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Review

Climate change adaptation in Bangladesh: Current practices, challenges and the way forward

Md. Arif Chowdhury^{a,b,*}, Md. Khalid Hasan^{b,c,d,*}, Syed Labib Ul Islam^e^a Department of Climate and Disaster Management, Jashore University of Science and Technology, Jashore 7408, Bangladesh^b Institute of Disaster Management and Vulnerability Studies, University of Dhaka, Dhaka 1000, Bangladesh^c Unit for Research in Emergency and Disaster, Faculty of Medicine and Health Sciences, University of Oviedo, Oviedo 33006, Spain^d Department of Primary Care and Population Health, University of Nicosia Medical School, Nicosia 2408, Cyprus^e Institute of Water and Flood Management, Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh

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ABSTRACT

Geographical location and socioeconomic dynamics have increased the vulnerabilities of the people of Bangladesh to the impacts of climate change. Effective adaptation practices would reduce the adverse effects on livelihood, health, agriculture, and the environment—particularly in the coastal areas. To cope with climate change impacts, diverse scientific and indigenous knowledge is being utilized. Nevertheless, various barriers are hindering sustainable adaptation. This review focuses on identifying the existing and likely adaptation strategies as well as the barriers to coping with the impacts of climate change in Bangladesh. Due to the increasing frequency and intensity of disasters, many people are being displaced towards urban settings, where natural and man-made challenges are hampering sustainable adaptation. A lack of in-depth knowledge about the vulnerabilities, overlooking the needs of local communities, and inadequate integration of policies and programs have also been identified as challenges to climate change adaptation.

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1. Introduction

Climate change vulnerabilities of developing and underdeveloped countries are increasing day by day. Among them, Bangladesh is facing severe impacts of climate change due to a paucity of economic, social, technological, and institutional resources [1]. Climate change will influence many driving factors of migration, impacting the most vulnerable communities [2].

Many resource-poor households already have recognized the impacts of climate change on their livelihoods and resources [3]. Coastal areas face extreme risk due to the increase of climate change-induced vulnerability and other social, economic, and environmental factors [4,5]. However, an overemphasis on technological innovations, critical cultural factors, exclusion of informal communities, and a breakdown in interaction and cooperation with institutional communities remain barriers to adaptation strategies [6].

Adaptation to climate change in coastal areas of Bangladesh is complex because of an amalgamation of different climate variabilities, geographical dynamics, and the involvement of different

stakeholders [7–9]. A crucial aspect of formulating national adaptation programs is to understand the impacts of climate change, practical adaptation practices, and implementation challenges faced in the real world [10]. Although migration is an adaptation to a variety of consequences resulting from climate change, it is a complex issue as exemplified by the mass migration from Bangladesh into Northern India over the past few decades, which has resulted in an increased tension and conflict among ethnic groups [11]. To ensure sustainable adaptation, it is essential to identify the barriers. This paper aims to review the effects of climate change on different aspects, such as agriculture, groundwater, livelihood and health in Bangladesh, and summarize possible adaptation practices and challenges. This review will help stakeholders from government and non-government sectors, including researchers and policymakers to understand climate change in Bangladesh from the perspective of adaptation.

2. Climate change and Bangladesh- an overview

In recent decades, there has been a noticeable increase in the frequency and intensity of extreme climatic events in Bangladesh [12]. The mean temperature has been rising at a rate of 0.20 °C per decade [13] (Supplementary Table 1). An increase of 153 mm of annual rainfall had been predicted for 2011–2020 [13], and subsequent studies have found an increasing trend for three seasons, except for the

* Corresponding authors at: Institute of Disaster Management and Vulnerability Studies, University of Dhaka, Dhaka 1000, Bangladesh.

E-mail addresses: ar.chowdhury@just.edu.bd (M.A. Chowdhury), khalidhasan@du.ac.bd (M.K. Hasan).

winter, which is getting cooler and drier, while the rest of the year is getting warmer and wetter [14–16].

