STUDY OF CHANGING WATER CONFLICTS AND THEIR IMPLICATIONS FOR WATER SECURITY IN POLDER-29

by

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MASTER OF SCIENCE IN WATER RESOURCES DEVELOPMENT

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A thesis submitted by

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Dedicated

to

MY BELOVED FAMILY

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ABSTRACT

Water conflicts at the local level have received less attention globally as well as in Bangladesh and have comparatively been less researched. Local level water conflicts, mediated by hydrological, social, economic, institutional, and environmental drivers, are often complex in nature and intensify or change dimensions from one type to another, often deepening social inequality. Hence, these issues warrant more attention from policy makers and water managers. The issues are more prevalent in southwest coastal Bangladesh due to susceptibility to hazards, land use changes, large scale interventions, and conflicting nature of water use practices. This study aimed at identifying the spatial and temporal dynamics of water conflicts and their drivers in a southwest coastal polder, namely Polder-29, and evaluated roles of water security programs and institutional systems in mitigating conflicts. The methodology included application of PRA tools and household survey data to map temporal and spatial variation of drivers and the resulting conflicts, land use change analysis to examine changing nature of conflicts with time, hydrological analysis to elucidate spatially varied nature of conflicts, and application of PRA tools and stakeholder diagramming to map institutional structure, roles, and responsibilities, and to investigate ways to mitigate conflicts.

Eight different water conflicts were identified, which include large scale shrimp farming vs agriculture, agriculture vs saltwater shrimp, agriculture vs small-scale freshwater gher, u/s vs d/s conflict, policy level conflicts, institutional conflicts, user vs environment conflicts, and conflicts due to land use change. These conflicts are highly diverse in nature and vary spatially and temporally with different livelihoods and land use practices. Agriculture vs large-scale brackish shrimp farming was the dominant conflict in the south in 1990s. Even after the exodus of large-scale shrimp farming, this type of conflict is still prevalent in the form of agriculture vs small-scale saltwater shrimp, together with emergence of newer conflicts, e.g., institutional conflicts, and user vs environment conflicts. Marginal and landless people have been most affected by brackish shrimp farming. The northern part saw an extensive increase in small-scale freshwater ghers, leading to discords between farmers and gher owners. Blocked canals by ghers have hampered irrigation and have disrupted hydrological connectivity, resulting in silting up of drainage canals, water congestion, loss of fish biodiversity, and reinforcement of pre-existing conflicts between u/s vs d/s resulting from topographical differences. Institutional conflicts mainly occur between ‘O&M committee’ under the WMA and informal ‘beel committee’ dominated by local elites and powerful groups, and between LGIs and O&M committee. Major conflicts stem from the control of sluice gates and the drainage canals, with WMGs yet to get control of sluice gates in several sub-catchments and LGIs and local powerful groups getting involved in leasing the sluice gate and canals.

While engagement of WMGs in micro-credit and other economic activities is important for their sustainability, strong WMGs form the basis for effective and sustainable water management. Water management has not received as much attention in all areas as other economic activities did, which incapacitates many WMG members as they are unaware of their roles and responsibilities in terms of water management. Also, LGIs’ participation in WMOs’ activities has been less than expected, although there is evidence of more effective planning and design of water management in one sub-catchment via effective sharing of information and interaction between WMOs and LGIs. To mitigate conflicts, the WMGs, O&M committee and WMAs need to be more closely involved in decision-making and other important processes and interacting with other stakeholders, with LGIs supporting both in decision making and implementing process. A pre-requisite is well-functioning water management infrastructures, to be achieved via routine and periodic maintenance by O&M committee and major maintenance by BWDB. Continuous monitoring of WMOs should be conducted by BWDB with the help of local government. Priority-based conflict mitigating programs, proper positioning of stakeholders according to their priority, roles and responsibility, strengthening human capacity through proper training and strengthening livelihood groups are essential in mitigating local level water conflicts in Polder 29.

TABLE OF CONTENTS

List of Tables

List of Figures

Abbreviations and Acronyms

AO	Agricultural Officers
BC	Beel Committee
BG	Blue Bold
BWDB	Bangladesh Water Development Board
CBOs	Community-Based Organizations
D/s	Downstream
DEM	Detail Elevation Model
DoA	Department of Agriculture
DoF	Department of Fisheries
DTW	Deep Tube well
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
FO	Fisheries Officers
IDI	In-depth Interview
IPSWAM	Integrated Planning for Sustainable Water Management
IWRM	Integrated Water Resources Management
KII	Key Informant Interview
LCS	Labor Contracting Society
LGI	Local Government Institution
LULC	Land Use Land Cover
MoLGRDC	Ministry of Local Government, Rural Development and Co-operatives
NGO	Non-Government Organization
NWRC	National Water Resources Council
O&M committee	Operation and Maintenance committee
PWM	Participatory Water Management
STWs	Shallow Tube well
U/s	Upstream
UNDP	United Nations Development Program
UP	Upazila Parisad
UZP	Upazila Parishad
WARPO	Water Resources Planning Organization
WB	World Bank
WM community	Water Management Community
WMA	Water Management Association
WMG	Water Management Group
WMO	Water Management Organization

Chapter One: Introduction

1.1 Background of the study

Globally, water related conflicts are increasingly presenting as one of the most important challenges for water resources planning and management. Freshwater is a valuable but contested resource, and as it becomes less available, with reduced access, water related conflicts tend to become more frequent and more intense (Seter et al., 2018; Pahl-Wostl et al., 2013; Stetter et al., 2011; Kramer and Annika, 2004). Conflicts occur over different geographical scale: when water resources are shared by multiple countries, as in transboundary water disputes (Petersen-Perlman et al., 2017; Wolf, 2007; Wolf et al., 2003ab); when conflicts take the form of inter-state or inter-province water resource sharing and contestation (Khan and Awan, 2020; Pani, 2010; Gizelis and Wooden, 2010; Noshab and Mushtaq, 2001); and local level conflicts across inter communities as well as intra-communities, representing users of different, often conflicting interests, in a geographically small area (Sultana et al., 2017; Funder et al., 2012; Funder et al., 2010ab). However, importantly disputes or management decisions on one level may very well impact conflicting interests on another level. The degree of tension or dispute between users and the possibility of tensions being converted to conflicts are shaped by a number of socio-economic, cultural and political factors (Kramer and Annika, 2004).

While water-related conflicts have received wider attention in many studies for relatively larger geographical domains, many water conflicts play out at the local levels surrounding water use, and arguably more than in transboundary context. However, local level conflicts, have received less attention and have comparatively been less researched (Funder et al., 2012; Funder et al., 2010ab; Ravnborg et al., forthcoming; Thomasson, 2005; Mehta 2005; Sultana et al., 2017). These widespread local level conflicts over water resources are impacted by a range of environmental, climatic, and socio-political factors, and in most of the cases deepen inequality and constrain adaptive capacity of the marginalized and disadvantaged communities, and hence warrant more attention from policy makers and water managers (Wolf et al., 2003; Zeitoun and Allan, 2008; Swatuk and Wirkus, 2009; Funder et al. 2012; Sultana et al. 2017). The multi-scale nature of processes often makes local water resources management in terms of water access and control more complex and heterogeneous within communities, and interventions for natural management or for increasing access to water resources, without sufficient knowledge of different drivers of conflicts at local level, can enhance existing conflicts or add to new sources of competition and potential conflicts over common pool resources such as water (Peters, 1984; Juul, 2001; Crow and Sultana, 2002; Mehta, 2005).

Local level conflicts are interpreted as local contestations and confrontations over natural resources, which arise with regards to access, allocation, development, and management of resources. At the local level, a major driver for conflict is the perceived inequitable access to water and land resources and hence injustice, which can result from decreased availability of water and/or degradation of water quality to the extent not suitable for use (Sultana and Thompson, 2017). This can also be precipitated by economic and political support for commercial interests unrelated to local community and/or long standing ethnic, cultural, racial, political and economic differences. In recent decades, rural areas have witnessed new water users entering the scene, as large-scale commercial farming, hydropower and biofuel production develop (Funder et al., 2012; Sultana and Tompson, 2017; Sultana et al., 2019) analogy with polder/LU change/shrimp farming.

The declining trend of the finite natural resources amid growing demand for them to satisfy the needs of different stakeholders present as the source of competition and conflicts, particularly over increasingly scarce surface water for dry season water use, for example, irrigation. It has been argued that climate change in the shape of climate trend or stresses are not the only or often the main cause of conflicts; rather climate change plays a bigger role in intensifying or multiplying conflicts (Sultana et al., 2017). For example, river salinity, increasing waterlogging, and more erratic rainfall have aggravated local conflicts. Nevertheless, environmental stresses affect natural resources productivity and livelihoods, which are likely to generate and/or reinforce conflicts in the way people respond to the changes (Barnett and Adger, 2007).

Unplanned land use change often leads to deterioration of decline of water and/or land resources, via conversion of water bodies and agricultural land to urban areas and/or different conflicting uses of land and water resources (e.g., brackish water shrimp farming), which degrades the eco-hydrological quality of the system and leads to dispute in access to land and water resources between different users, e.g., agriculture and aquaculture (Abdullah et al., 2017; Naz and Buisson, 2015; Islam and Tabeta, 2019). While population growth and poverty are important drivers of land use change, exogenous factors often assume the leading role in influencing change in land use and land cover (Turner et al., 2021; Lambin et al., 2001, 2003), which include economic opportunities, as mediated by institutional factors (social, political and infrastructural change). For example, shrimp aquaculture had been strongly supported by World Bank in Bangladesh until mid-1990s, which eventually led to the path of export-led growth.

Conflicts between upstream (u/s) and downstream (d/s) land and water users are common. This has often been precipitated by hydrological factors triggered by anthropogenic activities, for example, flood risk transferred to downstream as a result of flood protection at upstream, causing conflicts and forced cutting of embankment at upstream by people from downstream (Thompson, 2010; Chowdhury et al., 1997); land use change, flow modification, topographical differences, or flow obstruction (e.g., due to silting up of drainage canals) frequently present conflicting situation between upstream and downstream resource users in a local watershed (Fallenmark, 2000; Murshed and Khan, 2009; Chowdhury et al., 1997); and faulty design or miss-management with operation of structures often cause conflicts between head-end and tail-end of irrigation systems (Yapa et al., 2020; Saumyarathna et al., 2016). The other main source of conflicts is inequitable rights to public lands and waters, including elite capture and encroachment of floodplains (e.g., local or external investors grabbing public lands for fish farms) to the exclusion of poor women and men who depend on wild aquatic resources for their livelihoods (Sultana et al., 2019; Sultana and Thompson, 2017).

Water related conflicts tend to intensify in the coastal areas as coastal deltas represent important hub of natural/ critical resources and sensitive ecosystem and different forms of resources with high cultural, historical and economic importance (Uprety, 2006; Batista et al., 2014; Chu, 2006; Costanza et al., 1997; De Groot et al., 2012; Halpern et al., 2007, 2009), and the increasing pace of human development activities and people increasing demand for natural resources to ensure livelihoods lead to diverse, competitive and conflicting exploitation of resources (Agardy et al, 2005; Kiousopoulos, 2008; Tsilimigkas & Rempis, 2018), associated degradation of natural resources.

1.2 Rationale of the study

In the backdrop of the above discussion, it is clear that it is important to take a differentiated perspective on communities, which examines the ways in which different actors within communities engage in and relate to competition over water. This is particularly true for Bangladesh, where seasonal variability of water resources, land use change mediated by population growth, poverty and economic drivers, degraded water quality and local power dynamics create conflicts among different groups of people, with often the poor, disadvantaged and marginalized groups ending up on the losing side.

Land and water are precious natural resources, but unplanned land use change and incompatible water use practice create different types of conflicts (Parvin et al., 2017). This problem is more prevalent in the coastal area of Bangladesh due to its diverse resources, susceptibility to water related hazards, and competitive and conflicting nature of water use practices (Chowdhury, 2010; Abdullah et al., 2017; Naz and Buisson, 2015; Islam and Tabeta, 2019). The southwest coastal zone represents an important hub of different forms of resources, which have undergone major changes (especially land use) since 1960s due to physical processes such as tidal and storm surge flooding and salinity intrusion, and multiple human activities such as large-scale polderization and intensive shrimp farming. These induced considerable impacts on agriculture, water supply and livelihoods, which generated social inequalities and conflicts in the form of unequal distribution of resources and opportunities to using them (Abdullah et al., 2017; Naz and Buisson, 2015)

While conflicts between agriculture and shrimp farming is well-documented (Abdullah et al., 2017; Naz and Buisson, 2015; Islam and Tabeta, 2019), the nature of conflicts in a given hydrological and socio-economic setting is often very complex and of varying nature, and with time the conflicting issue continues to grow or change its dimension from one type to another, with growing social inequality, mediated by hydrological, social, economic, institutional, and environmental drivers (Naz and Buisson, 2015; Bulleri and Chapman, 2010). Conflicts are seen among different groups of people (user-user conflicts) defined by livelihood types or geographical locations (e.g., upstream vs downstream), and between human activities and environment (user-environment conflicts) (Parvin et al., 2017; Naz and Buisson, 2015; Chowdhury et al., 1997). Conflicts also arise from implementation of different water management projects (Murshed and Khan, 2009; Rahman and Salehin, 2009; Sultana et al., 1995), often associated with non-functionality and/or inappropriate design and operation (often driven by local power dynamics) of water control systems (e.g., drainage canals or sluices) (Murshed and Khan, 2009; Faruque, 2009; Rahman and Salehin, 2009; Mozahedy, 2009).

In sum, several earlier studies in Bangladesh regarding conflicts have been conducted focusing on agriculture and shrimp culture or salinity (Chu 2006; Murshed and Khan 2009; Naz and Buisson 2015; Nguyen-Khoa and Smith 2004). Little importance has been given to the phenomenon of changing nature of water conflicts and their dynamic characteristics in coastal

Bangladesh. Besides, conflict management and governance of natural resources are given low attention and importance though conflict is a common phenomenon in the context of natural resources extraction. In particular, the strategies of the poorest community members in water conflict and cooperation remain relatively poorly understood. A better understanding of such strategies is needed to facilitate equitable rural water governance, which can also provide insights for the broader analysis of the ways in which marginalized groups respond to and are affected by competition over scarce resources.

In line with the above discussion, this study investigated the complex nature of different conflicts and their dynamics at a local scale in a complex hydrologic and socio-economic setting and explored suitable water programs and institutional roles in alleviating local level water conflicts which impede achievement of water security and equity among different groups of people. The findings are thus expected to provide insights into adopting interventions informed by these considerations.

1.3 Objectives of the study

The current study was an attempt to investigate the complex nature of different water related conflicts and how they evolved with time in response to different drivers in a southwest coastal polder, namely Polder-29. Reconnaissance field investigation had insinuated that different forms of conflicts exist among the same livelihood groups (e.g., farmers) as well as between different livelihood groups (e.g., between agricultural farmers and shrimp farmers) in different sub-watershed units. The conflicts are associated with different land use practices, changing land use, topographical differences between upstream and downstream affecting water availability, obstruction across the natural drainage canals, siltation of canals, and conflicting use of river water (e.g., through operation of sluice gates or other means).

The overall aim of this study was thus to identify the drivers of conflicts in the complex hydrologic and socio-economic settings, as in Polder 29, and capture the dynamics of the changing nature of conflicts under changing environmental and anthropogenic stresses. The specific objectives of the study are as follows:

i. To investigate spatial and temporal characteristics of water conflicts and their drivers, in hydrological, socio-economic, and socio-political contexts.
ii. To evaluate roles of water security programs and institutional/management systems in mitigating conflicts.

1.4 Limitations of the study

The findings of the study are applicable to the study area, i.e., Polder 29. While somewhat similar situation may prevail in other polders with similar bio-physical and socio-economic characteristics and institutional structure, extrapolation of the result to the other areas should be done cautiously.

Extensive stakeholder consultation and analysis could not be carried out due to time constraint. All field work was carried out before the advent of COVID 19 pandemic. Further field visits for more in-depth understanding of the drivers of conflicts (e.g., via case studies) or validation of findings were not possible because of the pandemic. The situation also restricted organizing a planned stakeholder workshop with participation of the relevant stakeholders as a platform for conflict mitigation.

Non availability of high-resolution satellite images and high-resolution DEM affected the quality of LULC change detection and delineation of sub-catchments of the study area.

1.5 Organization of the thesis

The thesis is divided into eight chapters. *Chapter Two* reviews different dimensions of water related conflicts, with a heavy focus on conflicting situations and their causes, drivers, and challenges in the context of Bangladesh. *Chapter Three* presents the physical and socio-economic settings of the study area (Polder -29), with a particular focus on characteristics overall go the presence or lack of which could be potential sources of water related conflicts at the local level. *Chapter Four* presents methodology employed in the study. Chapters Five through Chapter Eight presents the results of the study, in alignment with the overall goal and objectives of the study. *Chapter Five* presents a detailed characterization of the study area, based on secondary data and information as well as primary data analysis. It particularly illustrates the present or baseline situations with the institutional system surrounding water resources management in the study area, the functionality and performance of different water control structures in different sub-catchments of the study area, availability of water and related resources and their competing uses, including different land uses across the study area, and the extent of hazards and their influences on resources and use. *Chapter Six* presents the identification of conflicts, their spatial and temporal variations based on field data and satellite image analysis. *Chapter seven* presents identification of conflict creating drivers where changing nature of conflicts and their associated drivers are described. *Chapter eight* presents mitigating measures through stakeholder's roles, responsibilities, and different programs with proper stakeholder's involvement. *Chapter nine* presents the conclusions, overall summary and findings of the study.

Chapter Two: Literature review

2.1 Introduction

Water is a fugitive natural resource responsible for water conflict, which is created from the supply of uncertainty and variability, user interdependency, increasing scarcity of freshwater as a consequence of interaction of the human and environmental factors in water resources (Uprety, 2006; Frederick, 1996). People, all over the world race against water resources for their needs or to ensure livelihoods. Like other resources, water is known as a common open access natural resource in 3rd world countries like Bangladesh (Heinz, 2002).

Worldwide, there are a set of examples regarding conflicts that are related to water or water relevant issues govern by different types of factors (Campbell et al., 2000; Skarlato, 2013; Skarlato, 2013; Brown and Raymond, 2014; Acuña, 2015; Damonte and Glave, 2012; Lecoutere, 2011; Ali, 2006; Murshed and Khan, 2009; Rahman et al., 2011; Rahman et al., 2013). For example, in Kenya Campbell et al. (2000) explored conflicts among farming, herbing and wildlife that were created for competitive and over access of scarce resources specially land and water. These types of conflicts gradually intensified and have a. dynamic nature due to different types of drivers. Also, Skarlato (2013) found environmental and resource conflict in North American coastal region which is related to land, water and fisheries. Wennersten (2008) presented Baltic Coastal Region as an example of coastal conflicts due to conflicting human actions and interests, water pollution, competitive exploitation of natural resources (freshwater), and landscape change.

Improper strategy of management system, and lack of participatory management were also found to have created water associated conflicts in coastal environment identified by Brown and Raymond (2014). In Peru, socio-environmental conflicts resulted from the lack of governance and institutional arrangement that had exponentially increased in recent decades (Acuña, 2015; Damonte & Glave, 2012; Lecoutere, 2011). Mujwahuzi (2001) identified diversity in interests and goals, competitive scarce resources, lack of coordination among different organizations, uneven social structure and power practice, and unmet demand as drivers for water conflicts. Water conflicts were found in Tanzania, as a consequence of the ambivalent activities between farmers and fishermen, large-scale irrigation and traditional irrigation system, and upstream and downstream users, triggered by unavailability of freshwater (Madulu and Zaba, 1998; Mbonile, 2005; Mujwahuzi, 2001).

Water related conflicts of the above nature have been more intensified in coastal zones, which are considered as one of the important hubs of natural properties and different forms of resources with high ecological, cultural, and economical importance (Batista et al. 2014; Chu 2006; Costanza et al. 1997; Groot et al. 2012; Halpern et al. 2007, 2009; Uprety, 2006). On the other hand, coastal zones are thought to be the most dwelt (home to 40% of the world's population), exploited as well as productive and threatened areas due to its diverse, competitive and conflicting characteristics (Agardy et al, 2005; Kiousopoulos, 2008; Tsilimigkas & Rempis, 2018). Unplanned, competitive and unequitable use of coastal resources lead to the negative socio-economic and environmental impact that sometimes make a background to create conflicts in coastal regions (Adger et al. 2001). For coastal and marine areas, user-user conflicts from human activities and user-environment conflicts from human activities and environmental sensitivity have been documented (Ehler and Douvere, 2009; Kiousopoulos, 2008). Also, agriculture and aquaculture conflict has been identified as the result of ecosystem changes (Adger et al., 2001).

