment. Excess rainfall subsequent runoff, sedimentation in the rivers, deforestation, landslide, improper drainage, unplanned road and water management infrastructure, low agricultural wages, and the effect of climate variability may be considered as the main reasons for the devastation due to flash floods. Despite this, an outsized number of populations remain food insecure, social, immoral, and political instability, and insecurity pushed them to a vicious circle of poverty. The Northern region has long been lagging behind mainstream national development although the economic development of Bangladesh is moving steadily at a moderate pace. The authorities have taken many tasks along with the guidance of countrywide and nearby techniques to persuade economic growth and has as a consequence organized plans through the years to boost the country's development. It is difficult to foresee the country's overall progress without the development of the Northern region as it covers a major part of the country and population which deserves unique improvement initiatives. The future challenges in the context of climate change are also a first-rate challenge for the sustainable development of the region.

This study aims to fill this gap by integrating a) climate change affect ES and b) climate change effect on char dwellers' livelihood as well as socio-economy in the northern regions of Bangladesh. According to the logic of the capital-based approach, however, this article is designed to assess the evolving risk to char livelihoods resulting from rapid climate variability, partisan state policies, inadequate infrastructural and institutional arrangements, etc. This article, however, is assessed through the lens of undermining economic capital, human capital, social capital, physical capital, and natural capital. Besides, climatic stressors, scarce rainfalls, excessive rainfalls, high temperatures, and delayed rains the risk and weakens of the rural livelihood resilience to climatic and anthropogenic disturbances. Hence, improved technology and infrastructures, strengthening social supports, and diversification of people's activities and assets can uplift livelihood opportunities (Ellis, 2000; Carr, 2013; Reed *et al*., 2013).

2. Literature review

The impact of climate change on ES and livelihood

In Bangladesh, several studies reported climate change, natural disasters, migration, and livelihood (Hutton & Haque, 2003; Baki & Gan, 2012; Kelman & Khan, 2013; Islam & Hossain, 2014; Paul & Islam, 2015; Islam & Hasan, 2016). A range of authors (Turton, 2000; Knutsson & Ostwald, 2006;

Amos *et al.*, 2015). using the Sustainable Livelihood Approach (SLA) were assessed livelihood vulnerability in comparison with five livelihood assets, human, financial, physical, natural, and social capital. The degree of vulnerability depends on ecological, socio-cultural, and financial-political views (Hesselberg and Yaro, 2006). Ribot (1995) showed that social causality and physical processes are interlinked. This paper best considers the literature which demonstrates that climate change has an effect on ES and livelihood in the northern char areas of Bangladesh. During the last decade, Bangladesh has achieved remarkable progress in terms of poverty reduction owing to steady economic growth and strong bilateral and multilateral support along with the government. Determining the economic value of char land is crucial whilst developing sustainable char land development plans and market-based ecological protection strategies. Provisioning ecosystem services (Crops and livestock) have been negatively affected by climate change and landscape change (Musakwa, Mpofu & Nyathi, 2020). ES is extensively laid low with human activities (Pereira, 2020). The char dwellers in northern regions are the most vulnerable in terms of extreme poverty due to climate change negatively affecting the ES in particular Provisioning Services reason for poverty, miseries, vulnerability, and their livelihood.

Char dwellers encountered multiple assorted reasons diverse with climate change, natural disasters, and socio-economic vulnerabilities that are more desirable than their choice to migrate. Seasonal floods, riverbank erosion, lack of employment, and cash deficits were prominent factors for char dwellers' migration (Islam, 2018). There is a lack of employment opportunities, isolation from the mainland is considered as most of the key factors for poverty, misery, and distress. Lack of modern cultivation knowledge, technology deficit, and crop diversification was revealed as another source of poverty and vulnerability of the char areas. Wetland ES, the drivers of change, and the influences of those drivers on ES and peoples are highly dependent on these livelihood strategies sourced from ES (Bhatta, 2016). By providing proper forecasting, training, and raising awareness an economic imperative is elaborated which can help permanently protect natural capital in rural areas and successively safeguard human wellbeing, sustainable economic development as well as social wealth (Haaren, 2015). Limburg *et al.* (2002) reported that most functions and related ecosystem processes are inter-linked, sustainable use levels should be determined under complex system conditions, taking due to account the dynamic interactions between functions, values, and processes (Boumans *et al.*, 2002). Socio-cultural value, ecological criteria, social values (such as equity), perceptions play an important role in determining the importance of natural ecosystems and their functions for the betterment of human society. Mehring *et al.* (2017) advocated the adoption of a social-ecological perspective for current research on ES supply and demand, so on affect these context unique temporal and spatial dynamics. Ecosystems and their services are sustainable stewardship from central to local governance arrangements. These governance arrangements are based on participatory approaches protecting tribal rights and prioritizing self-sufficiency and the use of sustainable resources (Everard *et al.*, 2021).

In the context of global climate change, the Intergovernmental Panel on global climate change (IPCC) adopts a variant of this definition, stated because the degree to which a system is vulnerable and/or unable to deal with adverse effects of global climate change, including climate variability and level of extremeness (IPCC, 2007). High temperature, flooding, and irregular rainfall pattern affects the paddy cultivation and winter crop production which also increased pest and pathogen prevalence, quite local adaptation strategies, like changing both agricultural practices and water harvesting and management. To increase the adaptive capacity of poor households, Bhatta *et al.*, (2015) suggested it's essential to incorporate global climate change adaptations within the local planning process. Global climate change impacts are decreasing the potential of the ecosystem to provide essential services to the communities. The principal livelihood sources affected by the worldwide global climate change impacts are agriculture, forest resources, and water resources to attenuate the communities around the reserve. Various adaptation techniques and cropping strategies to strengthen agriculture, biodiversity conservation, and also water resources management are stated by Boon and Ahenkan, (2012).