Coastal and riverine communities in Bangladesh are highly vulnerable because of their low adaptive capacity and direct exposure to natural disasters [17]. Riverbank erosion and other climatic hazards have affected the lives and livelihoods of these communities [18]. Many people have resettled their families due to these hazards, and most of the climate-induced internally displaced people are being relocated to char lands – islands separated from the mainlands and surrounded by adjoining rivers [19]. Several studies have revealed that the community living in the char lands display the most vulnerability to climate change [20]. People living in the char lands encounter multiple natural disasters and socioeconomic vulnerabilities that drive them to migrate from one char to another [21]. Perceptions of local people on climate change and the consequences of climate change are presented in Table 1.

2.1. Groundwater and farming

Climate change has a considerable impact on evapotranspiration, runoff, and the decline of groundwater levels in Bangladesh. Greater use of surface water has been adopted as one of the policies to reverse this decline [24]. However, surface water is expensive and scarce. Consequently, many small farmers have attempted to switch to aquaculture, changing the traditional agricultural landscape [25].

In Bangladesh, vulnerability to climate change is high due to a significant dependence on agriculture. About 60% of the population of coastal areas rely on agriculture for their income [26]. In the aftermath of Cyclone Aila in 2009, 82% of the shrimp cultivators switched to rice and other crop cultivation [27]. However, the yield of crops is decreasing due to salinity intrusion, which may reduce crop outputs by 15.6% [28,29]. This leads to further diversification into aquaculture

[27,30,31], and a feedback cycle leading to increasing soil salinity [32]. A significant loss in agricultural productivity is expected from sea-level rise-induced land inundation as well [33].

2.2. Cities and migration

Global mean sea-level rise is expected to be within the range of 0.29 m to 1.1 m by the end of this century [34]. The coastal effects of sea-level rise include increased frequency of floods, inundation of wetlands, and increased shoreline and riverbank erosion [35–38]. This affects income and livelihood opportunities, leading to internal and international migration from coastal areas. Men moving in search of livelihoods leave women behind with a lack of socioeconomic security for the family [39].

Approximately 90 percent of rural migrants permanently settle in urban centers, i.e., Dhaka, Chattogram, Khulna, and Rajshahi [40]. People in megacities, especially poor migrants, are the most vulnerable to climate variability and natural disasters [41,42]. The Land Surface Temperature (LST) of Dhaka has increased by around 2 °C due to the expansion of built-up areas [43]. Despite being resource-constrained, many community-level initiatives tend to exclude the urban extreme poor [44]. Also, the public health and infrastructure sectors are predicted to be affected in the urban regions of Bangladesh due to increased migration [45]. Significant predicted impacts on urban areas are presented in Supplementary Table 2.

2.3. Public health

Climate change compromises human health, and uncommon diseases have become more prevalent in Bangladesh [1]. Climatic elements and pollution are severely affecting the health sector [46–49].

Table 1
Perceptions of local people on different variables and consequences of climate change in Bangladesh.

Aspects	Perceptions of local people on climate change	Effects of climate change	
Climate variables	Temperature	<ul style="list-style-type: none"> - Increase <ul style="list-style-type: none"> • More hotter days in summer • Number of warmer days • Frequency of unusually warm days • Scarcity of drinking water • Frequency of diseases • Mortality in shrimp cultivation • Rate of evaporation leading to salinity intrusion • Requirement of labor from other areas for crop irrigation 	<ul style="list-style-type: none"> - Health and Hygiene - Loss <ul style="list-style-type: none"> • Production • Earning
	Rainfall	<ul style="list-style-type: none"> - Decrease <ul style="list-style-type: none"> • Rate of rainfall in rainy season • Number of annual rainy • Crop growth and production - Late-onset of rainy season 	<ul style="list-style-type: none"> Loss of <ul style="list-style-type: none"> • Cash crops • Cash • Freshwater fish
	Alteration of cold	<ul style="list-style-type: none"> - Delay <ul style="list-style-type: none"> • Paddy cultivation during summer • Bloom - Damage <ul style="list-style-type: none"> • Potato cultivation • Betel leaf production • Winter season crops • Crops color • Inflorescence of mango 	<ul style="list-style-type: none"> - Loss <ul style="list-style-type: none"> • Crop production
Climate phenomenon	Monsoon	<ul style="list-style-type: none"> - Shortening of rainy season 	<ul style="list-style-type: none"> - Salinity is being increased
	Tropical cyclones	<ul style="list-style-type: none"> - Increase <ul style="list-style-type: none"> • Rate of frequency and intensity of cyclones • Height of storm surge • More flooded areas by storm surges 	<ul style="list-style-type: none"> - Loss <ul style="list-style-type: none"> • Life <ul style="list-style-type: none"> • Agriculture crops, cattle, and other forms of livelihood - Damage <ul style="list-style-type: none"> • Infrastructure
Impacts on nature	Sea level rise	<ul style="list-style-type: none"> - Increase <ul style="list-style-type: none"> • More flooded land by high tide • Salinity affected areas 	<ul style="list-style-type: none"> - Increase <ul style="list-style-type: none"> • Salinity affected land • Land erosion