Bangladesh is not an exception where water resource management for the benefits for all, especially the poor and marginalized, is of immeasurable importance (GoB, 2013; GoB, 2018). According to the Bangladesh Water Act 2013, water sources may be natural or manmade; for instance, pond, canal, khal, beel, haor baor, lake, and rivers are the sources of water. Surface water, groundwater and rainwater as well as any artificial reservoir are treated as water resources (GoB, 2013). Due to the seasonality of water availability, Bangladesh faces umpteen problem both scarcity and abundant water. In the monsoon, plentiful of freshwater availability is observed, whereas scarcity is seen during the dry season (Rahman et al., 2021; Vidal et al., 2014). Dry season water scarcity is aggravated because of transboundary nature of rivers (Khalequzzaman, 2019). This has particularly affected the coastal belt of Bangladesh, which is facing salinity problem and scarcity of freshwater (Abdullah et al., 2017; Azman et al., 2009). Per capita water availability is expected to decline with increasing population and decreasing water availability (Ahmad et al., 2001), as was earlier predicted (Figure 2.1).

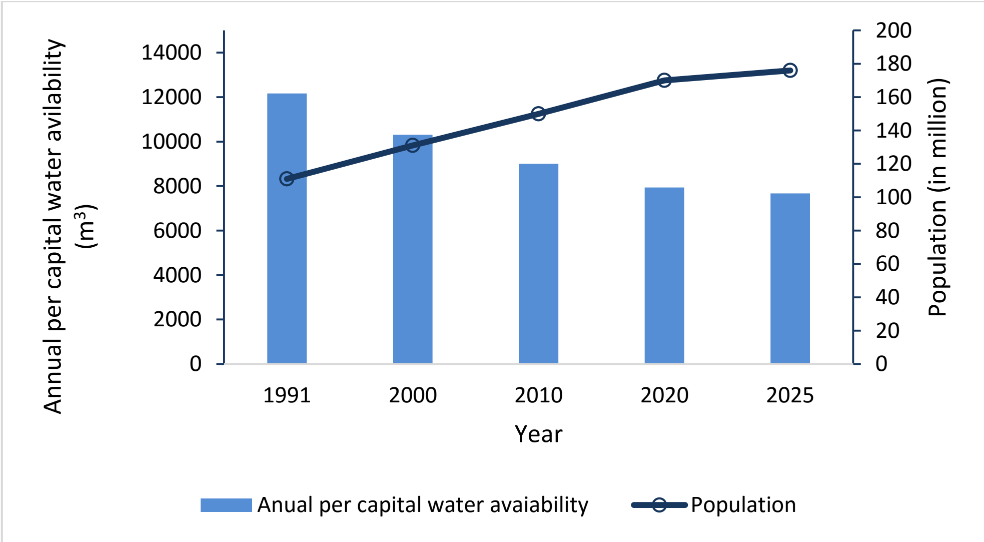

Figure 2.1: Water availability with the population acceleration. [Source: Ahmad et al., 2001]

2.2 Water related conflicts in Bangladesh

Bangladesh is not an exception to water related conflicts as the country widely recognized to be on the front line of climate change having a large population densely packed into a delta vulnerable to changes in sea level, floods, and cyclones. Major public investments since the 1960s have built water management infrastructure (particularly embankments) in much of the country to protect land and people from floods, tides, and storms. There is also a history of informal local collective action in water management (Duyne, 1998).

In Bangladesh, most of the conflicts take place due to water and land related issues. About 11% (more than 17 million) population of Bangladesh engage in fisheries, whereas 52% labor force are involved in agricultural sector for their livelihood contributing to 14% of GDP (BBS, 2018). The fact that majority of the livelihood are based on seasonality increases the likelihood of conflicts as resource declines during the dry season.

2.2.1 Conflicts generated by large scale interventions

In response to increasing damage to monsoon crops and homesteads by recurring floods, large scale flood control projects have been implemented since early 1960's, covering an area of about 5.3 million hectares (Rahman and Salehin, 2013). In the coastal zone, this was deemed necessary as the temporary earthen dams across rivers ("oshtomashi bandhs") were not sustainable any longer after the disappearance of the Zaminder system in the 1950s–1960s, with salinity intrusion and tidal surges causing routine crop damages (Nishat, 1988). This had eventually led to the implementation of 'polders' under the Coastal Embankment Project (CEP), with assistance from the World Bank. While these interventions contributed to several positive impacts and outcomes, in the form of increased protection and security, enhanced economic and development activities in the protected areas and increased agricultural production, the massive infrastructural program, associated with loss of river-floodplain connectivity, resulted in long-term environmental and socio-economic consequences and hence conflicting situations (Chowdhury et al., 1997; Rahman and Salehin, 2013; Thompson, 2017; Islam, 2006).

Conflicts between agriculture and open water fisheries

In the past, agriculture and fisheries were complementary in the floodplains. But with population pressure and intensive agriculture following the interventions, the two became in substantial conflict. The flood control projects were selected on the basis of engineering and economic criteria without much consideration given to the potential harmful impacts on capture fisheries and the wetland environment. The flood control infrastructure impinged in many ways on the life cycle of floodplain fisheries (ODA, 1995; Mirza and Ericksen, 1996; Ali, 1990, 1994), including loss of floodplain habitat during the monsoon resulting in a loss of fish production and blockage to the movements of fish (adults, juveniles, and hatchlings) between rivers and floodplains (Rahman and Salehin, 2013; Chowdhury et al., 1997).

Conflicts between agriculture and livelihood based on country boats

Once country boats alone offered 60% of all employment in the inland water transport sector (Rasheed, 1995). A total of two million people relied on country boats as their main source of income (Chowdhury et al., 1997). Country boats were able to reach outlying rural areas which are otherwise more or less inaccessible. During floods, homesteads in many low-lying parts of the country often remained isolated by water for four to five months, and boat transport was the only means of movement during this time. About 80% of Bangladesh's 68,000 villages were largely dependent on such traditional transport (Jansen et al, 1994). The flood control projects were found to have caused substantial negative impact on country boat-based livelihoods as summarized in Chowdhury et al. (1997); the flood control infrastructure had seriously impeded boat transport in half of the 17 projects investigated by Hunting (1992) and had caused major impacts in 19 projects and medium level impacts in 14 projects out of the 66 projects in NE region studied by Shawinigan Lavalin (1993).

Conflicts between upstream (u/s) and downstream

Flood control projects sometimes are understood to have caused flood risk transfer in increased flood risk in areas upstream, downstream and/or adjacent to the protected area, causing social conflicts (Thompson, 2017; Hunting, 1992; Alam et al., 1990). Generally, protection from river flood in one area leads to increased flood depths or discharge elsewhere. As a result of increased flood risk, people of the unprotected area sometimes cut the flood protection embankment in the past. Such public cutting was widespread throughout the NW region (Alam et al., 1990), with 10 public cut incidents found in 10 projects out of 17 flood control projects studied in FAP (Hunting, 1992) and 39 public cuts observed in the Chalan Beel Project in the NW region during the 1987 flood season, (Thompson, 2017; BWDB, 1987). Cutting of embankments had also taken place by people residing behind the protected embankment to ease off drainage congestion, for example in Chalan Beel, Kurigram South and Nagar River Projects (Thompson, 2017).

Degraded environment constraining resource use

The impact of coastal polders on sedimentation risks in rivers and associated waterlogging within polders is well-documented (Rahman and Salehin, 2013; Halcrow et al. 1993; DHV, 1989). The coastal polders have led to deterioration of river morphology and waterways in the southwest and south-central coastal region. The encircling embankments have decreased tidal prism (the water that would have moved into floodplain in the absence of embankments) with resulting decrease in velocity both flood and ebb tides, with much weaker fusing action during the latter. This has caused severe water logging inside the polders, leading to serious damage to agriculture, forestry, fisheries, livestock, homestead, and physical infrastructures. This was termed a ‘man-made disaster’ (Rahman, 1995). Many people had to leave their ancestral homestead by abandoning traditional livelihood activities (Rahman and Salehin, 2013). The Khulna–Jessore Drainage Rehabilitation Project was conceived, with emphasis on structural solutions, including the construction of large regulators. Local people did not support a structural solution and resorted to widescale protest. The traditional system of allowing natural siltation under the concept of ‘tidal river management (TRM)’ was later adopted and land became suitable again for cultivation. However, institutional issues with this concept surfaced later and TRM has since been not implemented to its potential.

Conflicts between agriculture and large-scale brackish shrimp farming

In the 1990s, increased demand and a high price for shrimp on the international market occurred. As the southwest had a history of limited-scale traditional shrimp farming, polders provided an opportunity for intensive shrimp farming. Many coastal polders constructed to protect agricultural land from inundation of salt water were turned into large shrimp ghers. The priority was reversed, and salt water was allowed in the ghers to raise shrimp. Land previously used for agriculture and mangroves was transformed, often forcibly, to shrimp farming. Wide scale land use conflict emerged and created social unrest (Islam, 2006; Haque, 2004; Karim and Stellwagen, 1998). As agricultural lands were turned into shrimp polders, the sharecroppers and landless wage labourers found themselves losing their livelihoods and began movements to resist the introduction of shrimp in their areas. This often resulted in violence. Several studies reported a reduction in land for cattle grazing (Maniruzzaman, 1998), death of trees and other vegetation (Alauddin and Tisdell, 1998), increased salinity of soil and water and a reduction in the drinking-water supply because of the introduction of shrimp farming (Islam, 2006).

2.2.2 Water conflicts at local level

At the local level, water conflicts are often very complex and of varying nature and are accentuated by hydrological, social, economic, institutional, and environmental drivers (Naz and Buisson, 2015). Conflicts are seen among different groups of people (user-user conflicts) defined by livelihood types or geographical locations (e.g., upstream vs downstream), and between human activities and environment (user-environment conflicts) (Parvin et al., 2017; Naz and Buisson, 2015; Chowdhury et al., 1997). Conflicts also arise from implementation of different water management projects (Murshed and Khan, 2009; Rahman and Salehin, 2009; Sultana et al., 1995), often associated with non-functionality and/or inappropriate design and operation (often driven by local power dynamics) of water control systems (e.g., drainage canals or sluices) (Murshed and Khan, 2009; Faruque, 2009; Rahman and Salehin, 2009; Mozahedy, 2009).

Researchers all over the world have identified the cause of natural resources-based conflicts particularly drivers of water conflicts are well documented where sociopolitical and socioeconomic influence over operations, lack of transparency, diplomatic complexity, quick and imbalance land use land cover change, competitive use of water resources were captured as main drivers (Sultana et. al., 2019; Nagabhatla et al., 2021; Dahlet et al., 2021; Salamé et al., 2021; Angelakis et al., 2021; Susman et al., 2021; Tariq, & Zhang, 2020; Nyam et al., 2020). A number of studies (Abdullah et al., 2017; Bulleri & Chapman, 2010; Haider & Akter, 2018; M. R. Islam & Tabeta, 2019; Murshed, 2009; Naz & Buisson, 2015; Sultana et al., 2019) have demonstrated that in Bangladesh, extensive shrimp farming, conflicting roles and unhealthy incentives between actors and stakeholders, weak coastal infrastructures are major drivers for local level water conflicts.

Agriculture vs shrimp aquaculture

Even after the exodus of large-scale brackish shrimp farming by external interest groups following an anti- saltwater shrimp movement in mid 1990s, shrimp farming continued in the form small ghers by the rich farmers and local powerful groups (Abdullah et al., 2017). Shrimp aquaculture eventually became a fast-growing industry, with the farm area growing from 20,000 ha in 1980 to 244,000 ha in 2014 (Karim et al., 2014), and nearly 12 million people directly involved in shrimp production and another 4.8 million supported by the other processes of shrimp industry (USAID, 2006). While positive impacts of shrimp aquaculture have been well documented (Belton et al., 2014; Jahan et al. 2010; Gammage et al. 2006; USAID 2006; Sharmin and Ali 2005; Pokrant and Reeves 2003; Hamid and Alauddin 1998), which include increased income, improved food security, enhanced employment opportunity (especially for women), etc., environmental, economic and social negative impacts have also been documented (Belton et al. 2014; Paprocki and Cons, 2014; Toufique and Belton 2014; Jahan et al. 2014; Hossain et al., 2013; Ahmed et al. 2010a,b; Ahmed et al. 2002).

Abdullah et al. (2016) explains how shrimp aquaculture has impacted livelihood around the Sundarban areas. Higher income households derived more income from shrimp and extended ownership to more land from the poorest, thus impacting the marginal farmers and landless and leaving them more vulnerable. Landless and marginal farmers tend to support rice farmers to gain benefits from traditional agriculture and to protect the environment from unplanned shrimp farming. These people have been the major protesters against shrimp farming compared to rice farmers, the reasons being the perceived negative impacts of shrimp farming, including destruction of environment, increased unemployment, increased salinity, reduced potable water and dismantling of environment (Paul and Roskaft, 2013).

Faulty or inappropriate operation of water control structures

In many freshwater environment, big farmers control the sluice gates according to their crop needs, while the gates remain closed when they needed to be kept open for fish migration

(Sultana and Thompson, 2017). Murshed and Khan (2009) found that a huge portion of beels in some areas of southwest coastal region remain dry due to intentional closing of the sluice gates and regulators, when the outside water level is relatively high, leading to significant reduction of water area coverage for fish species. Murshed and Khan (2009) also observed that the risk of conflict between beel dewatering (to increase agricultural land) and fisheries tends to increase with increasing scarcity of water resources. The diversification of such conflicts indicates that their probability of occurrence is significant. These conflicts may not be always expressed because of suppression of the voice of the weak in the community power structure.

Nath et al. (2020) observed that significant change of livelihood strategies and practice have taken place in the coastal polder system, especially in the case of agriculture and fisheries. Lots of unplanned inlets have generally been seen in the polder that helps to increase salinity flow, helping chunks of agricultural lands and other land use such as vegetation, char land, khas land ettc. turn into aquaculture. Sanchayan, et al. (2020) found illegal use, encroachment, and operation of water control structures by political leaders, land grabbers, and local administrations, and served as substantial source of local conflicts among different groups of people.

Elite capture aggravating local level conflicts

Water allocation via gate operation of the sluice gates is often controlled by the politically powerful people, who tend to serve their own interests (Dewan et al., 2014; Sultana, 2009; Nowreen et al.,2009; Murshed and Khan; 2009; Rahman and Salehin, 2009). Bernier et al. (2016) found that water timing and release often depend on local elites (and may require payments), diverting water for their interests can reduce local water availability in the dry season at the cost of crops or fisheries in other parts of the system. This is more often seen in the coastal environment, with local politically powerful and influential people, either being member of water management cooperative agency (WMCA) or part of the informal beel/ catchment committee controls the operation of the gates to maximize benefits, for example by allowing water (saline for brackish shrimp) when needed by them, or by actions which prevents or slows down drainage of water from within polders during monsoon (thus impacting Aman plantation), or by restricting water when needed by others (Nowreen et al., 2009; Murshed and Khan, 2009).

2.3 Conflict mitigation

Conflicts of an area depends on the issues of who and how the resources are to be controlled and used, relationship among stakeholders and user groups as well as institutions exist for governance (Murshed-e-Jahan et al., 2014). Right of access is one of the vital reasons for creating conflicts in Bangladesh. On the other hand, lack of regulations on local level conflicts during project design and implementation is another barrier to resolving conflicts. Moreover, lack of effective formal structures for water management and most importantly conflict resolution bodies, less coordination and act of overlapping activities and jurisdictions by different institutions often open new dimension of conflicts that reinforce existing water conflicts (Parven & Hasan, 2018; Sultana et al., 2019). Sometimes, victims of conflicts are unaware of the people or institutions they can convey the conflicting issues to for conflict alleviation as obligated by law.

To mitigate conflicting issues, policy implementations are highly recommended where formulating civil society organizations to implement a strategic plan to ensure human rights is getting popular. In Bangladesh, Ministry of Water Resources formulated National Water Policy in 1999 to guarantee effective and impartial administration of water assets, appropriate outfitting, and advancement of surface and groundwater, accessibility of water to all concerned, and institutional limit working for water resource administration. The Bangladesh Water Act, 2013 is for the most part follows the National Water Policy of 1999, and it is intended for coordinated improvement, administration, appropriation, utilization, security and preservation of water assets in Bangladesh (GoB, 2013; MoWR, 2015). Several studies have identified conflicting measures through community participation through the following activities (Murshed-e-Jahan et al., 2014).

- Workshops and meetings for ensuring multi-stakeholder participation in conflict management
- Participatory Action Plan Development (PAPD)
- Multi stakeholder committee for conflict resolution
- Awareness raising in fishing communities
- Informal institutions as conflict mediators
- Regional cooperation

Stakeholder's Analysis (SA) is an efficient approach applicable to situations where resources (e.g. forests, land, water, irrigation systems) are managed as common property rather than when resources are privately owned, particularly where traditional institutions regulating communal use and management are breaking down; and where resources are officially owned by the state but function in practice as open access resources (Alamanos et al., 2021; Ramirez, 1999; Renner & Opiyo, 2021). Moreover, different levels of stakeholders have distinct interests and agendas, which include macro and micro interests and range from government departments, environmental pressure groups and commercial interests to local farmers. In such contexts, not only the interests in natural resources but also the cognitive frameworks (knowledge base, decision making criteria etc.) and economic circumstances will vary considerably between stakeholders. SA would be particularly valuable in these conditions, as opposed to situations where competition may exist over use of a resource but the main stakeholders share similar interests and are fairly homogeneous (Mutahara et al., 2020; Peters et al., 2019; Renner & Opiyo, 2021).

Chapter Three: Study Area

3.1 Selection of the study area

Polder 29 in South-West coastal Bangladesh was selected as study area since this polder has been facing high poverty, bio-physical hazard, and agricultural water scarcity. Besides, physical accessibility and data availability was one of the main reasons to select the polder. Furthermore, this polder was constructed in 1966-71 by the Bangladesh Water Development Board (BWDB) and was one of the two polders selected as pilot project implementation under the Delta Development Project in 1988. Moreover, BWDB had taken intervention by IPSWAM project followed by 'Blue Gold' project who were working since 2003 to replenish the difficulties through structural rehabilitation and empowering participatory water management institutions. This polder is under the Khulna O&M Division – 1, BWDB, Khulna as administrative jurisdiction. Though several initiatives have been taken through projects for the better water management, water conflict had not been taken into consideration. Where these conflicts changing its nature and degrading water security that leads to conflict dynamic.

3.2 Location

Polder 29 - about 75 km away from the Bay of Bengal was located between latitude from 22.8021°N to 22.6458°N and longitude from 89.4213°E to 89.4250°E over an area of 79.30 sq. km in South-West coastal Bangladesh, covering five unions which includes Bhandar Para, Sahas, Sarappur, Dumuria and Surkhali across Dumuria and Batiaghata upazila of Khulna district (CEGIS, 2016). The location of the study area is shown in Figure 3.1.