Impacts on food production and food security

The northern char area is vulnerable against climate occurrences such as drought, floods, temperature, and rainfall variability. This vulnerability of the ecosystem impacts negatively on the livelihoods of the char dwellers. Despite this gloomy picture on rainfall availability, agriculture remains the predominant

option for the communities in the basin (Magadza, 2010; Mubaya and Ndebele-Murisa, 2017). Also, local business sectors progressively vacillate under increased demand for agrarian items, bringing to the front the significant issue of broad money-related and environmental risks. The volatility of the macroeconomic and general policy environments in the country worsen the situation and exacerbate agriculture and agrarian-based livelihood failure. The resulting extending interest for food requires an adjustment of the scene practices and is more capable and innocuous to the ecosystem food production (Moyo & Chambati, 2013). The highlighted multiple stressors context, which also incorporates population growth, has triggered disproportionate pressure on the agriculture sector for more prominent amounts of food (protein), animal feed, biofuels, and fibers. This developing interest in food security (Campos, 2012) and improved livelihood can best be met through an innovative systemic approach to the environment and technology nexus. Besides, with climate change added to the image, there isn't just expanded tension on agribusiness yet trade-offs among different land uses, like a contest for arable land, water, fisheries, minerals, and other regular assets. Diminished water levels, impedance with regular stream systems, and stream channel morphology through the development of enormous repositories for hydropower creation and the going with the fake flood (Tista barez) conveys also impact the inhabitant and fleeting untamed existence of the area, provoking potential human-normal life conflicts in the bowl. Those progressions have incredible importance for security, food production, and energy dynamics.

Climate change impacts may reduce income level and stability, through effects on productivity, production costs, or prices. Such variations can drive deals of useful capital, like dairy cattle, which decreases long-term household productive capacity. Exposure to risks lowers incentives to invest in production systems, often with negative impacts on long-term productivity, returns, and sustainability. Decreases and dangers to agricultural income have also been shown to have effects on household capacity and willingness to spend on health and education. Proof from continuous assessments of the impacts of various kinds of environmental irregularities on-farm pay exhibits that the impacts are generally conspicuous for the most unlucky farmers (FAO, 2015). Climate change impacts on agro-farming are related to impacts on human well-being and government assistance. Changes in crop yields will impact crop costs and climate change brings about extra cost increments of harvests (Nelson *et al*., 2009). Change in farming frameworks, driven by financial changes, ozone-depleting substance discharges, rural approaches, and different elements, is likewise influencing normal and managed ecosystems (Zaehle *et al*., 2007). Thusly, cornerstone ecosystem services such as carbon sequestration, water flow regulation, food, and fiber production are impacted by these changes. These two connecting natural issues as such can possibly truly sabotage the limit of multifunctional scenes to give the variety of fundamental ecosystem services (Rickebusch *et al*., 2011).

Key to the evaluation is the likelihood that individuals don't relocate due to climate change considering everything, but since of the way where climate change impacts their occupations, food security, and achievement (Afifi *et al*., 2016). Climate change can influence the idea of drinking water, which is basic to the incredible maintenance of enhancements, disinfection, particularly on the rate and regularity of food-borne ailments. Extended climate alterability, extended repeat, and power of ludicrous events similarly as drowsy nonstop changes will impact the steadfastness of food supply, access, and utilization. Climate change influences catch fisheries and the advancement of hydroponics in marine and freshwater conditions. Effects occur due to both perpetual climatic warming and related physical (ocean and inland water surface temperature, sea spread, waves, and tempest frameworks) and manufactured changes (pungency content, oxygen concentration, and maturation) of the maritime environment (FAO, 2015).

Impacts on social security

In October 2003 a report to the US Department of Defense (Schwartz & Randall 2003) got wide open consideration for giving a bleak future situation fighting states and enormous social aggravation because of dramatic climate change. The authors battled that their scenario was not only plausible but also that it would challenge US public safety inhabits that ought to be thought about right away. A few years later, eleven resigned US commanders and chief naval officers added more military position to the issue, contending that 'climate change can go about as a danger multiplier for unsteadiness in probably the most unpredictable locales of the world' and that this 'presents critical public safety challenges for the

United States' (CNA, 2007). Meanwhile, the German Ministry of the Environment (2002) stated that 'evidence is mounting that the adverse effects of climate change can, particularly by interaction with a number of socio-economic factors, contribute to the increasing potential for conflict', an argument later extended by the German Advisory Council on Global Change (WBGU, 2008). Climate change arrived at the most elevated level of the security plan in 2007, when the United Kingdom utilized its situation as the seat of the United Nations Security Council to put the issue before the Council. Foreign Secretary Margaret Beckett contended that the effects of climate change, like yield disappointment and waiting dry season, ocean level changes, and waterway bowl debasement 'went ... to the actual heart of the security plan' (UN, 2007). The President of the World Bank, Jim Yong Kim, promised to make climate change a priority of his 5-year term and warned that there will be water and food fights everywhere ...'. Various NGOs have repeated similar claims. Many academics such as (Bachler, 1999; Barnett, 2003 & Suhrke, 1997) have voiced more nuanced and skeptical views. The report by the German Advisory Council on Global Change (WBGU 2008) offers a complete rundown of a large part of the writing and disputes for and against the ecological change-security nexus. The vulnerability of climate forecasts and the exceptionally conditional nature of contention expectation join to make the investigation of the security ramifications of climate change an overwhelming errand. As of late, be that as it may, a companion checked on writing regarding the matter has started to arise (Nordas and Gleditsch, 2007; Burke *et al*., 2009; Buhaug, 2010; Theisen, 2012 & Scheffran *et al.*, 2012), and various exploration projects are currently underway. If taken seriously by the main premise providers of the climate-security debate, this new work could shift the debate to more nuanced and evidence-based predictions and recommendations.

Problems and possibilities for a climate–security

The trading off of military security for environmental security, or increased resources and energy to environmental security has not been. Instead, environmental change problems have been militarized; the emphasis has been placed on the environmental change as the cause of violent conflict rather than human insecurity; and on exogenous environmental threats to the state for which unspecified Others were seen to be responsible, as opposed to attending to domestic causes of environmental change (Barnett, 2001). So, understanding climate change as a security issue risks making it a military rather than a foreign policy problem and sovereignty rather than a global commons problem. This might help legitimize further getting of the unsustainable livelihoods of the North in the method of George Bush Snr at the United Nations Conference on Development in 1992, and George W Bush over the Kyoto Protocol. It might likewise prompt attention on getting an area against unwanted thump on impacts of climate effects like ecological displaced people, and on planning for clashes in significant exchanging regions the method of the arrangement of the US fast Deployment Force after the OPEC oil emergencies of the mid-1970s. Regardless of these issues with any potential climate change security talk, it might, in any case, have some utility.