Adapted from [22,23].

Malnutrition and scarcity of safe water are increasing rapidly [50,51]. Moreover, the unavailability of freshwater has direct and indirect effects on human health [52,53]. Water-borne, water-washed, and water-related diseases are reported to be 8%, 14%, and 11% higher in the coastal regions of Bangladesh [49,54]. Contaminated groundwater has been associated with hypertension, premature delivery, and acute respiratory infectious diseases [55–56]. In addition to the impacts on physical health, significant mental health effects have also been reported [57].

Migrant women in particular, are highly vulnerable to adverse health impacts [58]. Moreover, the critical health infrastructures, food supply, and necessary fundamental services are being directly damaged by floods and cyclones – limiting their capacity to deal with the emerging challenges [59]. Lack of proper healthcare support, including unavailability of gynecologic and obstetric care, adds to the suffering and may emerge as a societal source of conflict [60–62]. Impacts of climate change on health in Bangladesh are presented in Table 2.

The common coping strategies for health-related issues adopted in Bangladesh are given in Table 3. People prepare and store foods and essential medications for use during extreme weather events such as cyclones and floods. Netting around beds – particularly at dawn and dusk – is used to gain some degree of protection from vector-borne diseases by keeping out mosquitoes and fleas [72]. Personal hygiene is maintained to prevent food-borne and water-borne diseases, while community awareness and preparedness initiatives are taken to prepare for extreme temperature fluctuations.

2.4. Gender

Gender is one of the most important indicators of vulnerability encompassing a wide range of issues, including the loss of natural resources, access to information and decision-making, and livelihood opportunities [75–78]. Uneven power-based dynamics in various formal and informal institutions and sociocultural practices are the leading causes that make women more vulnerable [79,80].

Climate change affects food and water availability, increasing the pressure on females who generally are expected to take care of such household matters [81–83]. Natural disasters and the lack of safe water sources often make it necessary for women to walk long

Table 3
Adaptation to climate change-related health problems in Bangladesh.

Issues	Health coping strategies
Access to healthcare	Deciding between qualified and unqualified providers
Mental health	Discuss with relatives, friends, and neighbors, avoid self-medication and traditional practices
Extreme weather events	Preparation in advance for food and medications, availability of safe water, assurance of accessible public health service during a post-disaster situation
Vector-borne disease	Netting around beds, avoiding being outdoors at dawn and dusk
Food-borne disease	Maintenance of hygiene during preparation and consumption of foods
Waterborne disease	Precautions regarding health impacts of algal blooms
Disruption of air quality	Regular monitoring and warning during high pollution days
Heatwaves/ Cold waves	Health warning approach in community level, preparedness initiatives during emergency periods

Adapted from [72–74].

distances to collect water for their families [84]. Alston and Akhter projected that women will continuously experience food insecurity and unsafe water-related problems until gender equality is ensured at national and local levels [82]. Inadequate and damaged sanitation facilities lead to unhygienic practices and diseases where women and adolescent girls suffer the most [84]. Many pregnant women in coastal areas are diagnosed with eclampsia, hypertension, and pre-eclampsia [85]. Disasters, diseases, and lack of opportunities also severely limit the potential for women to earn additional income [86]. Increased access to education can help in building resilience and adaptive capacity in a gender-inclusive manner [87].

3. Climate change adaptation in Bangladesh: planning, program, and practices

The South Asian region represents the most diverse ecosystems and climate regimes in the world [88]. Therefore, it requires a coordinated international effort with finance, technology transfer, and capacity building to achieve global mitigation and adaptation goals.