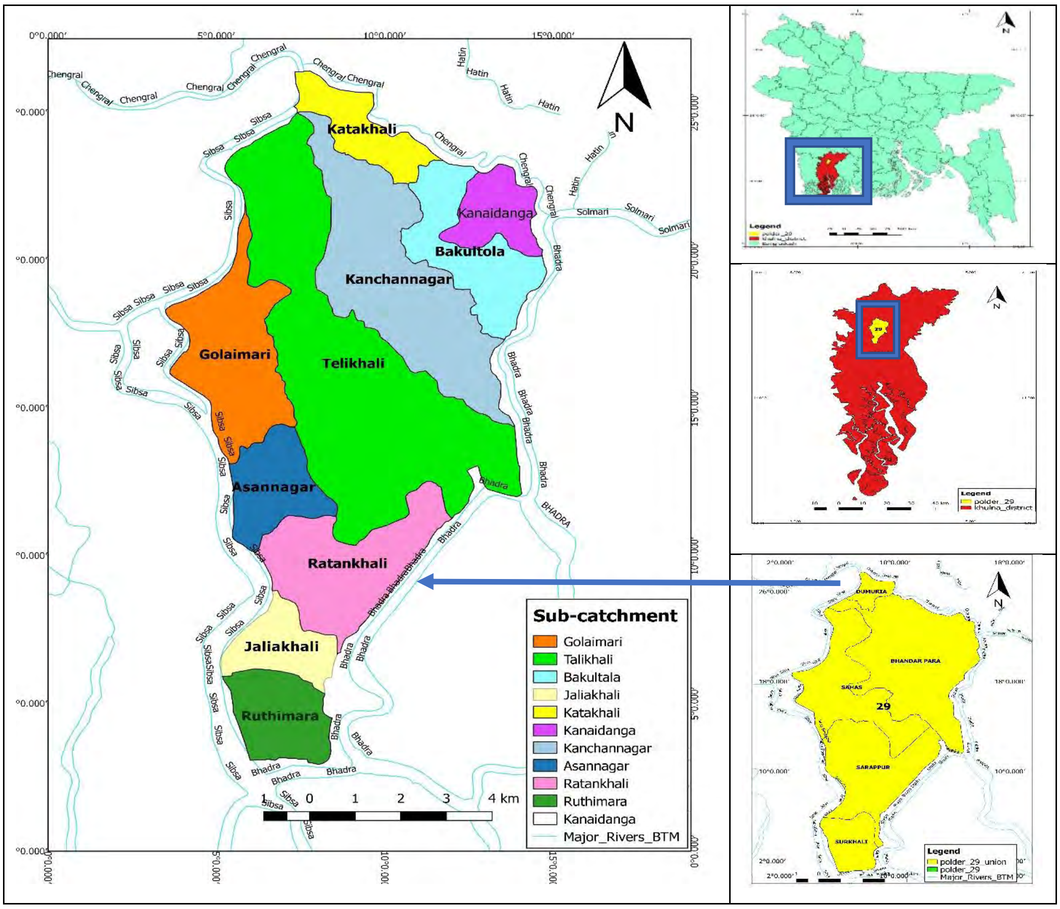

Figure 3.1: Location of polder 29 showing the catchments (study area)

3.3 Climate

The nearest rainfall station for polder 29 are Khulna BMD station, Dumuria, Paikgacha, Chalna and Kapilmuni BWDB station. During July and December, the height and lowest rainfall has been observed that are 343mm and 7mm respectively (1978 to 2008) (Blue Gold, 2016). Besides, maximum mean temperature in this polder remains around 30.4°C. Minimum temperature here fluctuate significantly between 15.37-25.2°C. May is recorded for the height average temperature and lowest average is experienced in January.

The study area having higher value of relative humidity compared to the other areas for being coastal characteristics. From starting of summer (April), relative humidity started to increase. The value increases more than 85% during June-September and starts to decrease from the first of monsoon following by rainfall. On the other hand, the height and lowest wind flow is observed in April (160kph) and November (40 kph) respectively. During a storm, wind speed rises up to 250-300 kph, for instance, 260 kph was recorded during SIDR 2007 (Blue Gold, 2016; CEGIS 2012, 2016).

3.4 Demography

There are 55304 population in polder 29 having density of 1023 persons per sq. km with 12560 households (Table 3.1). Number of male residences is lower than the female population (male female ration is around 100:101.21). Muslims, Hindus and Buddhists are available in this polders, among them 96% are belongs to Islam (Blue Gold, 2016; CEGIS, 2016). On condition to the ownership status, 54.31% land are leased in or leased out where 43.79% land are owned by landlord (Blue Gold, 2016). Similarly, the percentage of marginal (having no or <1 acre of land) and small farmers (1-2.5 acres) are 54% and 29% respectively, where only 4% people belongs to more than 7,5 acres of land (BBS, 2011b).

Table 3.1: Population of the study area

District	Upazila	Union	Total HHs[8]	Population			Sex ratio	Population density
				Both	Male	Female		
Khulna	Dumuria	Bhandar Para	3861	15860	7951	7909	101	1015
		Dumuria	451	1986	1000	986	101	1088
		Sahas	4654	19295	9603	9693	99	1024
		Sarappur	3908	15266	7524	7742	97	965
	Batiaghata	Surkhali	1445	5990	2944	3046	97	1024
Total/Average			14319	58397	29023	29374	99	1023

[Source: Blue Gold, 2016]

3.5 Occupations and livelihoods

Water oriented livelihood make polder 29 more sensitive as 56% of land is used as agricultural purpose where water bodies are in decreasing trend. However, the percentage of economically active people are about 27.25%, among them the percentage of employed and people who are engaging with household work are 38.63% and 61% respectively. Among distributing people of employed, 35% are involved in agriculture where crop farming, fishery with livestock and poultry are notable. From the perspective of day labourer, males are getting almost double wage in a day (abound 400 taka per day) then women folk, albeit more than 60% of total economically effective are even unemployed. According to BBS (2011b), people having age of 7 or above and are not going to school is defined as economically active. About 42.6% women are household in profession who helps her husband in agricultural activities beside their household work.

3.6 Education

Polder 29 is a place of having favorable appreciation for education in respect to equal opportunity of enrolling in school or educational institutions. In this study area, 51% people have elementary knowledge where for the percentage of male and female is 60% and 56% in some respects. According to BBS (2011a), attendance rate of any educational institutions up to 29 years is 41% albeit 59% is the not attendance rate.

3.7 Topography and land use

The study area is located with lower average elevations as reduced level varies from 0.96 to 2.16 m PWD. On the other hand, rest of the land is under the elevation between 1.38 to 1.61 m above MSL. The elevations are minor downward sloping from north to south that helps to flow water from upstream catchments to Bhadra and Ghengrail rivers. Moreover, elevations of maximum catchments near peripheral polder are relatively higher compared to central areas. Net arable area is about 5,466 ha, which is 69% of the total gross area (Table 3.2) (CEGIS, 2016). The coverage of settlements is 23%, water bodies (river/khals) is 7% and road is 1% of the gross area (Figure 3.2). About 390 ha (7% of net cultivable area) is under rice-cum-fish culture.

Table 3.2: Detailed land use of the polder area

Land use	**Area (ha)**	**% of Gross Area**
Net Cultivated Area (Agriculture)	5466	69
Settlements	1811	23
Water bodies (river/khals)	590	7
Flood	63	1
Gross area	7930	100

(Source: CEGIS, 2016)

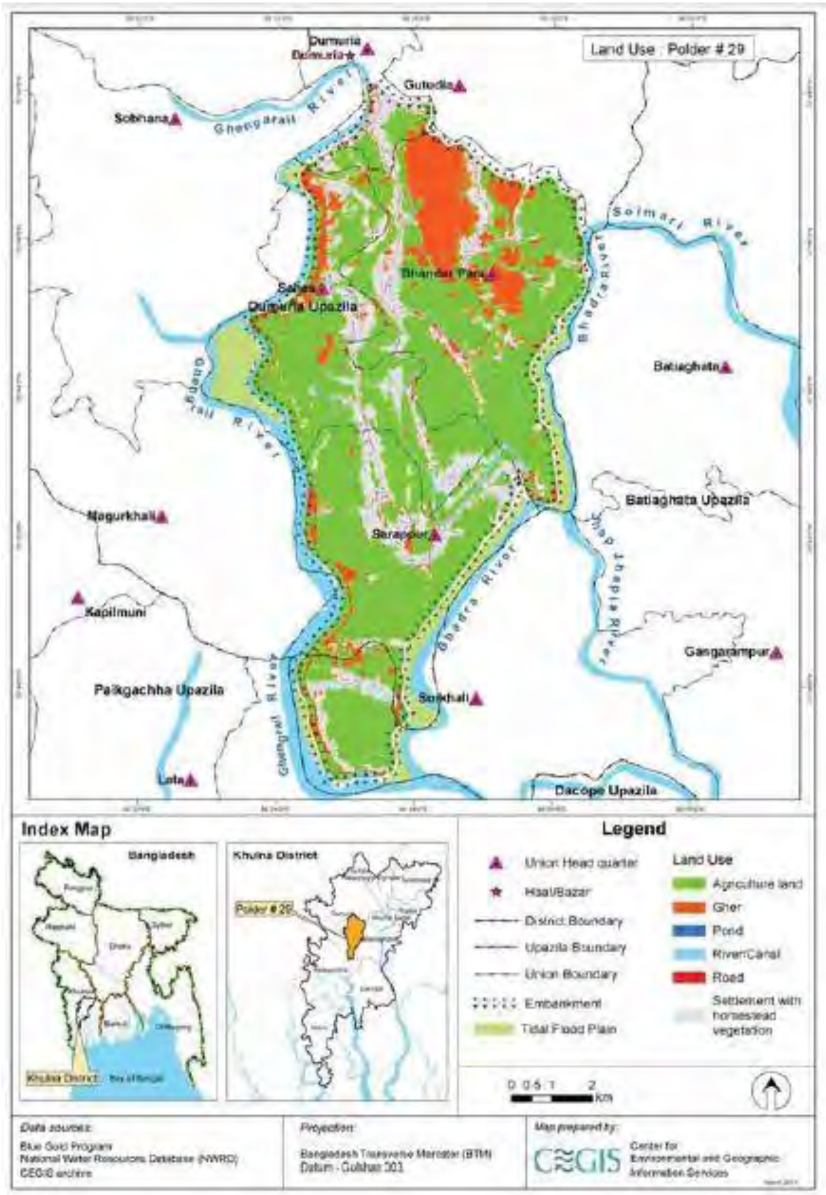

Figure 3.2: Land use map of Polder 29 (Source: Blue Gold, 2016)

3.8 Hydrology and drainage network

By using existent hydrological networks and structures, for instance rivers, canals, regulators and sluice gates (Figures 3.3 and 3.4), Polder 29 is divided into ten catchments, as demarcated in the Blue Gold project (Figure 3.1). Before the implementation of the Blue Gold project, most of the khals were being silted up due to high sedimentation and manmade interventions (Table 3.3). During the rainy season, around 98% Net Cumulative Area was under partially drained, meaning that water was draining very slowly, while 2% was drained poorly, with soils going under water for 15 days to several months in some areas (Figure 3.5) (CEGIS, 2016).

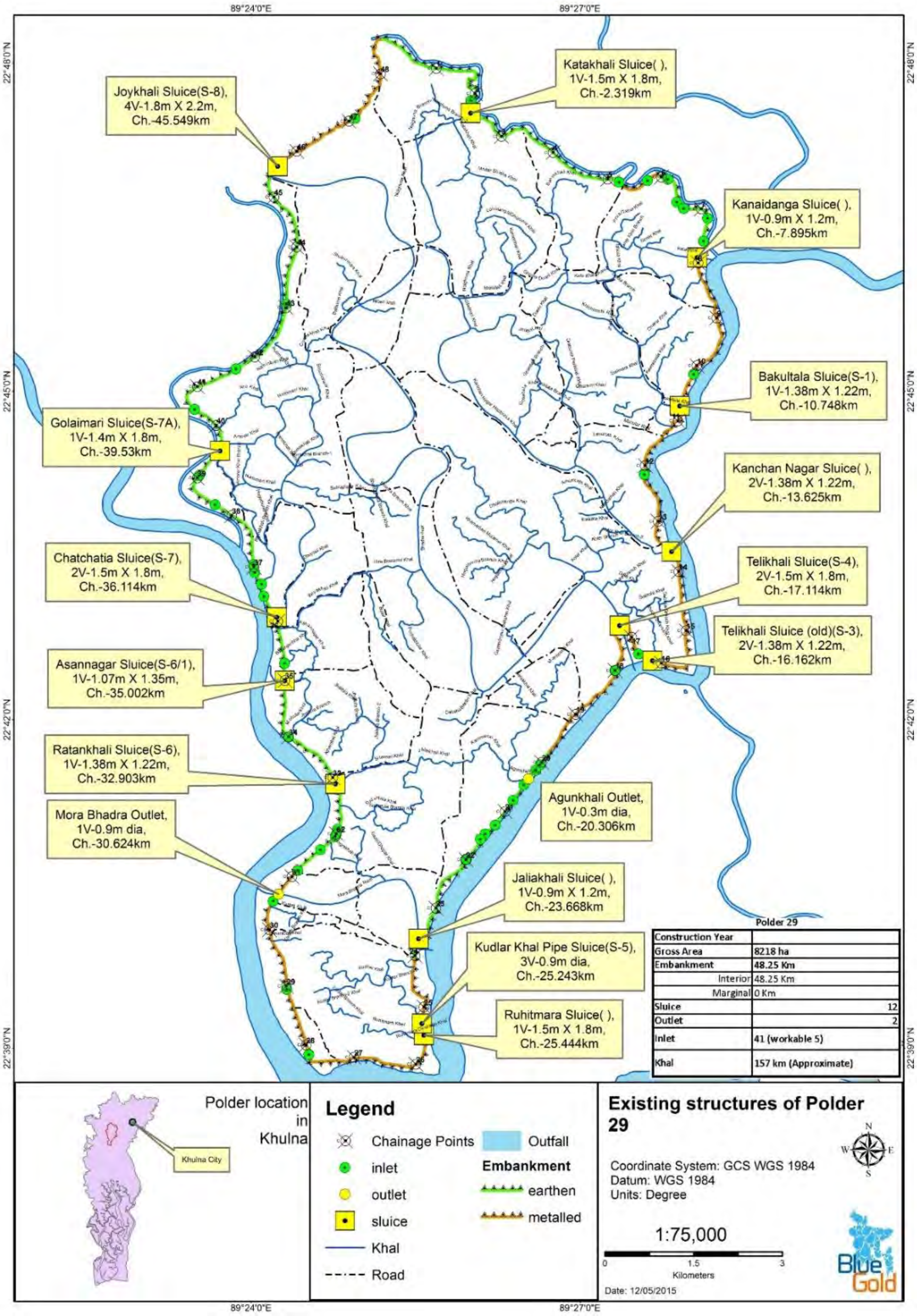

Figure 3.3: Existing drainage network in polder 29 [Source: Blue Gold Office, Khulna]

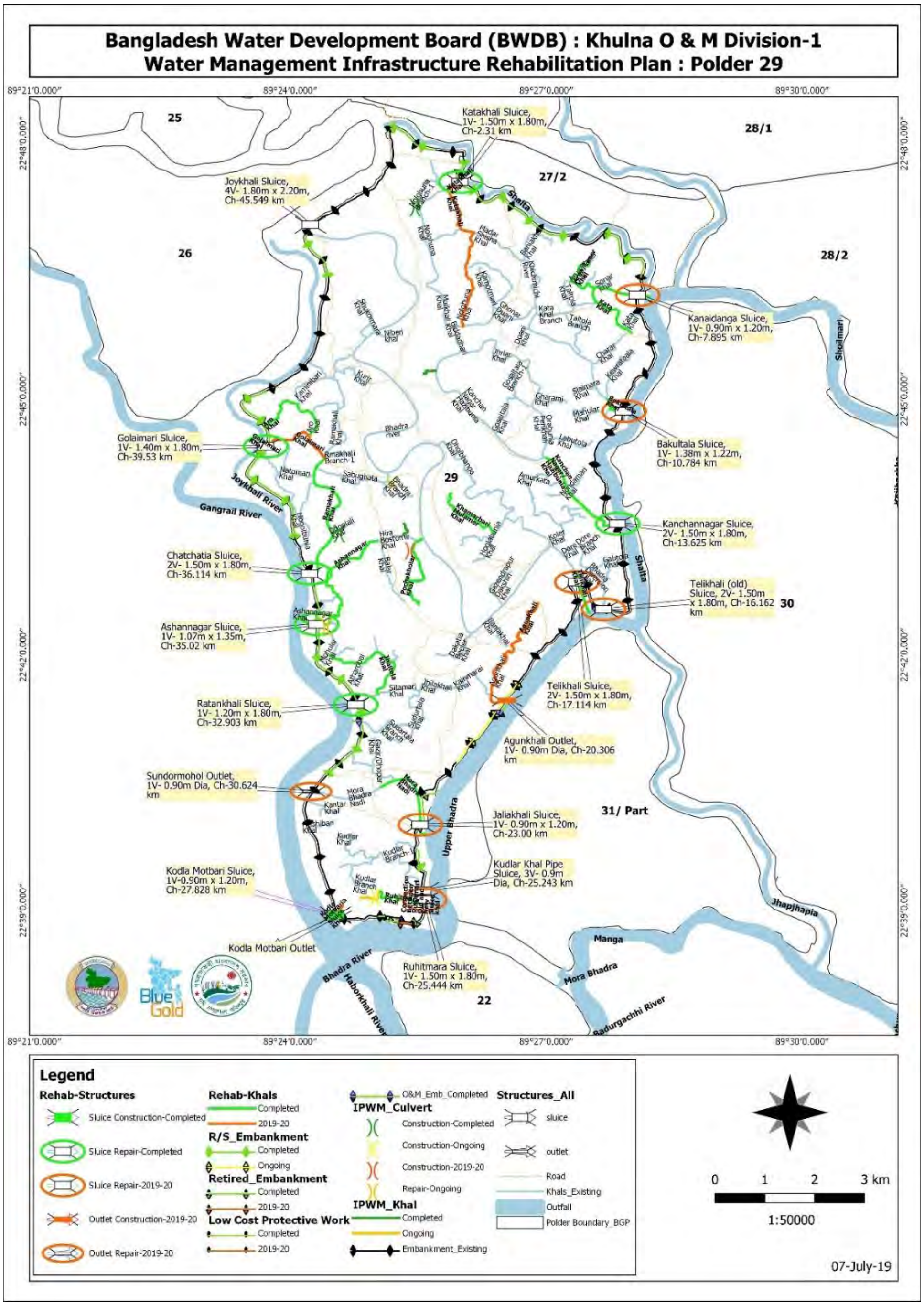

Figure 3.4: Drainage network rehabilitation plan under Blue Gold program in Polder 29
[Source: Blue Gold Office, Khulna]

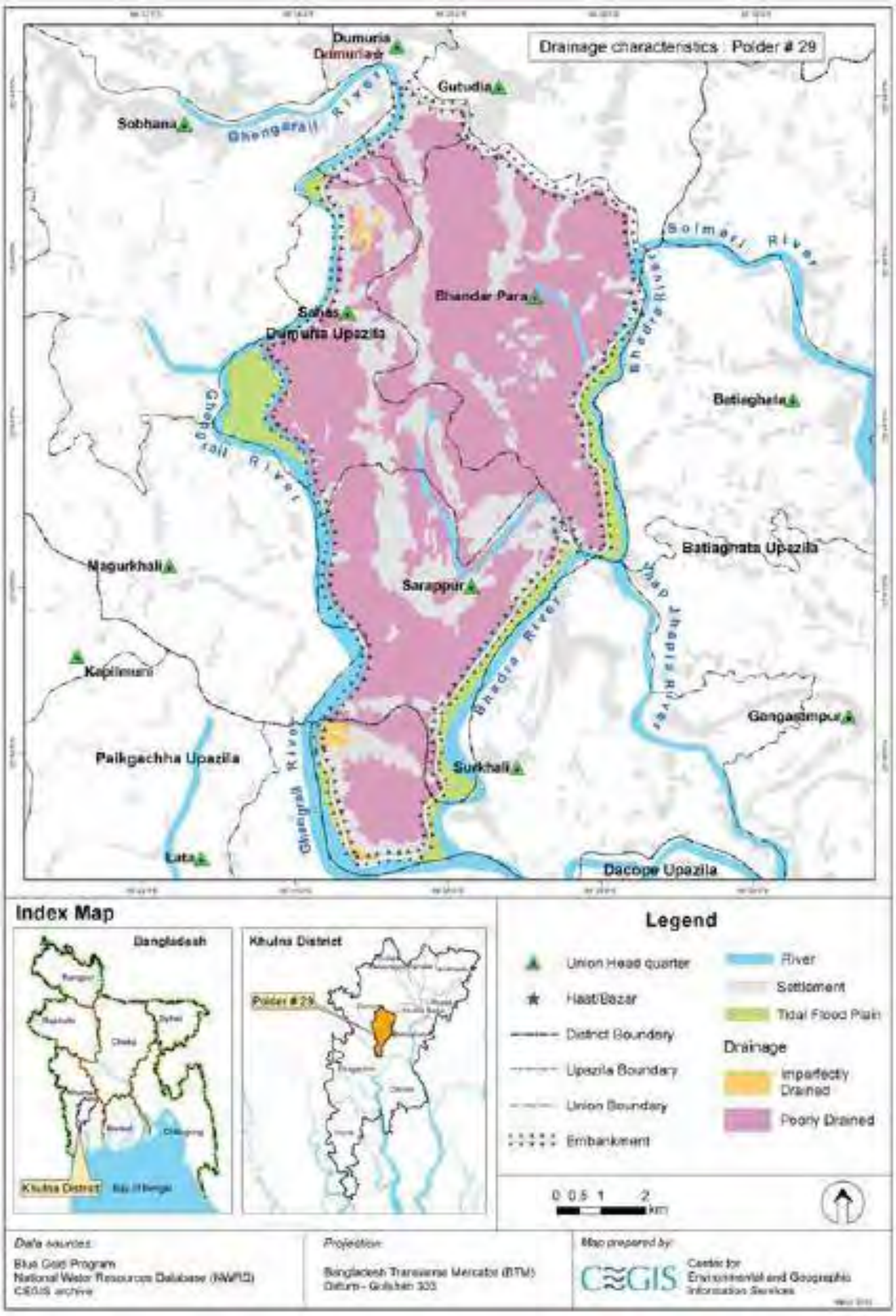

Figure 3.5: Drainage characteristics in Polder 29 [Source: Blue Gold, 2016]

3.9 Water Use

Average domestic water use in polder 29 is around 30 liters per capita per day (lpcd) (CEGIS, 2016) where standard value for this purpose is enumerated as 50 lpcd (Ahmed & Rahman, 2010; Blue Gold, 2013; CEGIS, 2016). Due to questionable shallow and subsurface saline water, people prefer deep tube well and rainwater for drinking purpose.