Security imparts a specific gravitas that is apparently vital in climate change strategy. In that climate change is a security issue for specific gatherings, recognizing it as such proposes that it is an issue that warrants a strategy reaction proportionate in exertion if not in kind with war. A basic and uncertain idea in the UNFCCC is its reference to 'perilous' levels of environmental change. Security encapsulates danger much better than concepts like sustainability, vulnerability, or adaptation, and it offers a framework in which danger can be recast as widespread risks to welfare and (in the case of small island states) sovereignty. Security can also serve as an integrative concept that links local (human security), national (national security), and global international security) levels of environmental change and 3 responses. It also integrates mitigation and adaptation as both are essential to security from climate risks. Finally, understanding processes that render insecurity, of which climate change is an important but not isolated factor, brings to the fore issues of justice and the global political economy. Although it should not be overstated, security addresses the possibility of violent social upheaval, and it brings military expenditure and its environmental impacts into the decision-making framework. The ability of conventional national security discourse and policy to appropriate climate change is a matter of how climate security risks are understood, and who talks about them. Through a grounding in the findings of the Intergovernmental Panel on Climate Change, a climate-change-security discourse could better resist appropriation from conventional national security as its key concerns will be rooted in respectable

science rather than conjecture. If used by IPCC scientists a change-security discourse will have a legitimacy that renders it less amenable to appropriation and rewriting by conventional national security institutions. If such a discourse downplayed and was cautious on the issue of violent conflict and refugees, and if it pointed to the justice issues that attend climate change insecurities, then it might helpfully integrate science and policy and usefully elucidate the nature of the 'danger' that the UNFCCC ultimately seeks to avoid.

From the above circumstances, it can be concluded that most of the research has been taken into consideration the problem of migration difficult with physical instability which includes housing and settlement, agricultural damages such as flood and erosion. But very few have comprehensively examined climate change and natural disasters negatively affect provisioning services that are vulnerable particularly socio-economic status for the char dwellers strain migration decisions. Considering the above-mentioned facts, this study has been undertaken to strengthen our understanding of the relationships between ecosystem services and poverty alleviation that negatively affect climatic factors. The research will produce new insight into identified frameworks that have a variety of purposes and applications basis of Sustainable livelihood also identification of valuation of ES in northern char regions of Bangladesh.

3. Research methodology

Study area

A total of 23.27% area covered in northern regions of Bangladesh is situated in the Tista and Jamuna basin and contains many tributaries of these, specially Lalmonirhat, Kurigram, Gaibandha, districts. The following three char land/area was selected according to population Size, area coverage, crop production capacity, vehicle facility, and Govt., Non-govt, and other activity availability.

Data collection

Primary data were collected from 400 Participants among three districts char. Various Govt. and non-Govt departments/stakeholders/service providers, staff, beneficiaries, and other relevant stakeholders were directly and indirectly associated with livelihood and climate-related issues from August 2019 to May 2020.

For objectives 1) to examine major livelihood activities

Checklists and the face-to-face questionnaires survey were conducted for identifying the individual ES. Checklists, preliminary discussions with communities, questionnaires survey, and FGD were also conducted to know the present status of ES.

For objectives 2) to assess the economic values of utilized Provisioning Services

a) Changes in climate and natural hazards (changes in temperature, rainfall, sunshine, humidity, wind speed, etc.) were measured by secondary data of BMD. b) perceived impacts on livelihoods (major natural hazards to livelihood resources, char products availability and effects on agriculture practices and production), c) role of local institutions and governance through FGDs, key informant discussion, and questionnaire was carried out at household and community level.

For objectives 3) to know the types of climate change and natural disaster-related threats

A questionnaires survey was conducted in 320 households. Key personal informants helped to guide and previous reports of NGOs were also used to select the most vulnerable areas/chars. Five Focus Group Discussion (FGDs) were conducted for livelihood activities. Questionnaires survey, key informant interviews (KIIs), and FGD were successfully conducted.