In order to adapt to the increased level of salinity, farmers are cultivating salinity-tolerant rice, switching to different varieties, trying different planting dates, converting paddy to fish production, and practicing crop rotation [89]. Several practices have also been introduced in the southwestern areas of Bangladesh under a project titled "Reducing Vulnerability to Climate Change (RVCC)" [90]. The adaptation practices for the agricultural sector are presented in Supplementary Table 3. For aquaculture, the adaptation practices vary based on climate variability (Supplementary Table 4).

People in the flood-prone areas of Bangladesh have a deep religious faith that lets the community accept natural calamities as divine tests [91]. Several studies have highlighted the importance of local knowledge in climate change adaptation. Greater flexibility can be achieved by utilizing local knowledge to integrate with adaptation-related decisions [92]. Examples of indigenous knowledge in adaptation are summarized in Table 4.

To ensure sustainable adaptation, institutional framework and capacity-building aspects should be addressed, including proper local and national governance [5]. Multilevel policy and institutional frameworks are connected with different forms of elements, and in some cases, these elements require reformation. Besides, a cumulative relationship among various components is a prerequisite to ensuring the development of adaptive capacity (Fig. 1).

Despite developing legal documentations in policy, plans, and programs on adaptation, institutional structure and capacity are not yet sufficient for mainstreaming climate change adaptation and disaster

Table 2
Impacts of climate change on health in Bangladesh.

Climatic variables or aspects	Impacts on health
Rising temperature and heatwaves	Headache, skin burn, hypothermia, heat-stroke, dementia, psychological disorder, mood disorders, anxiety
Changing pattern of rainfall	Skin diseases, cough, risk of snake bite, fever, cholera, diarrhea
Salinity intrusion	Hypertension, skin diseases, miscarriage of pregnant women, acute respiratory infection, diarrheal diseases
Natural disasters	Physical injuries, diarrhea, cholera, mental illness, malnutrition, infectious diseases, losses of lives
Floods and waterlogging	Cholera, diarrhea, malnutrition, skin diseases
Variable precipitation	Waterborne diarrheal diseases, non-cholera diarrhea, cardiovascular diseases, respiratory diseases
Increased breeding of vectors	Visceral leishmaniasis
Groundwater overexploitation	Melanosis, leukomelanosis, keratosis, hyperkeratosis, dorsum, nonsetting edema, gangrene, skin cancer
Stagnant weather conditions	Cardiovascular, respiratory, and allergy diseases
Groundwater pollution	Nervousness, damage of reproductive and endocrine systems
Decreased food production	Micronutrients deficiency, malnutrition

Adapted from [10,22,69–71,47,52,63–68].

Table 4
Possible adaptation strategies incorporating indigenous knowledge.

Elements	Examples
Biophysical and social disclosure	<ul style="list-style-type: none"> ✓ Integration of indigenous and scientific findings of climate change ✓ Local weather forecasting to reduce the impacts of changing patterns of rainfall ✓ Seasonal migration to limit the weather effects ✓ Conservation of water resources ✓ Minimizing the risk to natural hazards
Sensitivity to alteration and uncertainty	<ul style="list-style-type: none"> ✓ Conservation of common resources ✓ Cultivation of different types of crops in an extensive range of climates ✓ Indigenous soil and water management approach ✓ Circulation of risks through social networks ✓ Management of pasture for cattle grazing ✓ A local institution for maintaining the immediate flow of migrants
Adaptive ability and strategies	<ul style="list-style-type: none"> ✓ Application of indigenous findings in decision making ✓ Observe the people's changing behavior regarding resource management ✓ Observe the differentiation in society in the aspect of vulnerability and adaptation ✓ Understand the necessary tools for ensuring communication ✓ The importance of transformation of culture and damage of traditional institutions

Adapted from [93–95].

management in Bangladesh [104]. Organizational processes need to be developed to ensure national adaptation to climate change [96]. Different measures should be incorporated under institutional actions to promote the adaptation with proper implementation strategies.

3.1. Barriers to climate change adaptation

The effects of climate change cannot be measured within a boundary, as the impacts are experienced on a global scale [80]. Institutional obstacles combine with the natural causes to increase vulnerabilities and hinder adaptive capabilities [105]. The barriers regarding problem identification and improvement of adaptation plans are summarized in Table 5.