3.10 Fisheries

Both diversified brackish and freshwater fish is available in polder 29 having tidal in nature. There are two categories of fishery have been observed named culture and capture fishery. Fish habitats inside water bodies of polder areas (internal canals, khals, feeder and effluents) which have flooding in nature during spring are in the capture fisheries category. On the contrary, polder 29 areas are dominated by culture fisheries for instance gher oriented Bagda/Golda shrimp farming where pond based fishery is also include (Blue Gold, 2016).

3.10.1 Capture Fisheries

There are umpteen khals, canals and effluents exist inside the study area along with its peripheral rivers. Those water body serve as open water fish habitat. As for instance, Mora Bhadra, Ruhitmara khal, Katakhali khal, Khichimichi nadi, Golaimari khal etc. carries a lot of significance in capture fisheries and acts very important role in conserving aquatic resources. However, about 590 ha of land in the whole 1105 ha of fish habitat is expected as capture fishery, though these habitat are being grabbed and illegally encroached as gher oriented capture fishery (Blue Gold, 2016).

3.10.2 Culture Fisheries

Ghers and ponds are the major source of cultural fisheries in polder 29. Gher culture is expanding by degrees in which rice cum golda gher, golda cum white fish gher, bagda gher are noteworthy. Among them, rice cum golda culture is widespread where salt water oriented gher farming is exceptionally high in the southern part of the study area. Amount of natural cultural pond is about 5% of total pond, this is why local people especially elite groups have relatively more alacrity to gher oriented culture than pond (Blue Gold, 2016).

3.11 Hazards and disasters

3.11.1 Salinity

Dry season salinity in khals and peripheral river water were found to be 12 ppt and 18 ppt, respectively, whereas saline resistant horticulture was expected to sustain salinity levels up to 15 ppt (Blue Gold, 2016; CEGIS, 2016). CEGIS estimation from SOLARIS-SRDI revealed that over the period, soil salinity of the area inside the polder increased gradually. Local farmers reported that most of the water control structures were not functioning properly. As a result, they could not restrict intrusion of saline water inside the polder, which was reported as the major cause of the incremental increase in salinity inside the polder. The soil salinity and water salinity gradually increase with dryness from January and reach maximum level in the month of March-April and then decrease due to onset of monsoon rainfall (Blue Gold, 2016).

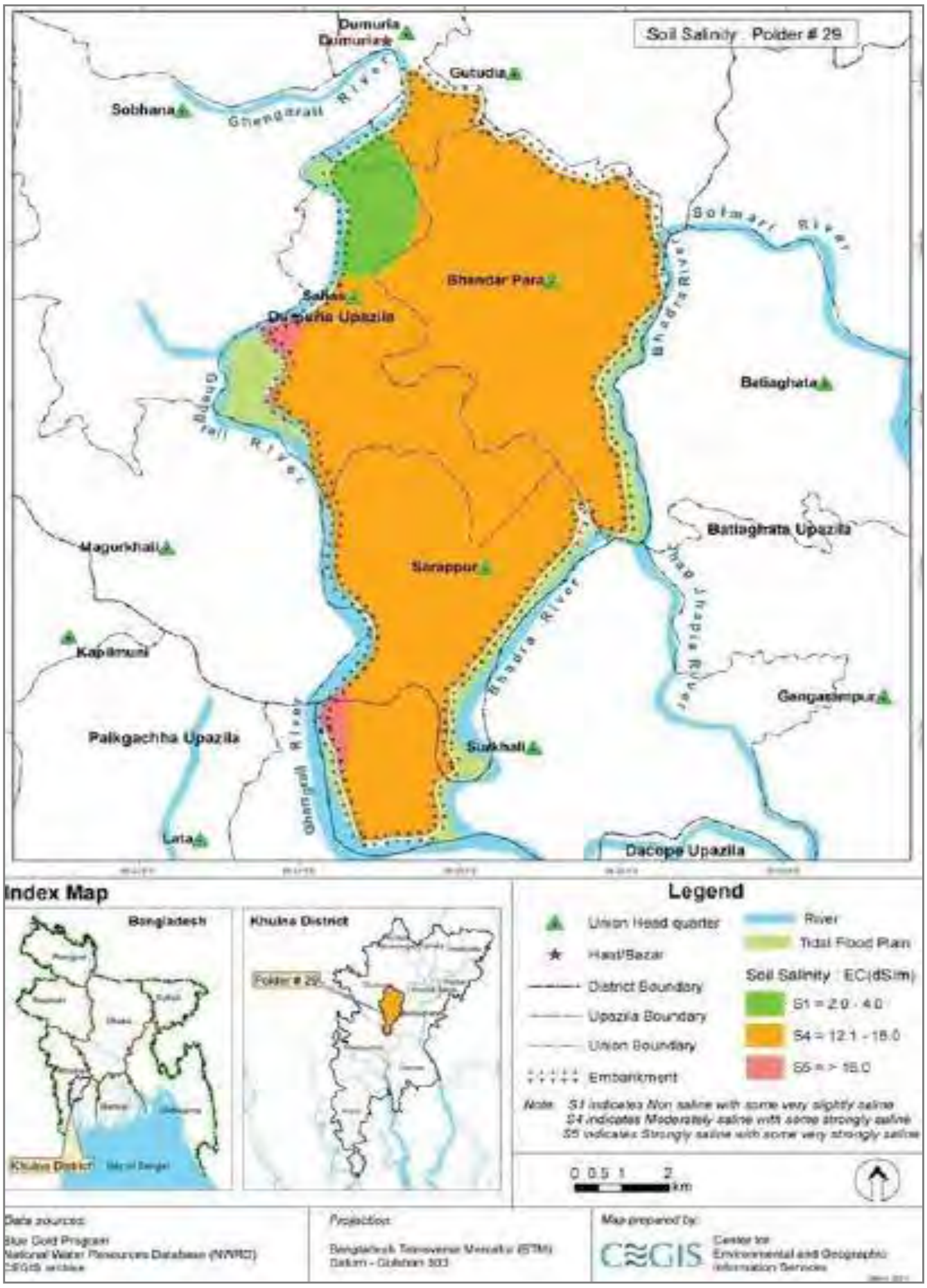

Figure 3.6: Soil salinity map of Polder 29 (Blue Gold, 2016)

3.11.2 Cyclones and Storm Surges in Polder 29

Tropical cyclones from the Bay of Bengal accompanied by storm surges are one of the major disasters in the coastal regions in Bangladesh. The high number of casualties is due to the fact that cyclones are always associated with storm surges, sometimes with surge heights of even more than 9m. For example, the 1876 cyclone had a surge height of 13.6 m and in 1970 the height was 9.11 m. By observing the tracks of different cyclones affecting the country in the last decade, the country's southward portion has been classified into three risk zones namely, high risk zone, risk zone, and wind risk zone. Polder 29 falls in the wind risk zone which possesses some vulnerability due to the strong winds, and surge heights associated with cyclones. From field observations, it was found that the polder did not undergo any major damage during the recent cyclonic events such as SIDR (2007), AILA (2009) and MOHASEN (2013) (Blue Gold, 2016, 2014b).

Chapter Four: Methodology

4.1 Introduction

As discussed in Chapter One, the objectives the study are to characterize water conflicts and their drivers, and to assess roles of institutional programs and/or water management programs in mitigating conflicts. To address these objectives, both primary data and information derived from the field and secondary data and information from different organization sources and published reports were used. The methodological framework is illustrated in Figure 4.1.

Study area selection

Polder 29, beset with persisting problems of agricultural water security, bio-physical hazards and the resulting high incidence of poverty, has been one of the polders selected under the Blue Gold project of BWDB. The Blue Gold project has had a major focus on institutional or governance improvement through introducing or reviving water management organizations (WMOs), together with rehabilitation of non-functioning water control structures, for better management of water resources within the polder. The polder thus represented a very good test case for studying local level water conflicts, given the perceived possible sources of conflicting issues with water. Besides, physical accessibility and data availability (e.g., from different reports published during the feasibility study phase of the Blue Gold program) also made the polder a good choice for the conflict study in question.

Reconnaissance field investigation for conceptualizing and framing research questions

Reconnaissance field investigation in the beginning of the study helped conceptualize the issues and frame the research questions. It insinuated that different forms of conflicts exist among the same livelihood groups (e.g., farmers) as well as between different livelihood groups (e.g., between agricultural farmers and shrimp farmers) in different sub-watershed units (defined based on drainage systems in accordance with different regulators/ sluices). The conflicts are associated with different land use practices, changing land use, topographical differences between upstream and downstream affecting water availability, obstruction across the natural drainage canals, siltation of canals, and conflicting use of river (e.g., through operation of sluice gates or other means), reinforced by elite capture of water. The reconnaissance investigation also suggested that there may be some mismatch between the way the sub-watersheds have been conceptualized in the Blue Gold project and subsequently the defined responsibilities of WMOs, along with the distribution and roles and responsibilities of the WMOs and the real situation in the field, which might be affecting smooth water management by the WMOs.

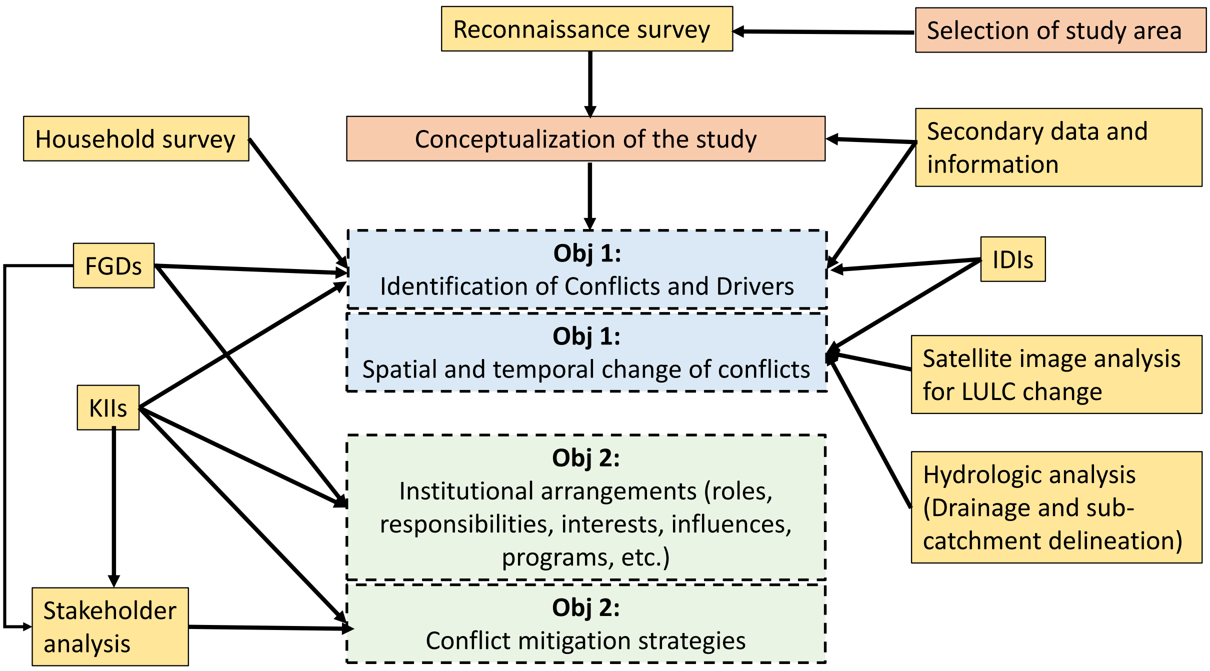

Figure 4.1: Methodological framework of the study

Application of PRA tools and using household survey data for discerning conflict dynamics

Primary data collection focused on the identification of conflicts and their drivers in the complex hydrologic and socio-economic settings that exist within Polder 29 and capturing the dynamics of changing nature of conflicts. At the same time, investigation of probable solutions to mitigating conflicts and ensuring equitable water security also dictated the type and approaches used for data collection.

A set of participatory rural appraisal (PRA) tools were applied to map temporal as well as spatial variation of drivers and the resulting conflicts. In-depth interviews (IDIs) with elderly people were conducted to perform timeline analysis of the changing nature of conflicts. Besides, focus groups discussions (FGDs) were conducted with major livelihood groups and members of WMOs in different sub-catchments to identify the varying nature and drivers of water conflicts and their implications for water security. Relevant data from the household survey conducted under REACH project of IWFM were used to further elucidate spatial distribution of land use, water security risks and drivers of conflicts.

Land use change analysis to examine changing nature of conflicts with time

To understand the temporal characteristics of changing nature of conflicts, change in land use, a key driver for conflicts, were analyzed via image analysis of satellite images (LANDSAT) for different time periods, with ground truthing done at multiple points within the polder. Besides, the timeline analysis conducted with the elderly people via IDIs was also used to corroborate land use change analysis.

Hydrological analysis to further elucidate spatially varied nature of conflicts

In order to capture the spatial variation of conflicts and identify the underlying drivers, detailed characterization of the sub watershed units of Polder-29 was made using the SRTM DEM data. The watershed analysis also helped identify the mismatches between the Blue Gold project delineation of sub-watersheds and the actual situation in the field (which was also corroborated by Blue Gold officials and the local respondents in KIIs). The analysis helped identify impact of human activities on drainage impediment through canal and water structures and the possible propagation of impacts of sluice gate operation practices, a potential source of upstream-downstream issues.

Application of PRA (KIIs) and stakeholder diagramming to map institutional structure, roles, and responsibilities

Key Informant Interview (KIIs) were conducted with relevant stakeholders to understand the institutional arrangements for water management and their respective roles and responsibilities, especially in the context of conflict management. This is a pre-requisite for investigating probable conflict mitigation strategies. KIIs also helped perform stakeholder diagramming with mapping of different interests and capacities of different stakeholders to address or contribute to conflict mitigation.

The methodological framework is discussed at length in the subsequent sections.

4.2 Secondary data collection

Documented data/ information sources

Important secondary information was also collected from different journals, published and unpublished reports from the LGED, BWDB, BBS, BUET, Blue Gold, IPSWAM and other government non-government organizations and/or projects. The purpose was to access location and area of the study, household size, number and occupation, distribution of farmers' categories, hydrometeorology (such as river water level, rainfall etc.), land types, water conveyance and drainage system, and agricultural and fisheries practices. Besides, the reports published under the IPSWAM and the Blue Gold projects helped conceptualize the study, frame research questions and preliminary understanding of possible sources of water conflicts and their drivers, and to assess roles of institutional programs and/or water management programs in mitigating conflicts.

Satellite image

The satellite images were acquired from the United States Geological Survey (USGS) with 30m resolution and having cloud coverage of less than 10%. Landsat-5 TM and Landsat 8 OLI-TIRS imageries were considered for the year of 1990, 2000, 2010 and 2019 respectively that were taken by using 138/43 path and row (Table 4.1).

Table 4.1: Detail about collected satellite image

Year	Date	Satellite image type	Resolution (m)	Row/path
1990	February & October	Landsat 4–5 Thematic Mapper (TM)	30	43/138
2000	February & October	Landsat 4–5 Thematic Mapper (TM)	30	43/138
2010	February & October	Landsat 4–5 Thematic Mapper (TM)	30	43/138
2019	February & October	Landsat 8 Operational Land Imager (OLI)	30	43/138

DEM of the study area

DEM was retrieved from the United States Geological Survey (USGS) Earth Explorer, SRTM. Figure 4.2 shows the detail elevation of the study area. The study area is located in the south-western hydrological zone of the country, with very low average elevations. Analysis using Digital Elevation Model (DEM) infers that the DEM value inside the polder vary from -7 to 14 m MSL (Figure 4.2). The elevations are more or less similar, with a very minor downward slope from north to south, which eventually draws water from the upstream basins to the Ghengrail and Bhadra rivers. There is also a radial topographic trend observer, as most of the land elevations near settlement, major River and the polder periphery are higher than that of the other central areas.

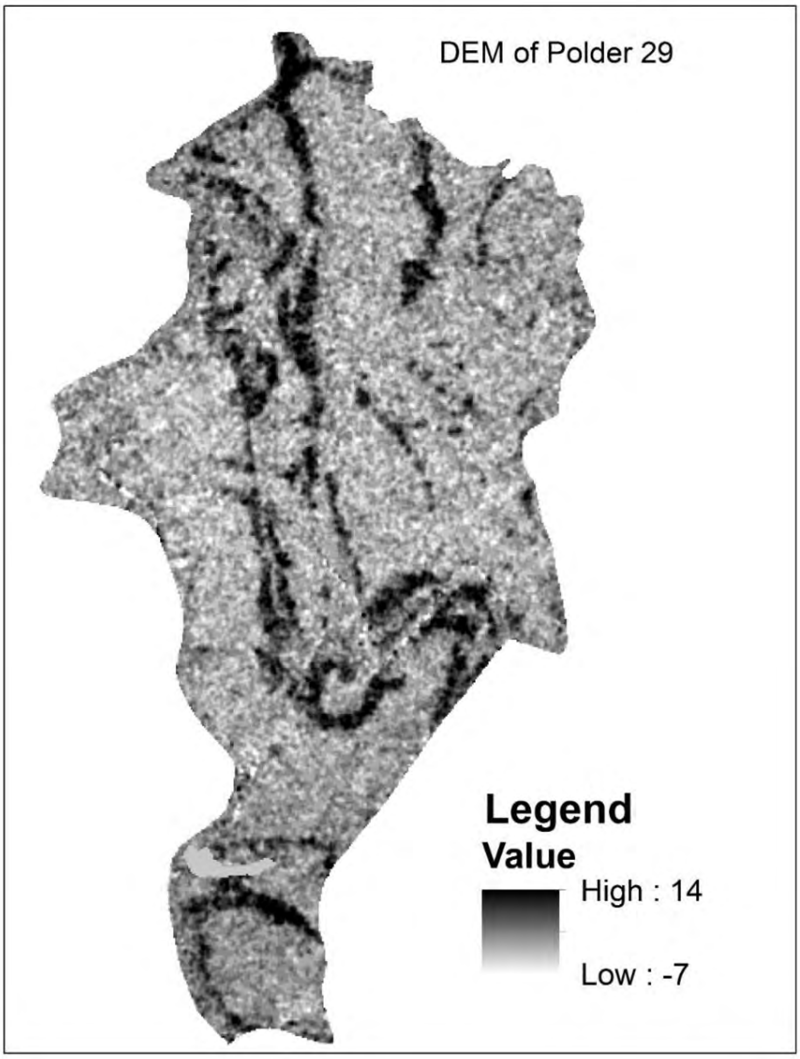

Figure 4.2: DEM of the study area, Polder 29.

4.3 Field data collection

4.3.1 Reconnaissance field survey

Reconnaissance survey is one type of brief survey for any kind of study that may facilitate individuals or groups by providing necessary information about the study area and to conceptualize and validate research questions and build up a framework for data collection. This preliminary survey also helps to select and find out appropriate stakeholders, and their number and locations. The main significance of this survey in the current study was to find out existing water related problems that hamper local water security and build a plan for the study. Field reconnaissance visits were made twice in the 4 sub catchment areas of Polder 29 to have a clear idea about the location, people, socio economic activities, project boundary, livelihood of general people, existing problems regarding water that helped in identifying problem, planning and later arranging FGDs and identifying people for key informant interviews as well as for in-depth interviews (Figure 4.3).