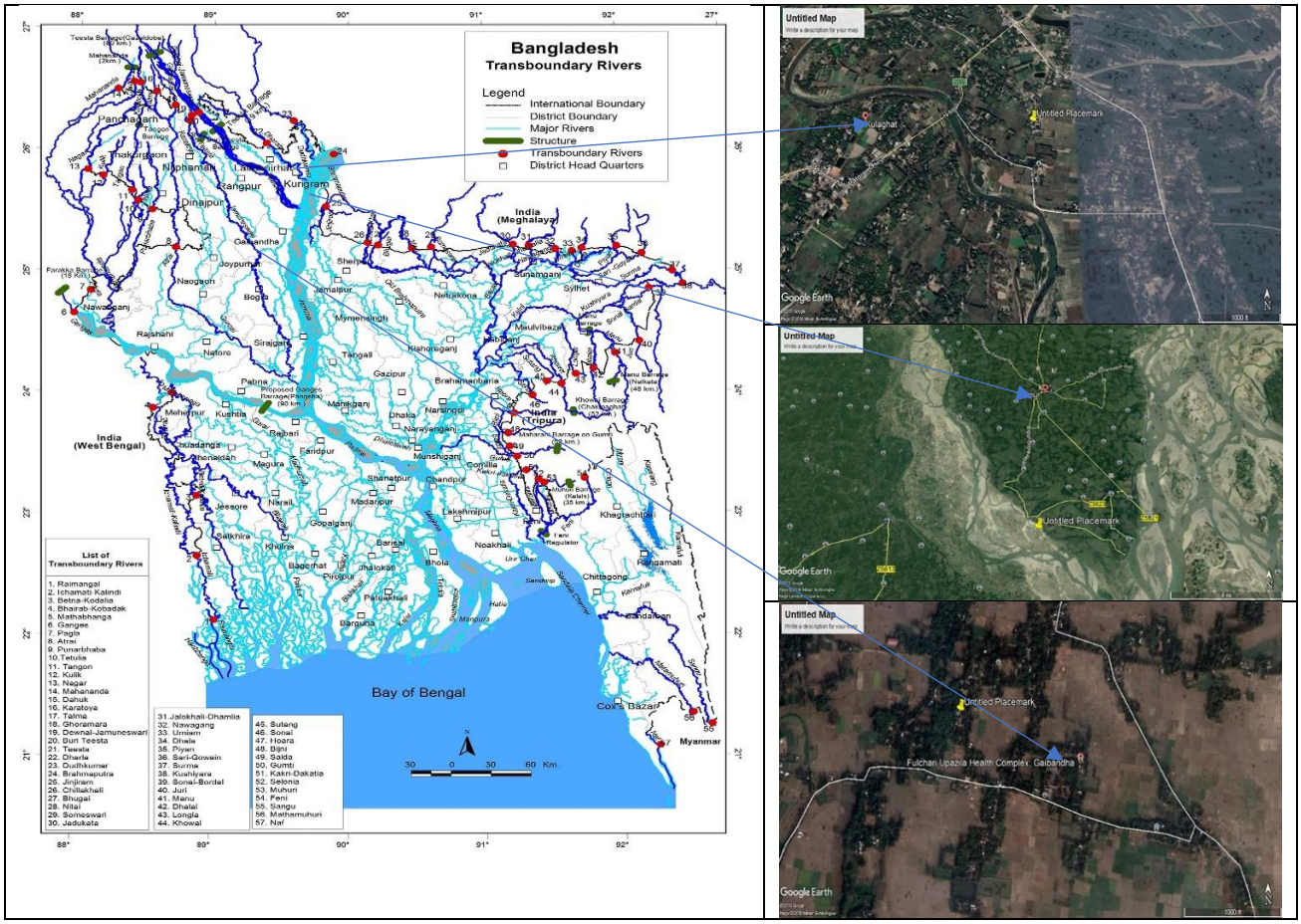


Figure 1**.** Map of Bangladesh; A. South Shivkuthir, B. South Char Bazra, Char Tangrakandy from Google Earth.

Data analysis

Secondary data were collected from different journals, reports, research papers, websites, government, and non-government organizations. The obtained data processed Statistical Package for the Social Sciences (SPSS, version 25) for graphs and charts and MS Excel (2019). Adobe Photoshop, Adobe Illustrator, Visio Drawing, and 3D Paint were used to process data into necessary information.

4. Results and discussion

Char land ecosystem services

In the study area, all respondents mentioned that most of these people are victims of river breakage or homeless and occupational farmers or fishermen. The soil here is enriched during the monsoon which makes it suitable for growing rice, watermelon, nuts, vegetables, and many different crops. The grass on the chars provides land for cattle grazing. It was noticed that 99% of char dwellers reared domestic animals on these grassy fields. Fishermen go out to the rivers right next to the char to work. In the study area, respondents were asked about the valuation and importance of ES. 99% of respondents didn't know the most important services of the ecosystem, like fish or goat, were bought and sold in markets but some ecosystem services, wildlife viewing or a view of the river, were not traded in markets. 35% of respondents argued that they didn't pay directly for many ES because people are not familiar with purchasing such goods. It does not mean that ecosystems or their services have no value, or cannot be valued in economic (BDT) terms.

Table 1. Ranking of ES, examples of economic good, and present status of the services (Lower number indicates the higher preference).

ES value		Examples of economic goods provided	Ranking		Status of the services
Provisioning	Direct use value Material benefit	Food (e.g. Production of fish, wild game/hunting, fruits, and grains)	agricultural production; 1		Increase production but some indigenous species are lost
			fish; 1		Increase production but some indigenous species are lost
		Water (e.g. Storage and retention of water for domestic, industrial, and agricultural use)	domestic use	2	Groundwater table 93%
			irrigational		Shallow tube wells 95%
			aquatic production		Surface Runoff (90%) and groundwater table (10%)
		Raw Materials (e.g. fibers, fodder, peat timber, fuelwood, fertilizer, construction material, etc.)	fibers	3	Loss of indigenous species
			fuelwood		Loss of indigenous species
			fodder		Increase production
			Natural fertilizer source; 7		Decrease
			peat timber		Decrease
		Ornamental resources species	aquarium fish and plants like lotus, pani singara, etc.; 8		Decrease
		Transport (e.g. Wetlands are a source of navigation)	Small boat; 9		Main transport due to increase flooding.
		Natural medicinal resources (e.g. extraction of medicines and other materials from biota)	natural medicines; 7		Decrease
	Option value	Genetic resources (e.g. biochemical production models and test-organisms, genes for resistance to plant pathogens)	resistance plant pathogens species; 7		Decrease
Regulating	Indirect use value	Air quality regulation (e.g., capturing dust particles)	1		High
		Moderation of extreme events (e.g. storm protection, flood prevention, riverbank erosion, fire prevention)	2		Frequency becoming worse more
		Climate regulation (e.g. Source of the sink for greenhouse gases, influence local and regional temperature, rainfall, and other climatic processes incl. Carbon sequestration, maintenance of humidity patterns)	2		Getting worse day by day
		Regulation of water flows/hydrological regimes (natural drainage, floodplain function, storage of water for agriculture or industry, drought prevention, groundwater recharge/discharge)	2		Getting down day by day
		Water purification/detoxify cation/waste treatment/pollution Control (e.g. retention, recovery, removal of excess nutrients and other pollutants)	3		Not so bad but sometimes people throw up the dead body of an animal
		Erosion prevention (e.g. retention of soils and sediments)			Frequency becoming worse more and uneven
		Soil formation/conservation (e.g. sediment retention and accumulation of organic matter)	4		High
		Pollination (e.g. habitat for pollinators)	1		High

		Biological control (e.g. seed dispersal, pest species, and disease control	4	High
Cultural	Direct use value Nonmaterial benefit	Swimming, recreational fishing, sightseeing Aesthetic (e.g. appreciation of natural scenery, other than through deliberate recreational activities)	5	Good
		Recreation & tourism/Ecotourism, Wilderness (remote-non-use) (e.g. Opportunities for tourism and recreational activities)	6	Not arranged but the high possibility
		Spiritual & artistic inspiration (e.g. source of inspiration; many religions attach spiritual, scared and religious values to aspects of wetland and forest ecosystems, songs), Cultural heritage	5	Not arranged but the high possibility
		identity (e.g. sense of place and belonging)	7	
	Non-use	Educational (e.g. Opportunities for formal and informal education and training) matter for research, artistic representations	6	Less done but becoming essential
Supporting (Extra abiotic)	Direct	Extraction of sand gravel, hydropower generation, Biodiversity, and Nursery service (e.g. habitats for resident or transient species)	2	Very good condition but unutilized
	Option	Gene pool protection/endangered species protection	4	Very good source
	Indirect	Nutrient cycling (e.g. Storage, recycling, processing, and acquisition of nutrients)	1	Very good condition but unutilized

Climate change in northern char area

Changes in temperature

In (figure 2a), shows that the increasing trend of daily maximum temperatures about 1.5°C. Whereas daily minimum temperatures trend in lightly decrease (Figure 2b) from the Bangladesh Meteorological Department (BMD) over the period 1970–2019.