The integration of policies is one of the most significant challenges for ensuring proper adaptation (Fig. 2) [104]. The lack of institutional processes and weak organizational capabilities hinder the implementation of various adaptation-related projects and programs [110]. There are also challenges in developing fair and robust assessment frameworks for resilience [111]. Lack of awareness - sometimes along with spiritual norms and traditional systems - are barriers to climate change adaptation [91]. Furthermore, gendered rules and beliefs of specific regions impact adaptation practices and can impede livelihoods [112].

4. Conclusion

From this review of climate change impacts and adaptation, it is clear that Bangladesh faces a variety of challenges, and the following concerns must be addressed:

- The specific aim of adapting to climate change under an inclusive process should be confirmed and reflected in the national policies. In addition, proper governance and budget allocation should be ensured [91,117].

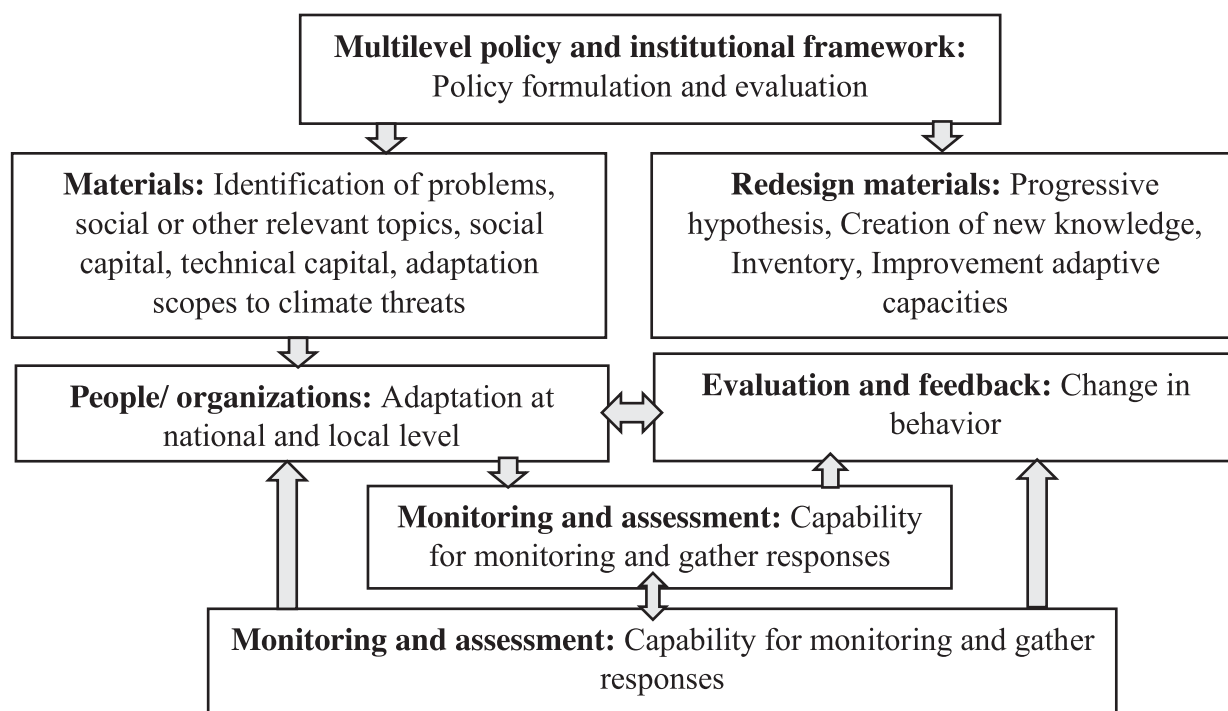


Fig. 1. The role of institutions in inspiring adaptive capacities at the households and community level. Adapted from [96–103].

Table 5
Barriers to climate change adaptation in Bangladesh.