Figure 4.3: Field reconnaissance survey in Assannagar

4.3.2 Application of PRA tools

Participatory Rural Appraisal (PRA) is thought to be one of the effective paths to gather primary data from rural areas. It is considered one of the best approaches to share and learn knowledge from rural community and find out exact problems and local solutions. There are a basket of methods and tools under the PRA. Depending on the type of data and information required for the purpose of this study, Focus Group Discussion (FGD), and Key Informant Interview (KII) and In-Depth Interview (IDI) were chosen as the primary qualitative research tools. The locations where the PRA tools were used for the qualitative field research are shown in Figure 4.4. Tables 4.2 and 4.3 summarize the qualitative field work conducted in the study.

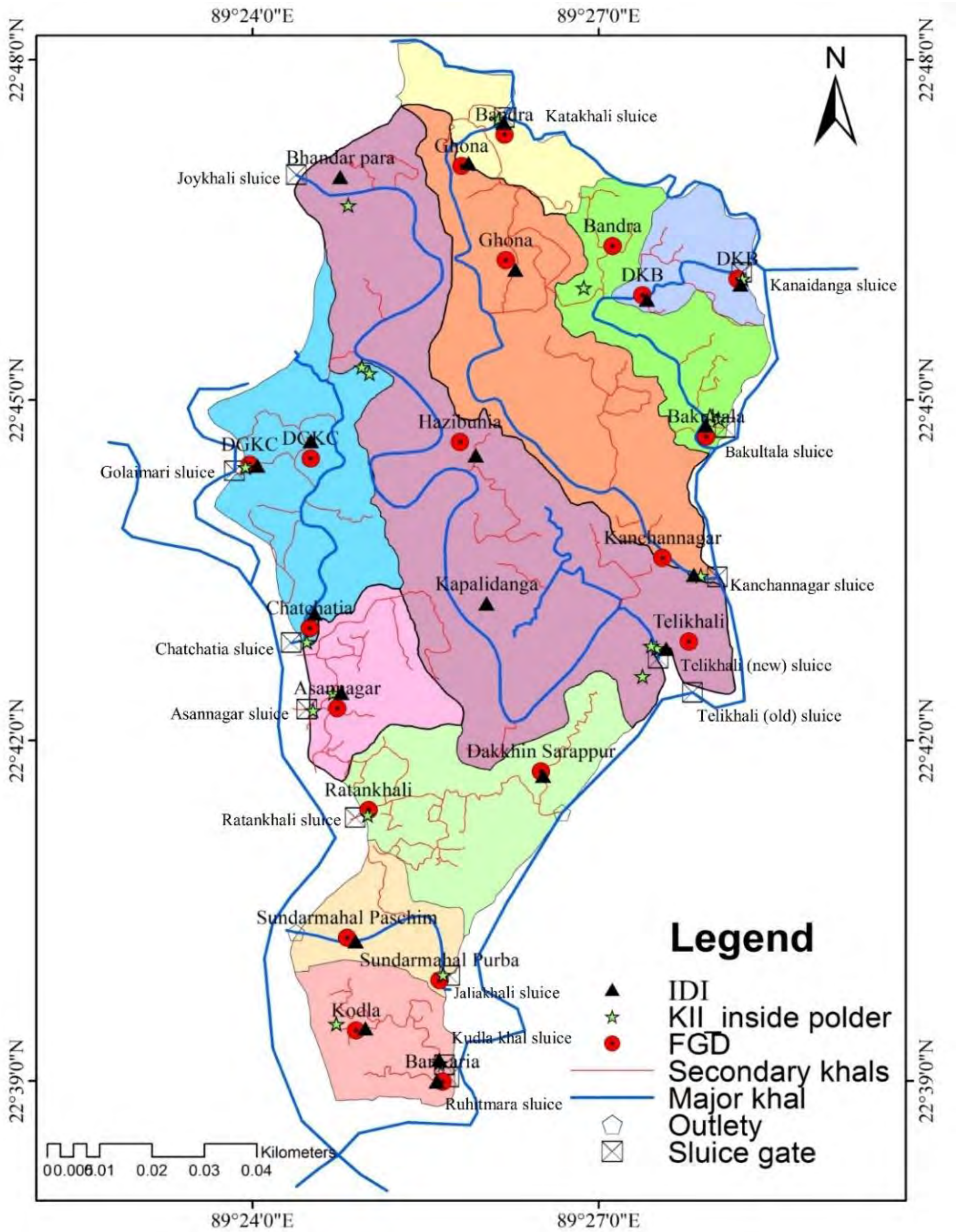

Figure 4.4: Map showing locations of FGDs, KIIs and IDIs in Polder 29

Table 4.2: Field methodology of the study area

SL No	PRA tools	Number	Interviewee	Time	Purpose
1	Reconnaissance survey	2	WMG members and Farmers	21-22 Feb 2019	Concept development
2	FGD	20	WMG members having at least 2 women	19-25 June 2019 and 9-13 Nov 2019	To identify conflicts, drivers
3	KII	24	Blue Gold officials, Sluice Gateman, O&M committee, WMG secretary and president, BWDB officials	19-25 June 2019 and 9-13 Nov 2019	Institutional arrangements for water management and their respective roles and responsibilities
4	IDI	20	Farmers and Fisherman	19-25 June 2019 and 9-13 Nov 2019	To perform timeline analysis & LULC validation

Table 4.3: List of Key Informants engaged in KIIs

Sl	KII respondents	KII number
1	WMG secretary	3
2	WMG president	2
3	O&M committee members	5
4	Up members (Sarappur 4no ward, Kodla, Sahas union 9no Ward, Sahas union 8no Ward, Sahas union 8no Ward women Member)	5
5	Chairman (Sharappur and Bhandarpara Union)	2
6	BWDB (Divisional Engineer, Khulna)	1
7	BlueGold official (Khunla office)	1
8	WMA	1
9	Sluice operastor (Bakultala, Telikhali, Chatchatia)	3
10	Previous beel committee Secretary (Asannagar)	1

Focus group Discussion (FGD)

Focus Group Discussion (FGD) is an effective way for capturing the thought of a group about a particular issue that exists in a certain community. FGD is commonly used to collect belief, concept and opinion of certain stakeholder groups on a specific theme. This is very useful while power disparity exists among participants and decision-makers. It is conducted with a homogenous category of minimum 6-8 person having analogous background. Facilitators of FGD create an environment for the participants to discuss community issues in order to collect data (Van Eeuwijk & Angehrn, 2017).

In Polder 29, a total 20 FGDs were done to gather data on diversified issues related to varying nature and drivers of water conflicts and their implications for water security, stakeholders' roles in amplifying and mitigating related issues. Two FGDs were conducted in each sub-catchment, one at upstream and another one at downstream, to capture the differing characteristics and issues of upstream and downstream. It was a team of four who conducted the FGDs, wherein the author acted as the facilitator. Major livelihood groups (farmers, fishermen, mixed farming groups) among the members of the WMGs were the target FGD participants of this study.

Each FGD involved 10-12 persons including minimum two gender (women) participants. FGDs were done either in the open field and local tea stall or at the office of water management group (WMG) (Figure 4.5). After collecting these qualitative FGD data, they were processed and analyzed to derive the findings of the study.

Figure 4.5: FGD at different WMG (a) Ruhitmara, (b) Kodla, (c) Dakkhin sarappur, (d) Bakultala, (e) Sundarmahal, (f) Chatchatia, (g) Ghona, (h) Hazibunia.

Key Informant Interview (KII)

Key informant interview (KII) is an approach to collect field data where key informants give a face-to-face interview about a specific issue or problem by using close or open-ended questions (Kumar, 1989). To recognize appropriate person for KII, local leaders and representatives might be the good source. In this study, 24 Key Informant Interviews (KIIs) were conducted with people involved in water management (e.g., Blue Gold office, BWDB, LGED, local government institutions, water management groups and associations) (Figure 4.6). Key Informants were selected while conducting the reconnaissance survey. Open ended questions were formulated before interview. Adequate notes and recordings were taken during interview for better data.

Figure 4.6: KII with (a) WMG members at Hazibunia and (b) sluice gate operator at Bakultala

In-Depth Interview (IDI)

The purpose of In-depth interview (IDI) is to collect detail information about something that has already arrived from previous data collection like KIIs and FGDs. It is a face to face, lengthy interview for deep understanding of a concerning issue where interviewees are encouraged to speak and share their experience in depth on the topic. It is a less structured but a very effective PRA tool for collecting primary data to reveal more detail information (Adams & Cox, 2008; Guion et al., 2011). In this study, 20 IDIs were carried out to perform timeline analysis of the changing nature of conflicts and associated drivers (Figure 4.7). Also, the authenticity of image analysis was verified in the IDIs. The target interviewees for IDIs were elderly farmer or fishermen having more than 45 years of age so that they can recall their experience and knowledge while describing the conflict dynamics.

Figure 4.7: IDI with elderly people at (a) Golaimari, (b) Chatchatia

4.3.3 REACH household survey

Besides, this study also used data from the quantitative household survey (2103 households in 77 Mouzas) conducted under the REACH project (https://reachwater.org.uk) between December 2017 and March 2018 in Polder 29, administered with a broader aim to characterize water security risks in the polder, in the context of drinking/domestic water services and the impacts of water-related hazards on livelihoods and wellbeing. The locations of the households are shown in Figure 4.8. In the survey design, risk profiles (low, moderate and high) of Mouzas were prepared based on secondary data (from census) and information (derived from qualitative field work) in relation to socio-economic vulnerabilities, wealth, hazards and existing water security status. The survey then followed a stratified sampling method, in which the risk profile was used as 'strata'. This study analyzed the survey responses around the questions of livelihood status and land ownership of the study area, hazard intensity and impact, status of water management organizations in Polder 29.

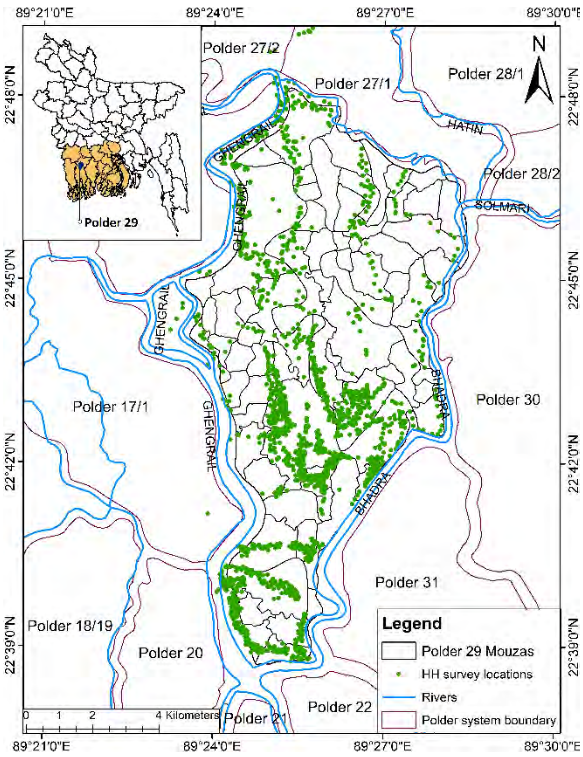

Figure 4.8: Locations of households in Polder 29 selected for REACH questionnaire survey (Source: Akhter, 2019)

4.3.4 Stakeholder analysis

Stakeholders include all those who will be affected and/or are perceived to be affected by the policies, decisions, or actions within a particular system. Stakeholders can be groups of people, organizations, institutions and sometimes even individuals. In the context of this study, stakeholders are those who are involved with and affected by the water management system of Polder 29 directly or indirectly.

Stakeholder analysis or diagramming was conducted with the help of mostly the KIs and partly the FGDs to understand the institutional arrangements for water management and their respective roles and responsibilities, especially in the context of conflict management. Stakeholder diagramming (Figure 4.9) was done following the approach suggested by European Commission (EC, 2000; ARB Toolkit, 2002) and used in several studies (e.g., Khan et al., 2022; Murshed and Khan, 2009). The key stakeholders were identified in four groups according to their primary role in influencing local water conflicts and their alleviation: decision makers (who take decisions), users (who use the result of decision or are affected by it), implementers (who implement the decision/ policy), and experts (who offer information, expertise, or means) and were placed in three tiers: co-operating, co-thinking and co-knowing, according to their degree of involvement. Co-operating stakeholders are the most closely involved in the issue, through active participation in the process and interaction with the other stakeholders (i.e., active involvement). Co-thinking stakeholders take part in passive consultation with other stakeholders but do not interact actively with others (i.e., consultation). Co-knowing stakeholders are only aware of the issue and do not actively participate in the interactions but may be informed of the process and progress.

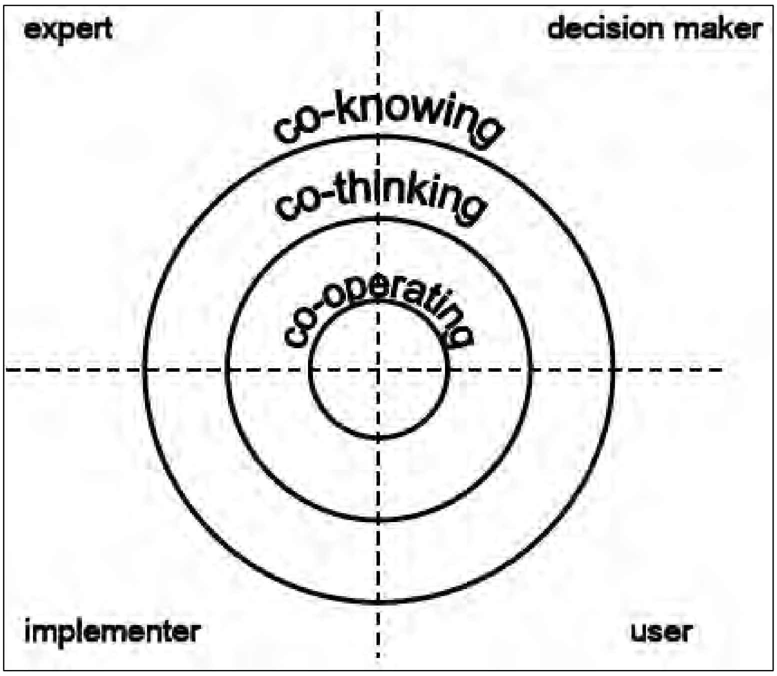

Figure 4.9: Stakeholder diagramming: type of stakeholder and their degree of involvement

4.4 Data analysis

After collecting all the data from the field survey, all the data were input in an Excel file and rechecked to ensure the quality of data. The qualitative information from FGDs, IDIs and KIIs were translated into English as these were conducted in Bengali (local language). The household survey data and documented reports were synthesized according to the needs of the study. Then these data were mapped in Arc GIS for data visualization. Furthermore, the satellite data and DEM of the study area were analyzed through ArcGIS 10.7 version that are described below.

4.5 Satellite image analysis

There are several steps to analyze satellite image. It begins with downloading satellite images from USGS website to change detection through supervised classification (Figure 4.10). Both geometric and radiometric correction have been conducted to process the satellite images for further analysis. The geometric correction confine with the process of geo-referencing of Landsat images with Universal Transverse Mercator (UTM) projection system with World Geographic System (WGS 1984), 45-degree northern hemisphere that were used.

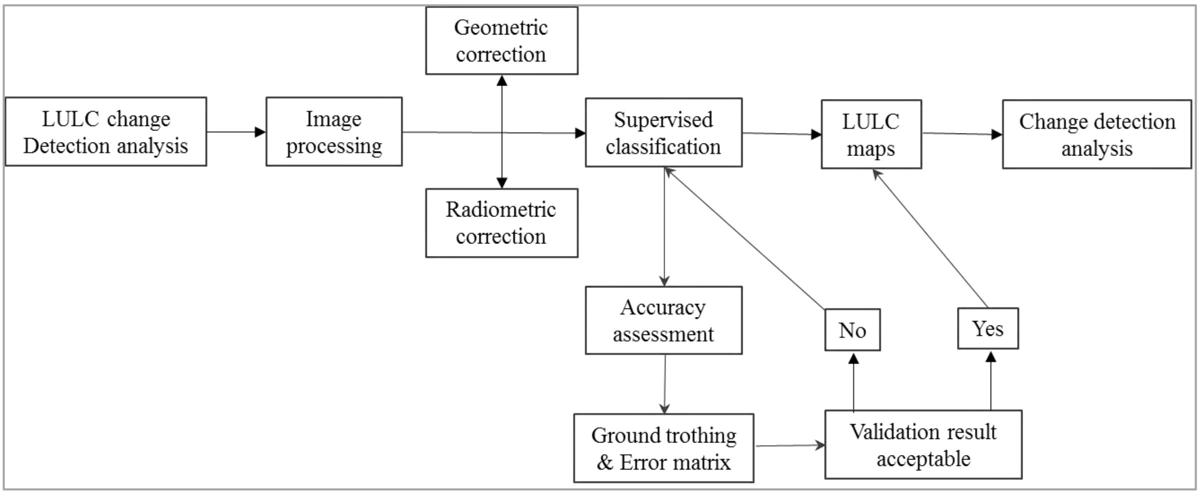

Figure 4.10: Methodology for satellite image analysis

On the other hand, the reflectance sensor data are influenced by many factors (e.g., atmospheric absorption and scattering, in-sensor factors, data processing procedures, etc.) (Teillet, 1986). Moreover, these effects need to be addressed to avoid the task complicated (Mas, 1999; Turker & Asik, 2002). Radiometric correction needs to capture the absolute surface reflectance digital number (DNs) generated from the satellite (Chavez, 1996). The study followed (López et al., 2016) for the radiometric correction of the satellite images.

4.5.1 Land Cover Classification

There are various types of classification methods to identify LULC status from RS data. Broadly, the methods are supervised and unsupervised classification approaches. The unsupervised classification method is based on the Iterative Self-Organizing Data Analysis Technique algorithm (Lu et al., 2004). On the other hand, supervised classification is based on training sample analysis, which is decided by researchers/experts and this type of classification method is more precise compared to others to see the accuracy obtained by the MLC method. Considering this benefit, the supervised classification method is popular and most widely used by many researchers (Fonji & Taff, 2014; Islam et al., 2015; Islam et al., 2018; Islam & Sarker, 2016). In consideration of this advantage, this study used supervised classification with Maximum Likelihood Classification (MLC) algorithm for LULC determination by using ArcGIS 10.3 software. The types of LULC found from the analysis are listed in Table 4.4.

Initially, the corrected images (geometric and radiometric corrected) of each date were compiled into a single layer using three bands to create false color composite (FCC) image to distinguish different LULC types like agricultural land, vegetation, and settlement.

Table 4.4: Land cover types

Land Cover Type	Description
Aquaculture	Shrimp farming gher, pond
Water Body	Internal canal, khal, river
Vegetated settlement	Trees, natural vegetation, mixed forest, gardens, parks and playgrounds.
Agricultural	Agricultural lands, vacant land, open space and crop fields

4.5.2 Error Matrix and accuracy of the study

Error matrix is one of the best ways to access accuracy of satellite image analysis for land use land cover detection as it aims to assess the effectiveness of sampling for land cover classifications (Hasan et al., 2020; Rwanga & Ndambuki, 2017). For error matrix, satellite image of 2019, October was selected where 187 ground points were chosen. 167 Google earth points and 20 field observation points were used as a reference source for ground truthing (Figure 4.11 and Figure 4.12).