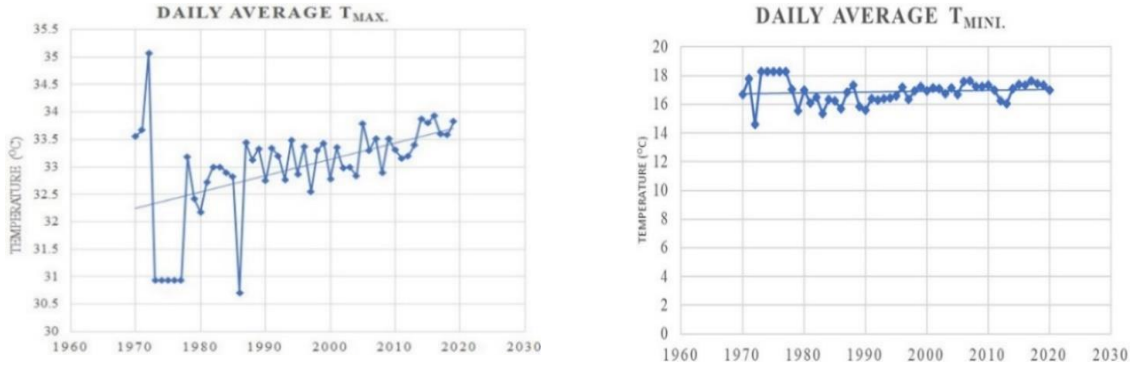


Figure 2. The figure shows a variation in (a) increasing trends of daily $T_{MAX.}$ (^{0}C), (b) decreasing trends of daily $T_{MINI.}$ (^{0}C) from the BMD over the period 1970-2019 in the Rangpur division

We know that every 1 °C increase in temperature results in a 10% decline in crop production/yield. So, it's one of the most important climatic factors that damage due to changes in the ecosystem service.

Changes in rainfall pattern

Table 2 below shows the recorded change in precipitation for the last 50 years. The mean annual precipitation in the Rangpur division from 1970 to 2019 is 175.60 mm in the Rangpur division, the monsoon precipitation has seen an increase over time, especially from the '80s to the 90s' (476.1mm in June-September). The data also show that there has been an increase in the total annual precipitation in

the ‘2000s’ century and that was due to increased precipitation in the Pre-monsoon, monsoon, and Post monsoon, while the pre-and post-monsoon periods have been dryer than in the ‘2010s to 2019s’.

Table 2. Changes in average rainfall patterns (in mm) from 1970 to 2019 in the Rangpur Division (BMD).

Years	Average annual	Winter (Dec–Feb)	Pre-monsoon (Mar-May)	Monsoon (Jun-Sep)	Post -monsoon (Oct–Nov)
1970-79	160.819	6.57	105.67	360.5	68.75
1980-89	193.434	11.33	145.5	476.1	63.2
1990-99	185.833	11.23	119.83	413.05	92.3
2000-2009	192.85	7.6	156.53	388.175	134.55
2010-2019	145.0746	4.96	132.03	312.83	39.29032

Changes in sunshine hours

The decreasing rate of daily average sunshine (hours) was recorded in the Rangpur division. Meteorological daily sunshine hours (Figure 3) data shows that about 1.5 hours decreasing rate from the Bangladesh Meteorological Department in the Rangpur division.

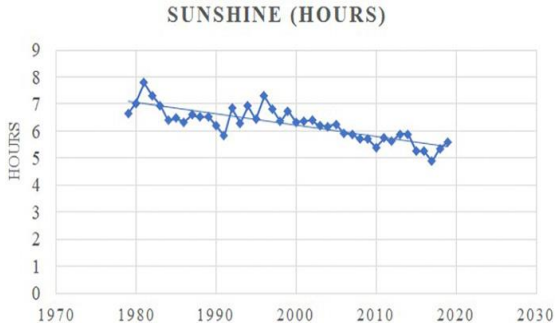


Figure 3. The figure shows a decreasing trend of Sunshine (Hours) over the period 1979-2019 from the BMD in the Rangpur division.

Changes in relative humidity

The daily average relative humidity was found to gradually decrease in the Rangpur division (Figure 4). Meteorological daily relative humidity (%) data shows in 1970 it was above 80% but in 2019 it declines below 80% that was about 5% from the Bangladesh Meteorological Department in the Rangpur division.

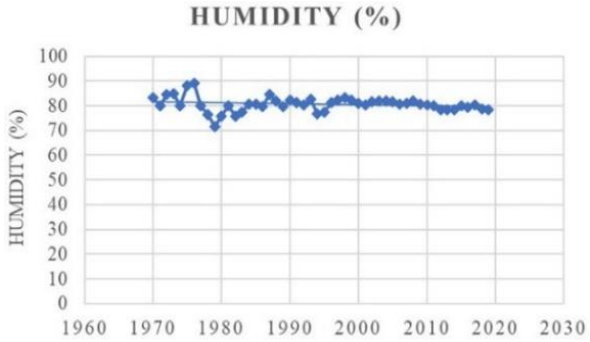


Figure 4. The figure shows declining trends of relative humidity (%) over the period 1970-2019 from the BMD in the Rangpur division.

Changes in wind speed

The daily average wind speed was found to gradually increase in the Rangpur division (Figure 5). Meteorological daily wind speed data shows that about 0.8 m/s increases from the Bangladesh Meteorological Department in the Rangpur division.

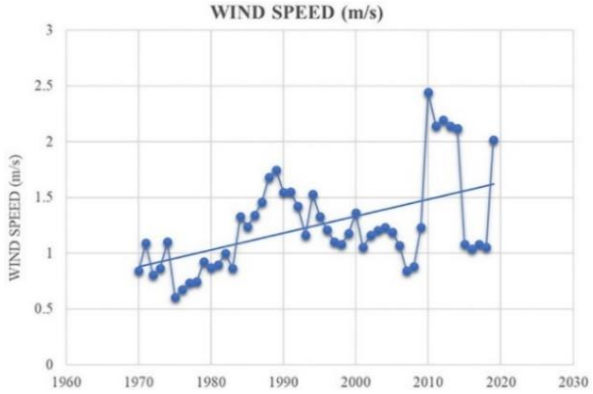


Figure 5. The figure shows increasing trends of wind speed (m/s) over the period 1970-2019 from the BMD in the Rangpur division.