Barriers	
Identification of problems	<ul style="list-style-type: none"> - Insufficient <ul style="list-style-type: none"> • Political desire • Pressure from people • Sufficient budget • Available resources • Knowledge on climate change impacts • Awareness of the topic • Governance with proper implementation - Absence of proper sense about duties for coordinating or working in adaptation practices - Competition among different planning obstacles - Increasing frequency of climate change scenarios - Unpredictability in scientific findings
Improvement of adaptation plans	<ul style="list-style-type: none"> - Insufficient <ul style="list-style-type: none"> • Cooperation among different stakeholders • Knowledge of people • Financial support • Impression of urgency - Absence of proper distribution of responsibilities - Dependency on others, e.g., project developers

Adapted from [106–109].

- Livelihood diversification is essential to create alternative opportunities for vulnerable communities and small-scale businesses, especially in the reality of the issues faced by agriculture and aquaculture [118].

- Rights of displaced persons need to be ensured to address their survival and physical security – especially in the slum areas. Legal recognition and protection should be offered to the climate-induced migrants to ensure global accountability.
- A climate change resilient health care system needs to be developed along with improved accessibility for vulnerable people [119].
- Access to safe drinking water should be secured for everyone to reduce the health risks [50,120].
- The adaptive capacity of women, in particular, should be prioritized from social, financial, political, and cultural perspectives [87,121].
- The application of local knowledge can promote adaptation in the local communities [95]. Additionally, knowledge sharing among different stakeholders can facilitate sustainable climate change adaptation and raise awareness across the society [122,123].

In this review, various factors related to climate change adaptation in Bangladesh have been summarized. Further research on adaptation to climate change for Bangladesh and other underdeveloped countries can be strengthened by investigating migration and gender issues, as well as policy and governance implications.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.joclim.2021.100108.

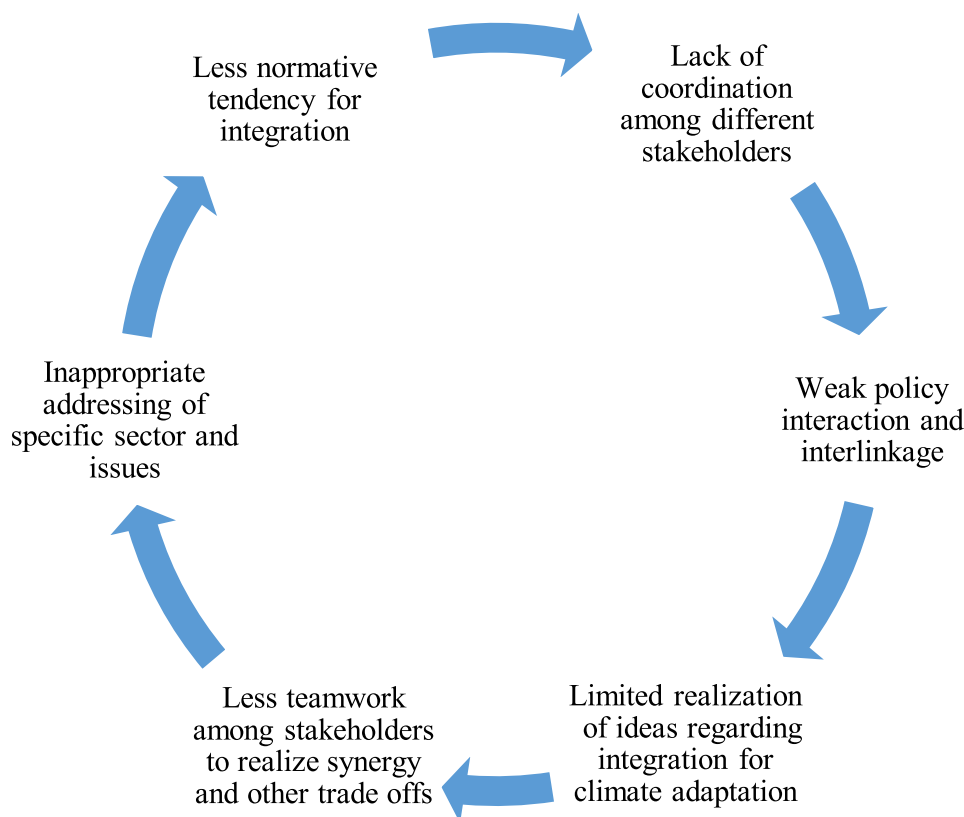


Fig. 2. Major obstacles in the integration of policy for climate adaptation. Adapted from [5,113–116].

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