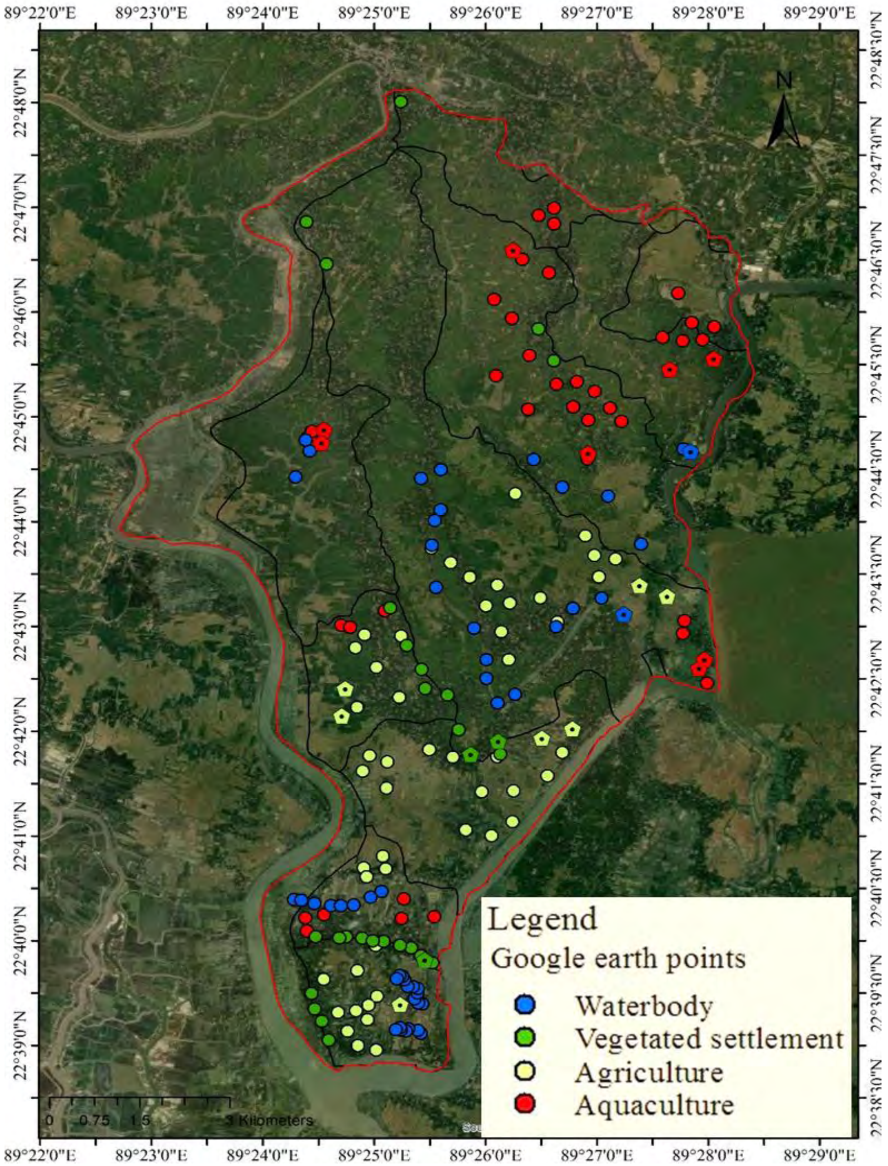

Figure 4.11: Ground truthing points for accuracy assessment of satellite image analysis

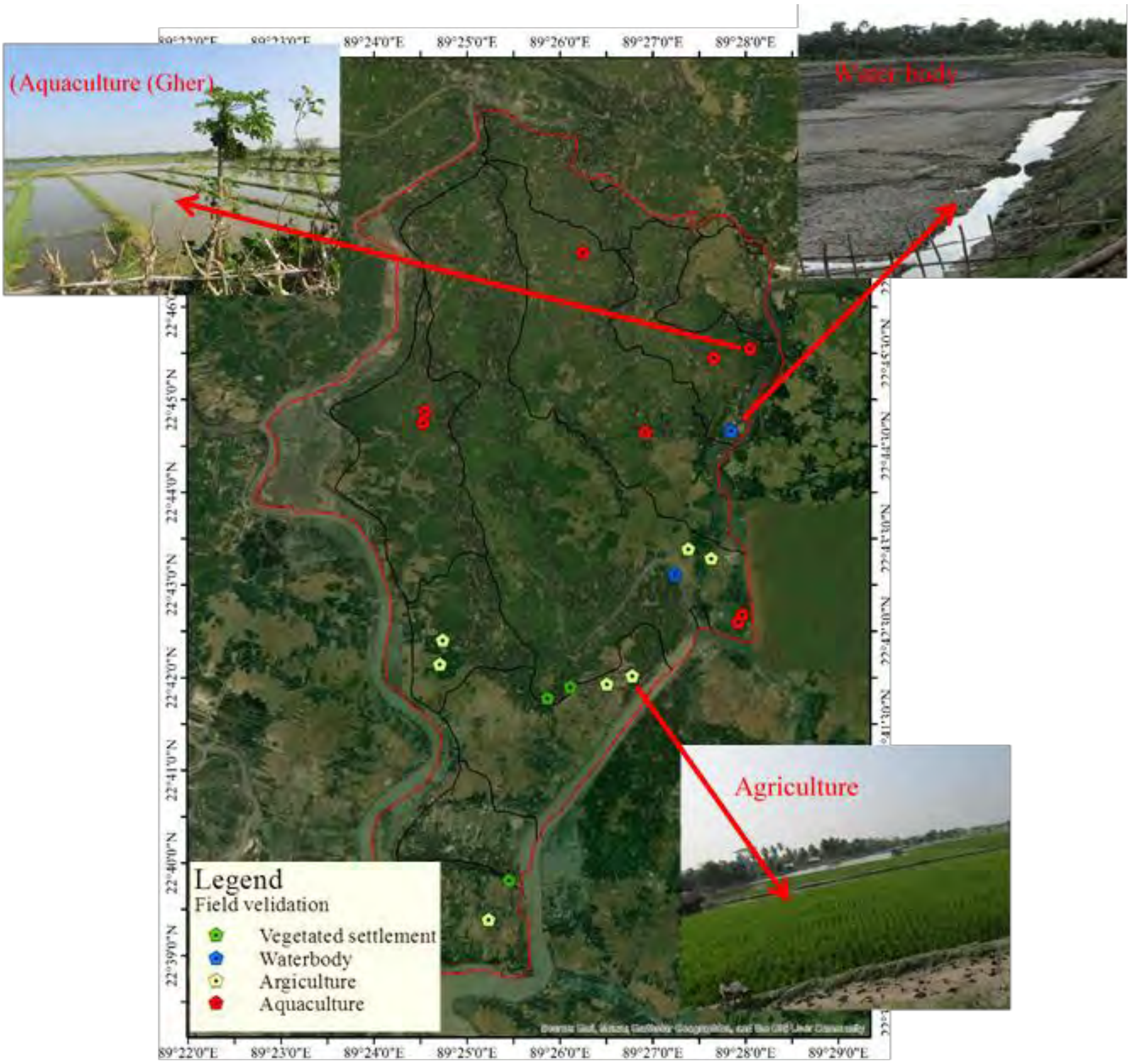

Figure 4.12: Field observation points for ground truthing

Table 4.5 presents the error matrix of the land cover classified image of 2019 that shows the relationship between ground truthing data and the corresponding classified data. Columns of the table represent produced value (map makers point of view selecting sample for the land cover) and rows express observed value (user's point of view, how accurately land class be presented on the ground). For accuracy assessment, the study have considered producer's and user's accuracy, commission and omission error, overall accuracy and Kappa coefficient followed by (Rwanga & Ndambuki, 2017) that have been derived from error matrix. The equation of the accuracy assessments are shown below:

User accuracy: $\frac{(Correct\ sample\ of\ a\ specific\ land\ use\ class)}{Row\ total\ of\ a\ specific\ land\ use\ class} \ldots \ldots \ldots \ldots (i)$

Producer accuracy: $\frac{(Correct\ sample\ of\ a\ specific\ land\ use\ class)}{Column\ total\ of\ a\ specific\ land\ use\ class} \ldots\ldots\ldots (ii)$

Overall accuracy: $\frac{(Sum\ of\ correct\ sample)}{Total\ number} \ldots\ldots\ldots\ldots (iii)$

Kappa coefficient:

$$\frac{(Total\ number\ *\ Sum\ of\ correct\ sample) - Sum\ of\ all\ the\ (row\ total\ *\ column\ total)}{Total\ number\ squared - Sum\ of\ all\ the\ (roe\ total\ *\ column\ total)} \ldots\ldots\ldots. (iv)$$

The land covers derived from the analysis and the land covers from Google Earth were well-matched with a better accuracy. The result showed that the Producer Accuracy (PA) ranged from 85% to 90% where User Accuracy (UA) found 100% to 77% (Table 4.5). Water body and vegetation were found to be more accurate for both PA and UA. Besides, overall accuracy was found 87.70% and Kappa coefficient is measured 0.83 that illustrates preferable accuracy for each land cover classification of its field of interest according to Fleiss et al. (2004).

Table 4.5: Overall accuracy and Kappa coefficient of all supervised classified images used

Bearing data							Accuracy Assessment			
LULC		Agriculture	Aquaculture	Water body	Veg. sett	Total	UA	PA	OA	Kappa
2019	Agriculture	44	5	4	4	57	77.19	88.00	87.70	0.83
	Aquaculture	4	45	1	1	51	88.24	86.54		
	Water body	2	2	46	0	50	92.00	90.20		
	Veg. sett	0	0		29	29	100	85.29		
	Total	50	52	51	34	187				

Note: UA = User accuracy; PA= Producer accuracy; OA = Overall accuracy

4.5.3 DEM analysis and catchment delineation

Topographic analysis was conducted using SRTM DEM data by using ArcGIS. DEM was classified into three categories. In first Scenario DEM value was considered ≤1 m MSL, scenario 2 was ≤2 m MSL, and scenario 3 was ≤3 m MSL (Figure 4.13).

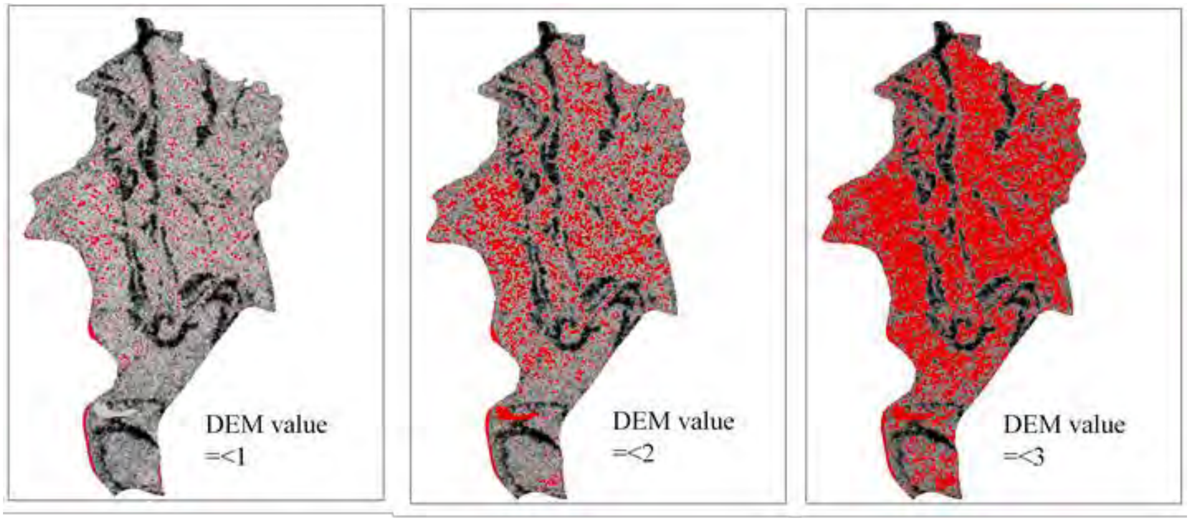

Figure 4.13: DEM of the study area at different scenario

Besides, for catchment delineation some sequential steps were followed. Delineation of catchment and stream network using DEM data are presented below:

a. ***Fill Sinks***: It is the first step of -processing. The objective of this step is to make a depression less elevation model. Here sinks in the original DEM were identified using the Sink tool. A sink is DEM pre usually an incorrect value lower than the values of its surroundings. These depressions points create problem as any water that flows into them cannot flow out. To ensure proper drainage mapping, these depressions were filled using the Fill tool and a fill DEM has found. Sinks are removed from DEMs using the standard flooding approach described by Jenson and Domingue (1988).

b. ***Calculate Flow Direction:*** In this step, the direction in which water would flow out of each cell has been determined. The fill DEM found in the previous step was treated as input here and the Flow Direction tool was used for this job. The output is an integer raster whose values ranges from 1 to 255. Flow directions were calculated using the eight-direction (D8) flow model which assigns flow from each grid cell to one of its eight adjacent cells, in the direction with a steepest downward slope. The D8 method was introduced by O'Callaghan and Mark (1984).

c. ***Calculate Flow Accumulation:*** It is the initial stage of defining the stream network system. Using the Flow Accumulation tool, the number of upslope cells flowing to a location were calculated here. The output flow direction raster created in the previous step was used as input here.

d. ***Define Stream Network:*** The most common method of extracting channel networks from DEM is to specify a critical support area that defines the minimum drainage area required to initiate a channel using a threshold value. In practice this threshold value is often selected on the basis of visual similarity between the extracted network and the lines depicted on topographic maps. The threshold value was specified on the raster of flow accumulation that derived from the previous step. This task was accomplished with the Con tool of spatial analyst tools. As a result, all cells with more than 'threshold value' cell flowing into them have been part of the stream network. For this study many trials were run with different threshold value and tried to match the DEM extracted channel with a reference channel of Polder 29.

e. ***Stream Segmentation****:* After derivation of stream network, a unique value was assigned for each section of the stream raster line, associated with a flow direction. The stream Link tool was used on two raster file that are extracted from the above step 2 and step 3 as input.

f. ***Catchment Grid Delineation:*** Using the Watershed tool, the catchments were delineated for specified locations. The flow direction raster and the flow accumulation raster based on fill DEM data that were found from the outputs of step 2 and step 5, respectively were used as input.

g. ***Catchment Polygon Processing:*** Finally, catchment polygons were found. Among them, the polygon on which the study area is situated is the catchment of interest.

Chapter Five: Detailed characterization of Polder 29

5.1 Introduction

After the construction of Polder 29 during 1966-1971, the polder has been rehabilitated under the IPSWAM project from 2003 – 2011 followed by Blue Gold project. These projects involved rehabilitation and/or rehabilitation of different water control structures and introduction (during IPAWAM) and strengthening (during Blue Gold) of institutions, i.e., water management organizations (WMOs). The presence or emergence of water management issues depend on the overall condition of water control structures and the performance of the institutions, for example, functionality of sluice gates, river erosion, saltwater intrusion, land use and land cover change, functionality of institutions, etc.

5.2 Institutional structure for water management in Polder 29

5.2.1 Role of BWDB in community-based water management

Under the Ministry of Water Resources (MoWR) in Bangladesh. Under this ministry, Bangladesh Water Development Board (BWDB) plays the major role in implementing and maintaining projects. According to Bangladesh Water Act (2013), the major responsibilities of BWDB include construction and O&M of water control structures like embankment, polder, and water control structures (regulators and sluices), along with dredging and re-excavation of river/canal, land reclamation and river training. Beside engineering approach which was the single focus of BWDB for water management since its establishment in 1958, it also started working through non-structural interventions since 90's upon realizing its necessity for implementing Integrated Water Resources Management (IWRM).

The community-based water management has evolved in Polder-29 in the same way as it did in some other areas of coastal region. This practice was formalized in the early 2000's through the development of 'Guidelines for Participatory Water Management (GPWM)' (MoWR, 2001) for involving communities in water management (e.g., in planning, decision-making, financial and physical participation, and community ownership) through creation of Water Management Organizations (WMOs).

BWDB implemented 'Integrated Planning for Sustainable Water Management' (IPSWAM) program during 2003-2014 to make the GPWM operational, via stimulating the transfer of responsibilities for operation and maintenance to the WMOs, and engaging communities in sustainable socio-economic development activities via community mobilization, formation of clusters of new water management associations at different levels, and structural rehabilitation (mainly regulators/ sluices and drainage canals) (Silva, 2012, Dewan, 2012, Dewan et al., 2014). In sum, IPSWAM first formed the WMOs in few selected polders in coastal Bangladesh including Polder 29 which have later been reformed during Blue Gold program with an expanded project area (Source: KII with Blue Gold officials).

After IPSWAM the Blue Gold program of BWDB took over the functionality of the WMO's in the selected areas, including Polder 29. The institutional system for water management in Polder 29 is illustrated in Figure 5.1. The GPWM specifies water management in three tiers: (i) Water Management Groups (WMG) at the lowest tier, i.e., for each small hydrological unit or social unit (para/village/ Mouza); (ii) Water Management Association (WMA) for apex level of the project or sub-project (i.e. the mid-level for each subsystem of the project), with general members of WMGs being the general members of WMA; and (iii) Water Management Federation (WMF) at the apex level of the project, with general members selected from all general members of WMA.

The Blue Gold Program (BGP) focused on creating an enabling environment for the coastal communities for economic development through the improvement of water resources management at the local level, especially to remove water-related constraints to crop production. The program thus funded repairs to sluice gates, re-sectioning and repairs of embankments and re-excavation of drainage khals within 22 polders, with the objective of draining excess water, preventing flooding, while improving access to water for irrigation (www.bluegoldwiki.com). Most of these works and tasks were undertaken by BWDB (under the Blue Gold program) with WMG support, with the WMGs themselves mainly being responsible for khal cleaning and better sluice operation. Khal re-excavation (including de-silting) was largely done using Blue Gold resources, with support from the WMG in most cases. Khal cleaning (removal of weeds, cross-dams, etc.) and improved operation of sluices were mostly done by the WMGs with their own resources (i.e., voluntary labour) and/or by groups of farmers. This is considered as an achievement of the Blue Gold program in establishing and strengthening the WMGs (www.bluegoldwiki.com). The construction and repair of culverts was however primarily done by Local Government Institutions (i.e., Union Parishads), as culverts usually crossroads which are a government responsibility. The infrastructural works under the Blue Gold program have reportedly contributed to water management situation being good or very good from 13% in pre-project situation to 69% by the end of 2021, according to the 2021 WMG endline survey (Blue Gold, 2021). The improvement has been greatest in Patuakhali district followed by Khulna and Satkhira districts, with the most widely reported improvement in water management infrastructure being re-excavation and de-silting of khals.

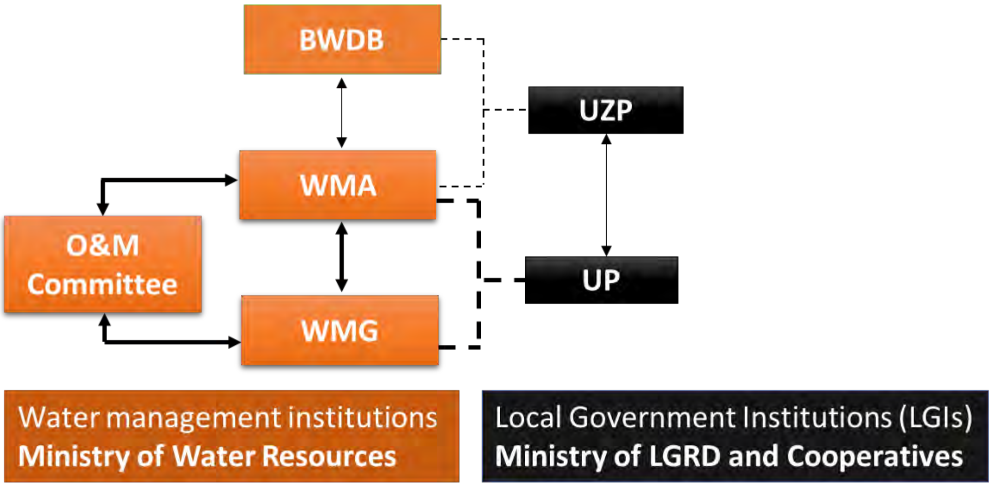

Figure 5.1: Institutional system for water management in Polder 29

5.2.2 Community-based water management organizations (WMOs)

The 'Blue Gold wiki' report (www.bluegoldwiki.com) presents the generic structure of WMOs in a polder as shown in Figure 5.2. Figure 5.3 shows roles and responsibilities of WMOs at different levels of scale in the context of in-polder water management.