Socio-economic conditions of the char dwellers

The study identified five capitals of livelihood (a) human capital include age 31-40 is the highest, family size and type medium (60%, 62%, and 65%), and education illiterate (18%, 20%, and 27%%), able to sign (29%, 34%, and 29%), in South Shivkuthir, Char Bazra, and Char Tangrakandy respectively. (b) social capital comprises households with no conflict, conflict resolving attitude, collective effort and local organizational members (70%, 69%, and 72%) of the respondents had the medium effect in South Shivkuthir, Char Bazra, and Char Tangrakandy respectively. (c) natural capital consists of the use of natural resources (land, sunshine, etc.) are high Possibility, (d) financial capital includes annual income 60%, 56%, and 58% income 30001 to 40000 BDT in South Shivkuthir, Char Bazra, and Char Tangrakandy respectively, loan and training, and (e) physical capital housing condition 60%, 62%, and 65% households of the char dwellers made tin-shed with tin walls, sanitation system 75%, 72, and 78% of toilets solves pit Latin, drinking water system 50%, 47%, and 48% used shared tube-well, health condition 55%, 60%, and 54% of the households were dependent on village doctors in South Shivkuthir, Char Bazra, and Char Tangrakandy respectively, digitalization (a mobile owner) 99% in each char.

Status of different capital:

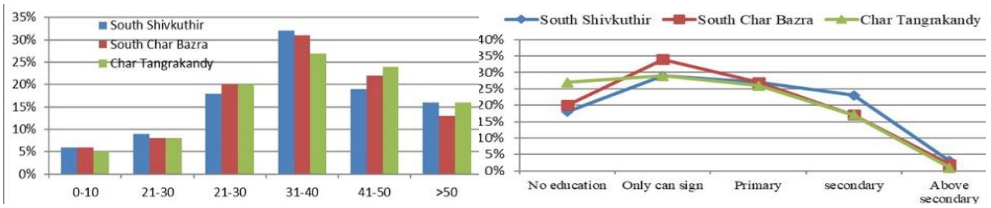
Capital	Diagram
Human capital -Age structure -Educational status -Religion and marital status -Family size and types	

Figure 6. The age group and Figure 7. Educational status in the study area

Table 3. Family Size and types of the study area:

Variables	South Shivkuthir (N=100)	%	Char Bazra (N=110)	%	Char Tangrakandy (N=110)	%
Large family >7 members	30	30	31	28	29	26
Medium Family (4-7) members	60	60	68	62	71	65
Small family (2-4) members	10	10	11	10	10	9
Household expenditure on food <3000 tk one month	58	58	66	60	68	62

	3001-4000 tk one month	37	37	40	36	39	35
	>5000 tk one month	5	5	4	4	3	3
	Household expenditure on education <100 tk one year	58	58	66	60	60	55
	101-200 tk one year	33	33	36	33	41	37
	>200 tk one year	9	9	8	7	9	8

Natural capital
-Soil
-River
-Water
-Tree
-Sunshine
-Fresh air
-Biological resources

Figure 8. Solar Panel, Sunny day Fertile land in South Shivkuthir, Char Bazra, Char Tangrakandy respectively

Financial capital
-Occupational status
-Annual income
-Credit access

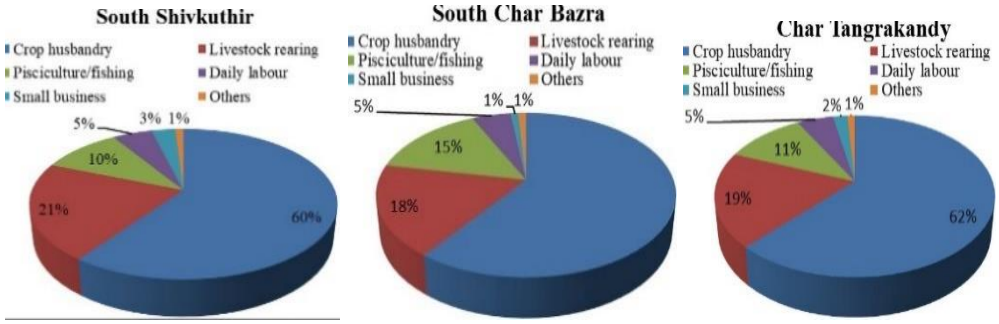


Figure 9. Occupational status in the study area.

Table 4. Annual Income in the study area:

Categories (BDT)	South Shivkuthir		Char Bazra		Char Tangrakandy	
	(N=100	%	(N=110)	%	(N=110)	%
20000 – 30000	19	19	24	22	22	20
30001 - 40000	60	60	62	56	64	58
40001 - 50000	11	11	13	12	17	15
50001 - 60000	6	6	8	7	5	5
>60001	4	4	3	3	2	2

Physical capital
-Housing condition
-Drinking-water facilities
-Health facilities
-Digitalization

Table 5. Health and Sanitary Facilities in the study area:

Facilities	South Shivkuthir		Char Bazra		Char Tangrakandy	
	N=100	%	N=110	%	N=110	%
Village doctors	55	55	66	60	59	54
Upazila health complex	40	40	39	35	45	41
Family planning	98	98	104	95	107	97
Vaccination	98	98	104	95	107	97
Maternal/infant mortality	99	99	109	99	109	99
Solves pit Latin	75	75	79	72	86	78
Without solves pit Latin	24	24	30	27	23	21
Open field/no Latin	1	1	1	1	1	1

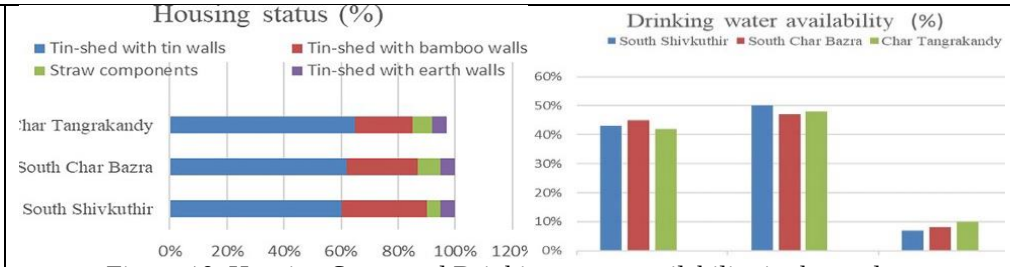


Figure 10. Housing Status and Drinking water availability in the study area

Social capital
-Interest to solve social conflicts
-Cooperation attitude
-Adaptive capacity