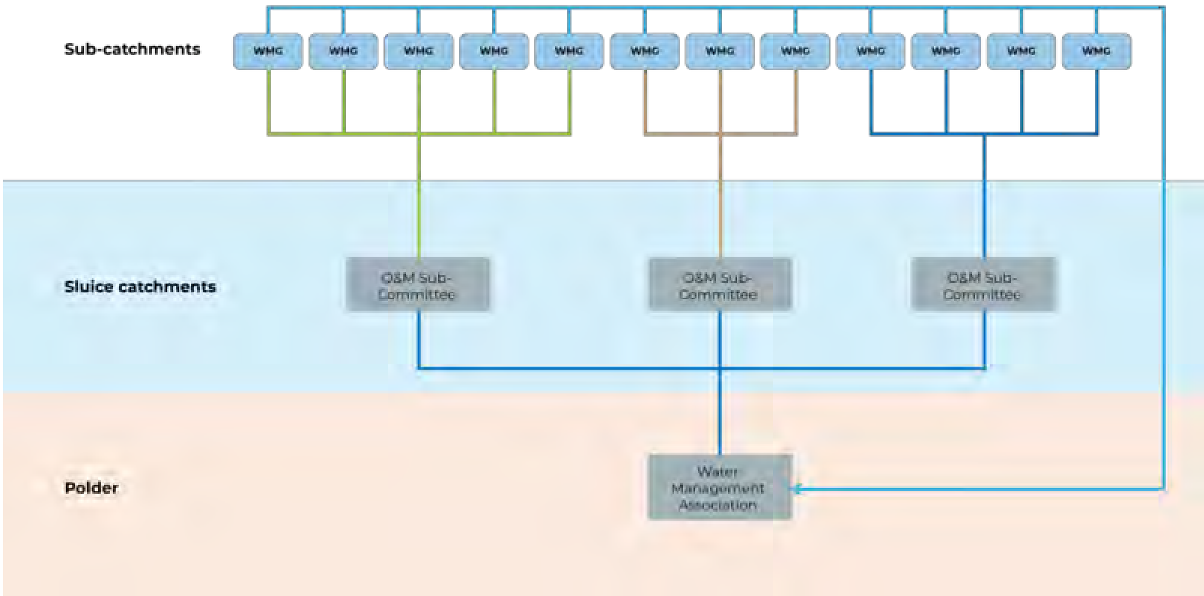

Figure 5.2: Structure of water management organizations in a polder
(Source: www.bluegoldwiki.com)

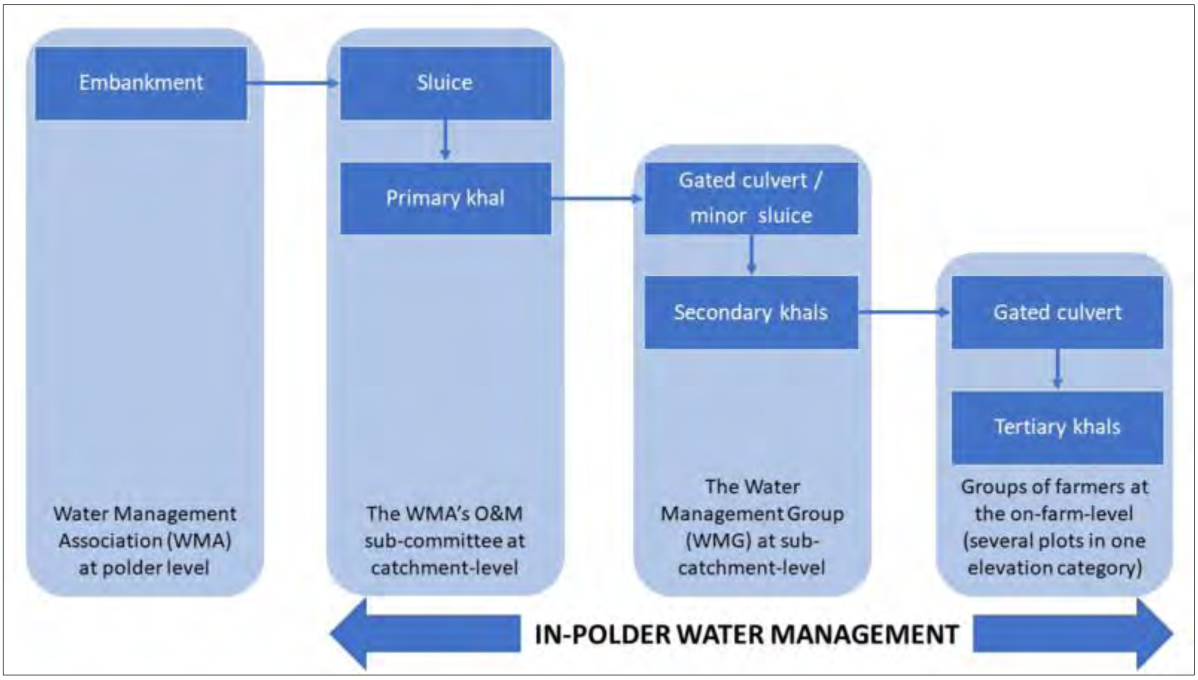

Figure 5.3: In-polder water management – interventions at different levels of scale (Source: www.bluegoldwiki.com)

Water Management Groups (WMGs)

Water Management Group is the basic unit of WMO, formed in alignment with the smallest hydrological unit or social unit (village/para). Each WMG is formed based on 12 members including minimum 33% women, landless and destitute and other members belonging to the families of farmers, fishermen, small traders, craftsman, boatman, aqua culturists, as the general members of WMG. Representatives from the concerned LGIs are the advisors of WMG.

There are 55 WMGs in Polder 29. The main responsibilities of WMG include operation and maintenance of the infrastructure, maintaining liaison with the implementing agency, LGIs and NGOs, and nominating sluice gate operator. As can be seen in Figure 5.3, the WMGs are expected to manage gated culverts and/or minor sluices and the secondary khals inside the polder. They would also maintain a register of WMG members, arrange meetings, document activities, and inform WMA about water management issues (source: KII with Blue Gold officials).

Water Management Associations (WMAs)

WMA is formed for either the apex level of project or the mid-level for each subsystem of the project. General members of Water Management Group (WMG) are the general members of

WMA. Representatives from the concerned LGI's are the advisors of WMA.WMA is formed for projects covering areas which are below 1000 ha. Broad tasks and responsibilities of the WMA include preparing budgets, providing general membership, resolving conflicts or issues referred to or from WMG, and liaise with implementing agency, LGIs, and NGOs, and signing documents for management transfer on behalf of WMGs with implementing agency (BWDB) or LGIs as appropriate. As can be seen in Figure 5.3, the WMAs, the responsibilities of WMAs in terms of in-polder water management is at the polder level (i.e., peripheral embankment) and they would ensure major sluice operations and managing primary khals systems through O & M sub-committees.

There are 2 WMAs (consisting of 23 WMGs based on 5 sub-catchments at Bakultola sluice and 33 WMGs based on 6 sub-catchments at Chotchatia sluice) in Polder 29.

Water Management Federation (WMF)

WMF is formed for apex level of any project. Representatives from all general members of WMA are the general members of WMF. Representatives from the concerned LGI's are the advisors of WMF.WMF is formed for covering projects below 1000ha. The broad tasks and responsibilities of the WMF includes liaise with implementing agency, coordinating the functions of various stakeholders in water management, preparing annual crop production plan and O &M plans and other production plans prepared by WMA etc.

In Polder 29 WMF has not been formed until the end of 2019 when the field work under this study was undertaken; however, KII with Blue Gold officials revealed that it would be formed soon.

Informal bodies for operation and maintenance

For the operation and maintenance of water infrastructures, the Catchment O&M sub-committees have been formed by the Blue Gold officials comprising of representatives of several WMGs in a single sub-catchment for operating sluice gates and for water allocation through canals between agriculture and fisheries. The WMAs are expected to coordinate with the O&M committee for effective management of catchment. However, in many places this was found to be controlled by the informal 'Beel committee'.

It may be noted that there had been such informal management body, known as '*Beel committee*', formed by BWDB even before the GPWM was introduced and implemented, with the prime mandate of water management in the catchment defined with respect to drainage sluice or regulator, including the operation and maintenance of the water infrastructure (e.g., operation of sluice gate or regulator), with the help of a gate operator, locally known as "Khalashi" (Source: KII with BWDB official). Although this informal body has disappeared in many places, they still exist in some places in the coastal area, including Polder 29. However, the composition of the committee is not the same, and in Polder 29 they are found to be comprised of some local interest groups and in some cases the UP member, especially around the sluice gates which are illegally leased out to them.

As acknowledged by the Blue Gold project, having control over the operation of sluices is significantly related to improved water management as well as to the institutional development of the WMGs (www.bluegoldwiki.com). Significant improvement was seen from 2019 to 2021 in terms of taking control of the sluices by the WMGs, as found from the WMG surveys done in 2019 (Blue Gold, 2019) and 2021 (Blue Gold, 2021), with most sluices in the 22 polders reported to being under the control of WMGs or catchment committees involving a number of WMGs. However, FGDs conducted during those times by Blue Gold found that some of the sluices were not fully under the control of WMGs. In some cases, even if sluice gates were under the control of WMGs, some of the drainage khals were under the control of others, including where khals had been leased out to influential individuals, usually for fish production. In these cases, WMGs are not likely to control the sluices at all times according to the community needs. There are apparently some conflicts; the khals are leased out by the Upazila administration, not by the BWDB, and there is a lack of coordination among the Upazila administration and BWDB. In some cases, WMGs solved the problem (not leasing out the khal anymore) by submitting an application to the Upazila administration to undo the leasing-out. But some FGDs expressed their fear that WMGs may lose control of water management infrastructure in the future (www.bluegoldwiki.com).

5.2.3 Local government institutions

The local Government institutions (LGIs) under the Ministry of Local Government, Rural Development and Cooperatives (MoLGRDC) provides supporting, facilitating and coordinating assistance to the concerned water management organization in respect of participatory water management at the local level. LGIs provides such assistance through their representation as advisors to the concerned WMOs and through their respective standing committees (source: KII with Union Parishad Chairman). There are a total 5 union parishads (UP) in Polder 29. UP provides supporting and coordinating assistance for participatory water management for project covering one union. When projects cover more than one union, Upazila Parishads (UZP) (e.g., Dumuria and Batiaghata Upazilas in Polder 29) provide supporting and coordinating assistance for participatory water management. As Polder 29 consists of 5 unions, such assistance would be provided by the Upazila parishad to the standing committee of WMOs (source: KII with UZ Agricultural Oficer).

5.2.4 NGOs

NGOs or community level self-help groups available at the local level assist the participatory process of the local stakeholders for water management activities. They carry out participatory process and social mobilization activities on behalf of the implementing agencies. NGOs which are currently working in Polder 29 include Uttaran, Nijera Kori, Ashroy Foundation and others. These NGOs give different types of training to the farmers, fishermen and women. They also play a significant role in critical or emergency situations and provide necessary support to the local people with the support of local government institutions.

5.3 Issues and characterization of sub-catchments

Physical and functional characteristics of the 10 sub-catchments of Polder 29 are summarized in Table 5.1, which are based on direct observations, FGDs, KIIs, IDIs and secondary literature and information obtained from the Blue Gold office. Figure 5.4 presents some glimpses of the field conditions at and around different water systems.

Table 5.1: Characteristics of catchments of the study area

Catchment	Name of Canals	Name of Sluices	Characteristics	Issues
Ruhitmara	Kudir khal, Ruhitmara khal	Ruthimara sluice Kudlar khal pipe sluice	Salty environment, Gher dominated saltwater shrimp farming, saline groundwater	River erosion, saltwater intrusion through sluices, grabbing of water structures (sluice, khals, khas land), khal/canal siltation, Social discrimination
Jaliakhali	Mora vadra nadi, Gazia dhopar khal	Jaliakhali sluice Mora Bhadra outlet	Salty environment, Gher dominated saltwater shrimp farming, saline groundwater	River erosion, saltwater intrusion through sluices, grabbing of water structures (sluice, khals, khas land), khal/canal siltation, drainage congestion due to gher.
Ratankhali	Kainmari khal, Sundortala khal, Jhilakhali khal, Sitalmari khal, Jhaltala br. Khal	Ratankhali sluice Agunkhali outlet	Mixing of salt and freshwater, Both Gher and agriculture, saline ground water	River erosion, grabbing of water structures (sluice, khals, khas land), khal/canal siltation, drainage congestion due to gher
Asannagar	Baler khal, Mohuar khal, Ashannagar khal	Asannagar sluice	Gher dominated freshwater shrimp farming, saline ground water	Number of ghers disrupt hydrological connectivity, grabbing of water structures (sluice, khals, khas land), canal siltation
Golaimari	Aro khal, Natomari khal, Amorar khal, Sabughata khal, National khal, Ramakhali khal	Chatchatia sluice Golaimari sluice	Gher dominated freshwater shrimp farming, relatively less groundwater salinity	Number of ghers disrupt hydrological connectivity, Topographical differences (u/s and d/s), canal siltation, drainage congestion
Telikhali	Sukur mara khal, Dholvanga khal, Pondkhali khal, Dora khal, Bhadra nadi, Gabtala khal, Dakatia beeler khal	Telikhali (old) sluice Telikhali (new) sluice Joykhali sluice	Mixed farming practice, focus on agriculture, relatively less groundwater salinity	Topographical differences (u/s and d/s), Number of ghers disrupt hydrological connectivity, water congestion, drainage & canal blockage and siltation, loss of hydrological connectivity
Kanchannagar	Madarshisha Khal, Nolghuna Khal, Lohidanga/Gurunia Khal, Labutata khal, Sialmara khal, Gharami khal, Kanchannagar/Hazibunia Khal	Kanchannagar sluice	Mix farming practice, focus on agriculture, relatively less groundwater salinity	Topographical differences (u/s and d/s), Number of ghers disrupt hydrological connectivity, water congestion, drainage & canal blockage and siltation, loss of hydrological connectivity
Bakultala	Khichimichi nadi, Kewratal khal, Ghonar khal	Bakultala sluice	Gher dominated freshwater shrimp farming, saline ground water	Topographical differences (u/s and d/s), water congestion, canal siltation, loss of hydrological connectivity
Kanaidanda	Kata khal, Arua khal	Kanaidanda sluice	Agriculture dominated freshwater shrimp farming, saline ground water	Topographical differences (u/s and d/s), loss of hydrological connectivity, canal siltation
Katakhali	Katakhalikhal, Sishakhal, Moikhali khal	Katakhali sluice	Gher dominated freshwater shrimp farming, Dry seasonal crop	Canal siltation, loss of hydrological connectivity, water congestion

Figure 5.4: Pictures of different issues in Polder 29, (a) Ruhitmara (b) small ghers at Bakultal (c) Grabbing khal/river and encroachment for gher at Hazibunia, Telikhali (d) Erosion at Ruhitmara (e) Water congestion, Ratankhali, Bhulbaria (f) water hyacinth blocked canal at Ghona, Kanchannagar

Ruhitmara sub-catchment is worth mentioning out of the ten catchments due to its characteristics and issues. River erosion and salty environment have made this area more vulnerable than the others (see Table 5.1 and Figure 5.4). Large scale saltwater gher is one of the vital characteristics in this catchment, which was developed due to the very close distance from two rivers, including the junction area of Shalta River and Ghengrail River. Jaliakhali and

Ratankhali sub-catchments both have relatively similar trait as Ruhitmara, though livelihood is more diversified in Ratankhali.

Telikhali and Kanchannagar on the other hand are the two largest sub-catchments in the study area with most diversified livelihood and topographical differences, resulting in conflicting interests in water management and use. Existence of internal khals affluent with water has led to land grabbing around the canals by the muscle groups of the society. Canal siltation and encroachments are existent in all sub-catchments in the entire Polder 29, causing a decline in hydrological connectivity day by day; this is particularly more prominent in Telikhali, Kanchannagar and Golaimari. Kanchannagar, Bakultala, Kanaidanga and Katakhali are located at the far north of Polder 29 having intensive small-scale shrimp ghers.

Sluices leasing for catching fish at the mouth of the sluices is a major source of income for the body who control the sluice though it is illegal according to the policy. But most of the time LGIs and local muscle men are involved in sluice leasing (for example, Chatchatia, Asannagar, Telikhali sluice gate). The leaseholder controls the sluice according to his benefit which sometimes creates problematic issue for the gher (pond used for fish cultivation) owners, e.g., sluice gate cannot be opened during excessive rainfall by the instruction of powerful leaseholder. As a result, the shrimp ghers are inundated and push away most of the fishes from ghers. Thus, leaseholder and a group of people are benefitted by catching those floating fish from canals and in the mouth of the sluice.

Besides, in Polder 29, khas land (an abandoned public property) and khas water bodies are grabbed or leased by local elites. Though rules of leasing are that no obstruction to water flow will be created, and government will take back the land by cancelling the lease in case of any breach of agreement. But in most of the places like Golaimari, Telikhali such conditions are frequently broken by illegal use of canals, creating barrier for catching fish (e.g., pata, Kumor), but no corrective measure have been taken by the concerned authority.

Sluice gates (e.g., Asannagar, Telikhali, Jaliakhali, Ruhitmara) sometimes become non-functional due to poor maintenance, as siltation in the sluice block the water flow. Besides, adjacent canals were silted up, losing its water holding capacity which is the biggest issue now. For example, Golaimari sluice gate was found fully nonfunctioning during field visit due to over siltation of Amorar khal. Consequently, Amorar khal, Aro khal, and Netormari khal silted up at the upper portion of Golaimari catchment. At Kanaidanga and Bakultala, siltation problem at the entrance of the sluice also exists, but local farmers remove the sediment on a regular basis. Some of the canals in Telikhali catchments are also silted up causing drainage congestion in the wet season.

Drainage congestion has been identified as the major problem inside the polder. Almost all the areas beside the silted-up canals inside the polder, which are directly connected to the Bhadra and Ghangrail rivers, suffer from tremendous drainage congestion. Some of the severely silted canals are Aro khal, Asannagar khal, Mora Bhadra khal, Bakultola khal, Telikhali khal etc. Villagers of Ruhitmara revealed that during monsoon and post-monsoon periods, Kodhlar khal and Ruhitmara khal cannot cope with the increased rainfall occurrences, causing drainage congestion which affect the agriculture production especially Aman rice during May to October.

Polder 29 has been experiencing riverbank erosion for a long time and the embankment was retired several times due to severe erosion of the Lower-Bhadra River. For the last several years, right bank of the Bhadra River has been eroding at Chadgarh and Baro Aria Bazar in the Upazilla Dumuria and Batiaghata, respectively.

5.4 Water control structures

The conditions of the water control structures and canal or drainage systems as of December 2019 are shown in Figure 5.5, which are based on direct field observations and participatory mapping with the local people during FGDs and KIIs. Embankment having a length of about 49 km exists around Polder 29 providing protection against tidal and storm surges and salinity intrusion. There are 14 numbers of drainage sluices and 1 drainage outlet constructed by BWDB within the polder (Figure 5.5). Among those, 6 sluice gates were repaired and 5 others were constructed under IPSWAM project from 2003 to 2011. Some of these structures again needed repairing and were taken up by the Blue Gold project. A number of these gates did not operate smoothly due to damages of the wheels and shafts used to elevate gates, for example the ones at Telikhali (Telikhali old sluice gate) and Golaimari (Chatchatia sluice gate). Siltation of the peripheral riverbed caused some of the sluice gates to remain non-functional, as were observed in Golaimari, Kanaidanga, Ratankhali, and Jaliakhali.

Mismanagement issues regarding the water control structures were also found to be prevailing. During field visit, it was found that some of existing sluice gates and outlets, for example Joykhali and Kanaidanda sluice gates, and Asannagar and Chatchatia outlets, were subjected to structural damage in recent years and were not maintained properly by the local people. The sluice gates at Bakultala and Telikhali were completely or partially broken. A new gate was constructed inside Bakultala khal under the Blue Gold project. This is now working as a well-functioning gate. Siltation in the river made the riverbed higher and left the sluice gate at Golaimari and Telikhali non-functional. The wheels and shafts for hoisting the gate at Golaimari, Kanchannagar and Ramkhali khal were either missing or found non-functional. These hoisting systems needed re-installation.