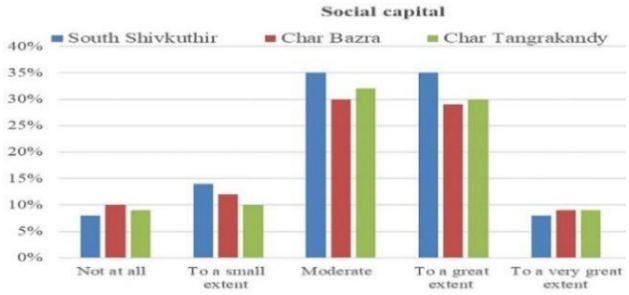


Figure 11. Status of different social capital

Effect of climate change on ecosystem services and char livelihood

Higher temperatures increase evaporation from the soil, water surfaces, and plants from the transpiration process known collectively as evapotranspiration. For that in char areas where rainfall increases, it may not be sufficient to offset overall soil moisture loss, affecting primary productivity and food production, i.e. supporting and provisioning ecosystem services are lost. Economic losses can be understood by measuring physical capital that is commonly traded in markets, Non-economic losses that are not commonly traded in markets include loss of habitat and biodiversity and damage to ecosystem services. For that climate change impacts are difficult to quantify but important to address. According to the questionnaire, char dwellers were asked about climatic stressors and impacts on ES, by remembering, understanding, applying, analyzing the evolution and innovation which were listed below:

Table 6. Climatic stressors and their impacts on ES and char livelihoods:

Climatic stressors	**Impacts on char ES**	**Impacts on char livelihoods**
Flooding and inundation	Hydrology disturbance i.e. primary production (eutrophication) river flow disruptions and pollution, provisioning (agricultural product, raw materials, genetic resources, etc.), regulating (nutrient mobilization), and supporting (e.g. habitats for resident or transient species), microbial proliferation (disease regulation).	Damage of rice, wheat, crops, and vegetables; the death of livestock and poultry; devastating homestead lands, infrastructures, markets, and communication networks; decrease in labor force activities; destroying income source, different disease attack
Riverbank erosion	Cultivable top soil part that source of huge microbes and organic matter or humus destroy. The high amount of sediment washout into the rivers.	Engulfing cultivable and homestead lands; destroying crops' fields; disappearing homes, shops, vegetable gardens, village roads, and markets; damaging livestock and grazing fields, food deficit, and hunger.
Drought and extreme temperature, heatwave	Without concomitating increases in precipitation, can lead to water shortages and increased stress for plants, that effect reducing plant growth, energy production also affects the food chain.	Affecting paddy, vegetables, crop cycles and diversification, a crisis of irrigation water, depending on rainwater, declining groundwater levels, reduction in drinking water sources, migration and loss of livestock, a crisis of agro-based activities, dying meadows, faltering yields.

Huge and untimely rainfalls	Suppresses plant growth, annual repeated rainfall may weaken plants physiologically or morphologically, withering crops after they've sprouted or washed them away. Inter-annual (between years) and intra-annual (within years) rainfall variants have important repercussions for provisioning service.	Decreasing rice production, winter crops, and vegetable growth and seedlings, a crisis in rainwater harvesting, crop cycle change, increased pests and pathogens in crops, livestock disease, and drought (particularly affecting paddy crops and vegetables), price hikes.
Cold wave, dense fog	Due to low humidity naturally, plants and animal want to uptake more water, nutrition, and shelter. That affects crop productivity, injured or killed by non-freezing low temperature, and displays a range of symptoms of chilling injury such as chlorosis, necrosis, or growth retardation, and biomass also loss.	Rabi crops, horticultural plantations, and other agricultural allied services affect. Vegetative growth of plants/seedlings impedes and may result in crop failure. Acquire food and fodder to feed livestock, if a cold wave is accompanied by heavy grazing animals are unable to graze hence requiring more fodder to be provided indoors. inadequate food exposure to low temperatures, animals may die of hypothermia or starvation, infrastructure also loss.

In the present climate change scenario may create ecosystems or biodiversity, animal and plant species respond differently. Marine biological communities can be quickly altered by increases in water temperature or acidity, which will impair the ecological functions of the marine ecosystem.

Northern Char livelihood that follows the sustainable livelihood framework

Finally, we identified five livelihood capital such as human capital, financial capital, physical capital, social capital, and natural capital that were vulnerable to different trends, shocks, and seasonality. We tried to develop a framework that follows the sustainable livelihood framework. In the study area, respondents were agreed to us in livelihood framework components, the details are explained here:

Vulnerability context:

Table 6. Vulnerability context

Trends	**Shocks**	**Seasonality**
Population trends	Human health	Of prices
Resources trends	Natural/Climatic	Of production
Economic trends	Economic	Of health
Trends in governance	Conflict	Of employment opportunities
Technological trends	Crop/livestock health	

Activity or strategy:

To overcome that vulnerability, they agreed to work. The activity or strategy was identified by 5 Focus Group Discussion (FGDs).

A. Government, Non-government (Local, National, and International), and Public-Private Partnership (PPP) work together for education, health, agriculture practices, livestock care, infrastructure development green industrialization development, participatory community or society-based development, the navigability of the river, environmental awareness related training, etc. There will be a Memorandum of Understanding (MOU) with govt. and/or PPP to conduct the above program or training session with a demonstration in a certain period. After evolution or research or community feedback if it fits for the char region, more MOU or programs will conduct but if not fit it must be turned away and exchange with another organization or department.

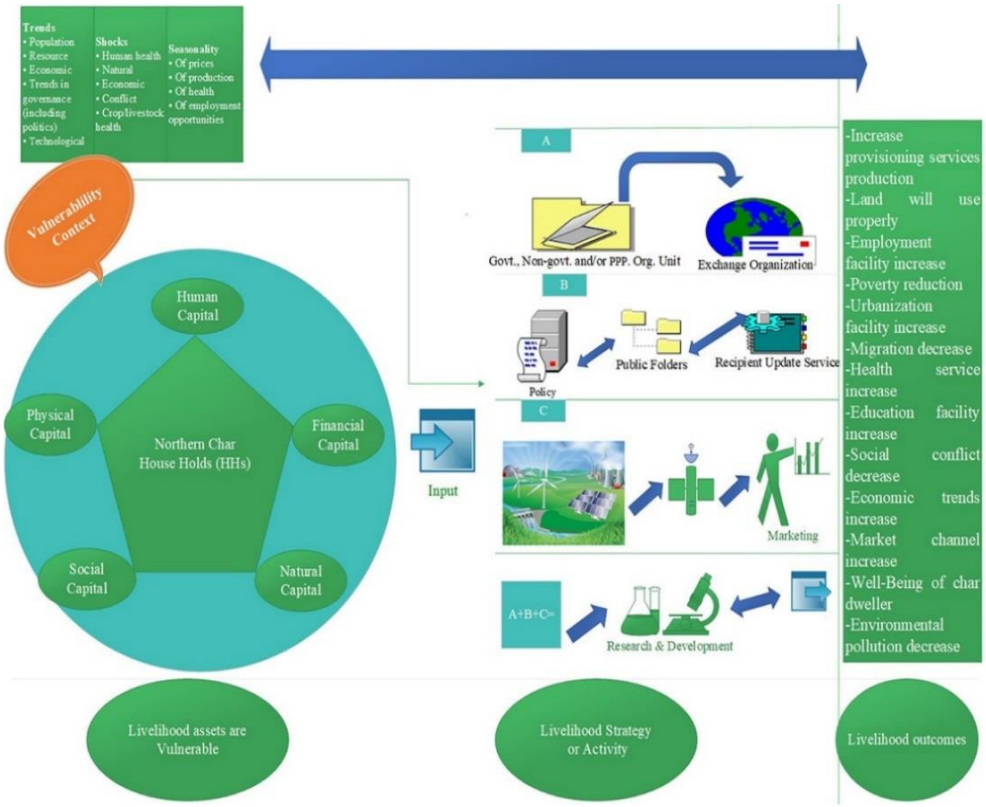


Figure 12. Proposed char land livelihood framework

B. Policies will be developed a) short term: ecosystem services-based activity such as rainwater harvest to reduce the flooding and erosion, solar power irrigation, all land will be cultivated, etc. b) midterm: Eco-farming-based cultivation i.e. use natural source-based fertilizer and pesticide, provide technological support, facilitate market linkage and c) long term: built green industry for char development. After public open vote or feedback, both policies and/or the public will update the services. Decision/action should be taken in the bottom to top, not in reverse otherwise local govt. can't strength for that livelihood strategy may fail.

C. After research or evolution of all the strategies, the outcomes will (Figure 12) increase provisioning services production, the land will use properly, employment facility increase, poverty reduction, urbanization facility increase, migration decrease, health service increase, education facility increase, social conflict decreases, economic trends increase, market channel increase, the well-being of char dweller, environmental pollution decrease, etc.

The proposed livelihood framework approach facilitates an understanding of the linkages between char dwellers' livelihood strategies, their asset status, and their way of using available natural resources, and is, therefore, a useful approach for understanding both the problem and the scope for promoting sustainable development at the local level.

5. Conclusion

Questionnaires survey, key informant interviews (KIIs), and FGD and experiences, supported by meteorological data (BMD). Climate change is negatively impacting the provisioning ecosystem services and the livelihoods of the char dwellers. Flooding and inundation, riverbank erosion, drought and extreme temperature, heatwave, huge and untimely rainfalls, cold wave, dense fog, etc. are the major climatic hazards that pose the greatest threats and risks to agricultural production, livestock rearing, and ultimately the livelihoods. According to SLF in the northern char area of Bangladesh, five capitals are vulnerable to low-income, health condition, educational status, housing status, drinking water availability whereas high social conflict, natural resources, and high population growth rate.

Agriculture (crop production and fishing) is the main source of income in the northern char area of Bangladesh.

In the northern char area, ES lies in its potential reciprocal benefits for biodiversity and human societies. The success of ecosystem management in developing countries like Bangladesh is dependent on Good Governance at root levels. Many scholars discussed it as central to successful adaptation. Policies for the protection of services are necessarily relevant to biodiversity conservation, maintenance, or recovery of biological diversity, and societies economic development should be strengthened. To invest in the current climate change setting is a wise decision. The impact of climate change on ES and livelihood is very difficult to forecast, it will depend on the resilience of biodiversity and ecosystem dynamics. The char dwellers have been practicing a range of both short-term and long-term strategies to deal with climate change impacts. For char livelihoods sustain, 1) Ensure education facilities, training for supporting the disaster-hit, and increase income-generating options and alternative employment opportunities by the Govt., NGO, and/or PPP partnership. 2) Provide low-interest loans, insurance of crop, and money deposit by initiating the special program and improving structural (embankment, road network, and infrastructure) development, setting up sanitary latrines, and campaigning on good practices of health and sanitation to improve the livelihood status. 3) Developing and introducing academic calendar adjustment with agricultural crop practices and disaster incidence and for their betterment to stable their livelihood should take Special "Chars one house one farm project/program." 4) Shifting agriculture practices from cereal crops to vegetables, investigations of more flood-tolerant varieties, and introducing new varieties of agriculture crops are major long-term adaptive strategies. They need potential buyers/special markets to sell their agricultural products. 5) A key challenge in assuring future food security is to apply not only scientific capacity but also the capacity of users to demand, interpret and apply scientific outputs effectively across the whole food system and multi-purpose landscapes. 6) Hydro-engineering embankments or dams could be constructed to reduce riverbanks erosion and settlement displacement. 7) The solar system could be constructed for local electricity demand, Geographical Information Systems (GIS) should be introduced in char-land data analysis, visualization, mapping, planning, and modeling for future char-land development planning and management. 8) Enhancing people's participation and community mobilization and access of the poor in char areas for resource collection and proper use for their livelihoods. 9) Strengthening the capacity of local governments and associated local institutions to reduce the vulnerability and increase the adaptive capacity of local communities. 10) Loss from climatic hazards can be kept to a minimum level. NGOs, civil society, and mass media should work to collaborate on community-wide disaster preparedness. Both print and electronic media can play a significant role in spreading the programs to the grassroots level.

The study would be preferentially targeted toward understanding livelihoods and on designing a program to support livelihood development has many benefits, and represents a valuable advance in development thinking and practice and gaining a better understanding of the likely impact of climate change on these ecosystems and livelihood in northern char area of Bangladesh. The conceptualizations are important and can be built a simple of the roles of marketing, green institutions, and technology in livelihoods and economic and social development without complicating them too much. In the charred area, it may offer significant benefits, effectiveness, and scope of livelihood analysis designing of a program for poverty reduction.

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