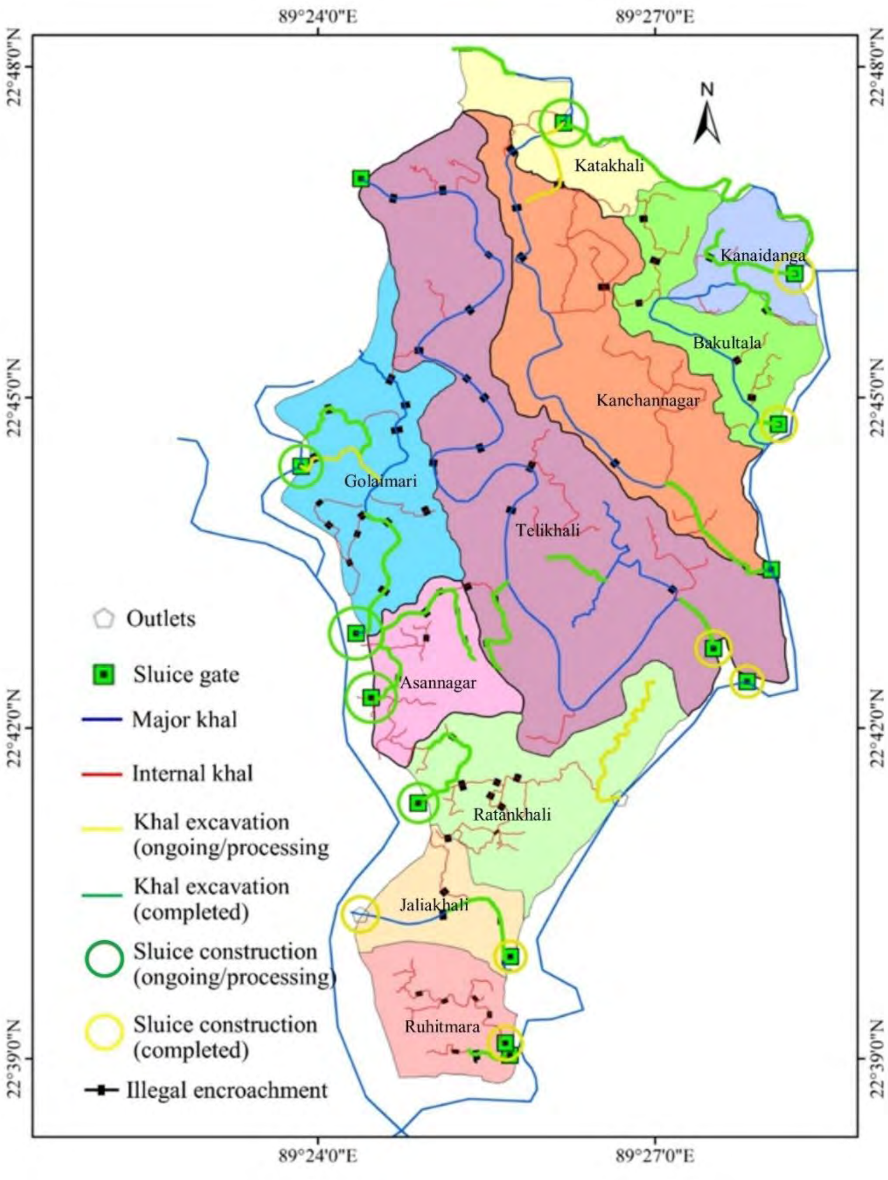

Figure 5.5: Water control structures of the study (2019-2020) (Catchment map from Blue Gold office, Khulna, modified with primary observation/ information)

Mismanagement was also observed at some other locations. Water hyacinths sometimes hamper the natural flow of various khals for example Dholvanga and Bhadra khals in Talaimari, Hazibunia khals in Kanchannagar, and kichimichi khal in Bakultala. The condition of most of the internal drainage khals was found completely undesirable due to encroachments, in the form of illegal fishing traps used by local people blocking the waterway, locally known as ‘Net’, ‘Pata’, and ‘Kumor’ (Figure 5.6). Net, a nylon-based textile, which is usually used for filtration, is placed across the canal for fishing. Pata, a bamboo-made structure with parallel holes/gaps one after another is placed across the canal for finishing. Kumor, a structure (4-8 meter long and 2-3 meter wide) made with branches of trees on canal bed on any side of the canal is used for the same purpose. This practice has been found rampant in almost all sub-catchments, especially in Telikhali, Kanchannagar and Golaimari.

Over the years, siltation, topsoil erosion and other land filling activities have resulted in gradual decline of water courses within the polder. The condition of Aro khal and Golaimari khal at Golaimari sub-catchment, Asannagar khal at Asannagar sub-catchment, and Kata khal at Kanaidanta sub-catchment were the worst of all. Water course in the Aro khal was almost non-existent with most of its area covered with grass. The width of the water course of Kata khal has come down to 2 feet from a very high range of 30 to 40 feet.

Figure 5.6: Local encroachment in Polder 29 (a) Net (b) Pata

5.5 Availability of water resource and uses

Groundwater, Surface water, rainwater are the main sources of water in Polder 29. Groundwater is pumped through tube-wells. Shallow aquifer is saline to different degrees everywhere in polder, while deep aquifer is fresh in the north, while it gradually becomes more and more saline in the south. Very few people use shallow tubewells (STWs) to extract water for drinking water; water from STWs is mostly used for other domestic purposes. While deep tubewells (DTWs) provide safer drinking water in the northern sub-catchments, such as Katakhali, Kanchannagar, Kanaidanga, Bakultala, Telikhali and Golaimari, in the rest of the catchments salinity in both shallow and deep aquifers restrict use of groundwater, with the people in areas in the south, such as Ruhitmara, Jaliakhali and Ratankhali severely constrained and resorting to alternative sources, including rainwater, and often having to travel far for collecting water for their drinking purpose or depending on vended water supplies. There are few community-based rainwater harvesting schemes, Pond Sand Filters (PSFs) and Managed Aquifer System (MAR) for providing better drinking water, by welfare NGOs, and through government or non-government projects.

Agriculture is dominated by rain-fed Aman paddy in the monsoon. Although Boro is grown in the dry season, its area is hindered because of constraints with irrigation water. Many ponds, khals and canals are found in Polder 29 but most of them are at the southern part (e.g., Ruhitmara. Jaliakhali, Ratankhali), which are either saline or remain dry during dry reason. In the northern parts (e,g., Kanchannagar, Bakultala), salinity issue in ponds and khals is less than the southern parts, but drying up of these water courses is an issue. Irrigation takes place using shallow groundwater in the north, for example, the two large sub-catchments, Telikhali and Kanchannagar, where groundwater salinity varies from 1000 to 1500 mg/l in many parts of the two sub-catchments (Akhter, 2019).

5.6 Water hazard intensity and magnitude

That occurrence of multiple types of hazards is a regular phenomenon in Polder 29 is apparent from the respondents of household survey (Figure 5.7). About 86% people mentioned river erosion as a major issue in 2015, which are mostly concentrated at Ruhitmara and Jaliakhali (Figure 5.7). Besides erosion, cyclone, tidal flooding, and water congestion are clearly major concerns for the in habitants.

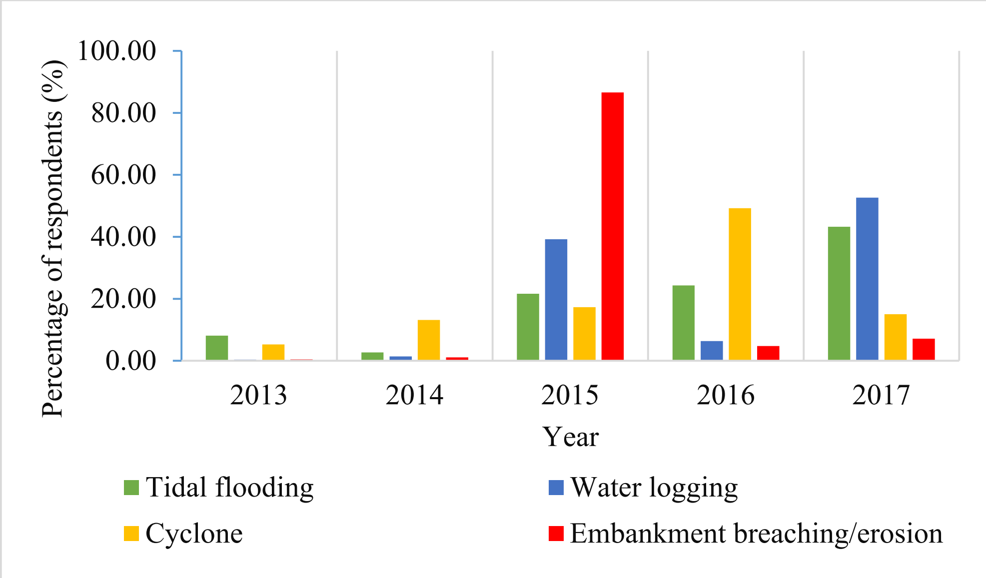

Figure 5.7: Hazardous events occurred in Polder 29.

Multi-hazard map was prepared, as presented in Figure 5.8, in conjunction with the local people, via participatory mapping during FGDs at different locations of the 10 sub-catchments. Although comparatively limited in areal extent, river erosion and/or embankment breaching associated with saline water flooding is a major issue in Ruhitmara and Jaliakhali and to some extent Ratankhali, which affect thousands of farmers, destroy their homesteads, and affect their livelihoods to a large extent.

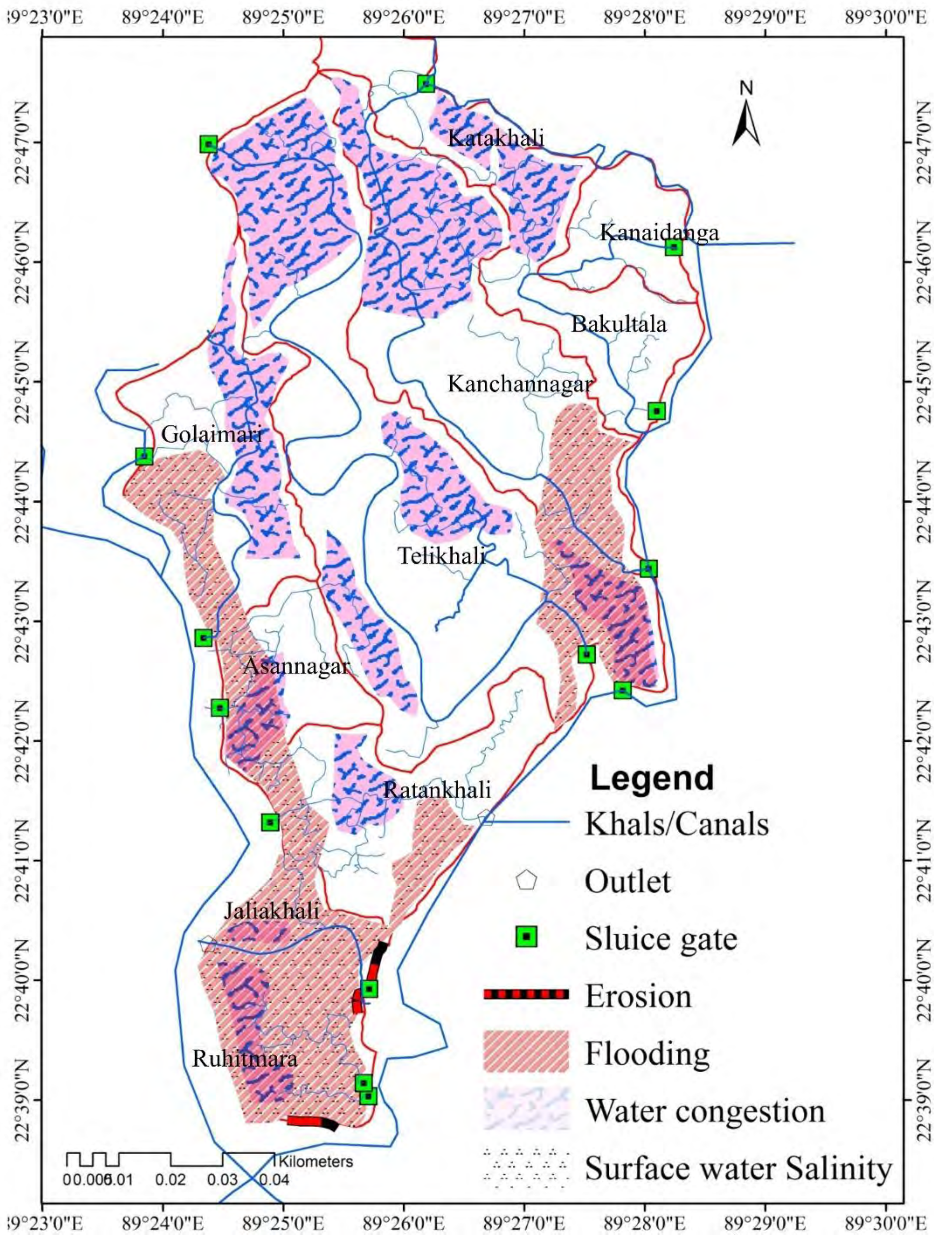

Figure 5.8: Participatory mapping of Composite hazard map of Polder 29

It was revealed from the FGDs and KIIs at Ruhitmara and Jaliakhali that riverbank erosion along Bhadra river at Polder 29 has been a problem since early 90's, with a sharp river bend having straightened up and hence requiring frequent retirement of embankment. Embankment is damaged every year during monsoon with high fluvio-tidal flows and strong wave action (Figure 5.9), causing widespread water logging (Figure 5.10) and rendering thousands of people homeless, and forcing them to live on the embankment (Figure 5.10). Apart from bank erosion and wave action that cause embankment breach, cyclones and associated storm surge also cause extensive damages to the embankments. Besides cyclone and associated flooding, drainage congestion is a widespread phenomenon in the Polder, especially in the norther sub-catchments.

Figure 5.9: Erosion at Polder 29 along Bhadra river

Figure 5.10: Extensive waterlogging insider Polder 29 because of embankment breach, forcing people to live on the embankment

5.7 Natural events and impacts

Conflicts in the study area also appear to occur due to some natural events, e.g., salinity intrusion or increasing salinity inside the polder, tidal flooding, and rainfall variability. These have led to issues with declining crop or fish yield, increased production cost, loss of agricultural homesteads, laboring opportunities, etc. Using the household survey data, Figure 5.11 illustrates that crop yield is declining about 69.1% for salinity, 62.0% for rainfall variability and 22.0% due to tidal flooding. On the other hand, 52.3% production cost, 25% fish diversity and 45.5% homestead agriculture are impacted by salinity issue. Relatively similar issues also arise because of tidal flooding and variability of rainfall. FGD respondents of the study area (in Telikhali, Jaliakhali and Bakultala) pointed out that sometimes ill-management of water systems such as illegal inlet construction, breaking or opening of sluice gate, and canal encroachment due to personal gain may enhance salinity intrusion and tidal flooding. On the other hand, conversion of canal/khal and/or river into shrimp ghers also reduces the number of freshwater reservoirs for the dry season (from November to March).

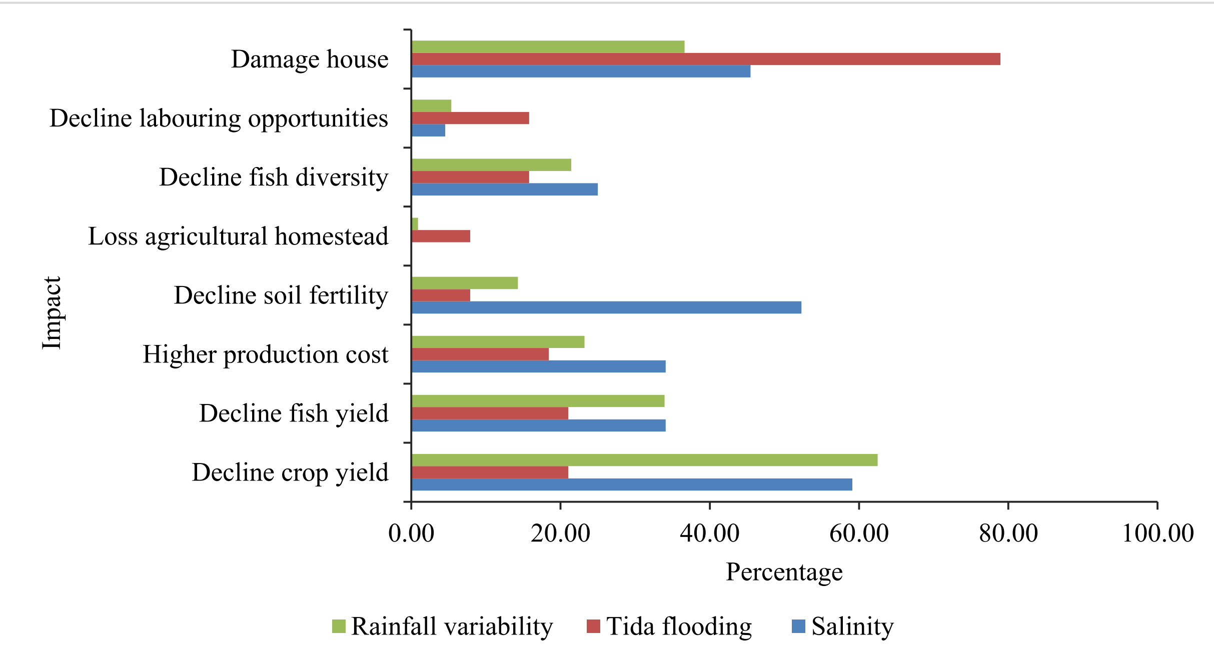

Figure 5.11: Impact of rainfall variability, tidal flooding and salinity. (Source: REACH household survey)

5.8 Land use land cover of the study area

The results obtained from the analysis of Landsat satellite imageries for the baseline year (2020) are shown in Figure 5.12 and the analyzed data are presented in Figure 5.13. A total of four LULC types have been identified in this study for all the selected years (the baseline is shown here). Land use map of the study area shows seasonal variability as well as spatial variation. For the wet season, northern parts (e.g., Katakhali, Kanaidanga, Bakultala, and Kanchannagar) and some portion of middle part (e.g., Golaimari) are gher (sweet water shrimp) dominated land, whereas southern and some portion of middle parts (Asannagar, Telikhali, Ratankhali, and Ruhitmara) are agricultural crop (wet season paddy, i.e., Aman) dominated. In Jaliakhali sub-catchment, land use in wet season represents a mix of brackish aquaculture and Aman, although Aman cultivation is problematic in areas adjacent to the brackish shrimp ghers.

On the other hand, in the dry season, northern parts and some portion of middle part like Katakhali, Kanaidanga, Bakultala, Kanchannagar and Golaimari are agricultural crop, i.e., dry season paddy (Boro) dominated, whereas, majority people of southern part (Jaliakhali, Ruhitmara and Ratankhali) and some portion of middle part (Asannagar and Telikhali), are practicing gher (brackish shrimp) farming. All over the polder area, the coverage under agricultural crop is 42.3% (wet seasonal paddy named Aman) in the wet season and 38.3% (dry seasonal paddy named, Boro) in dry season. In terms of aquaculture, the area coverage is 23.9% in the wet season and 14.7% in the dry season (Figure 5.13).

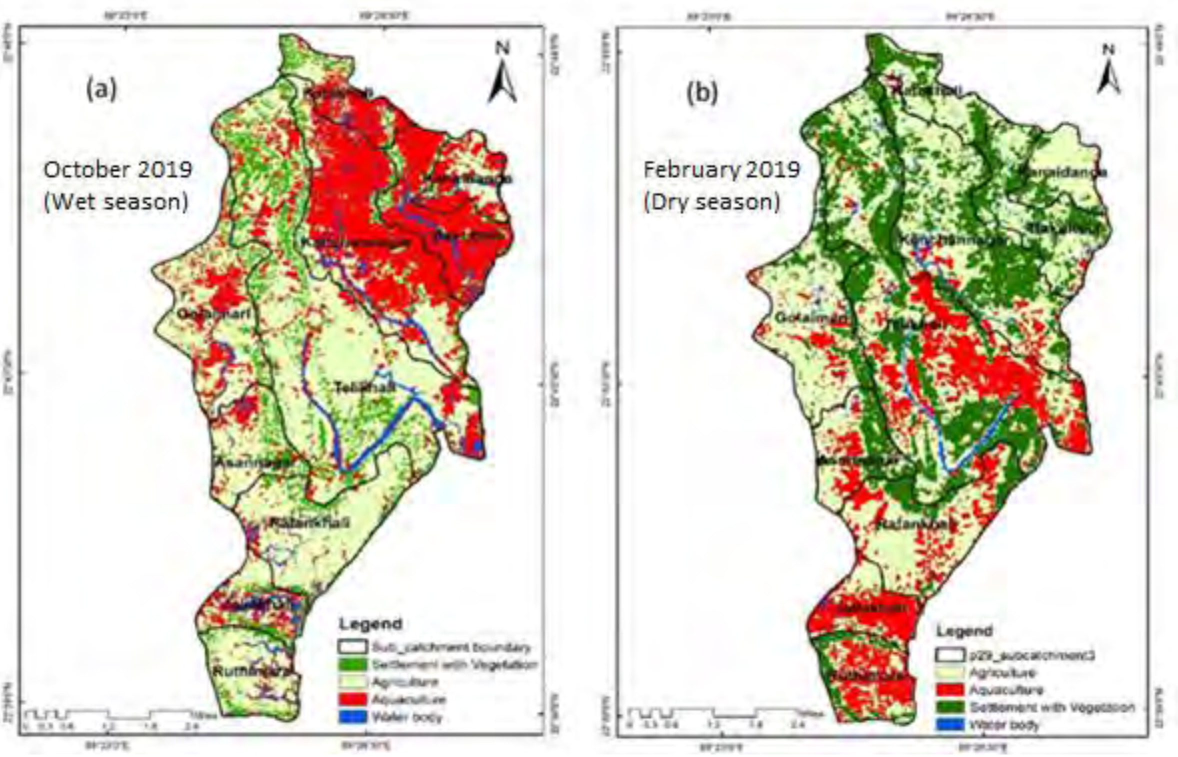

Figure 5.12: Current land use land cover map of the study area (a) wet season, (b) dry season

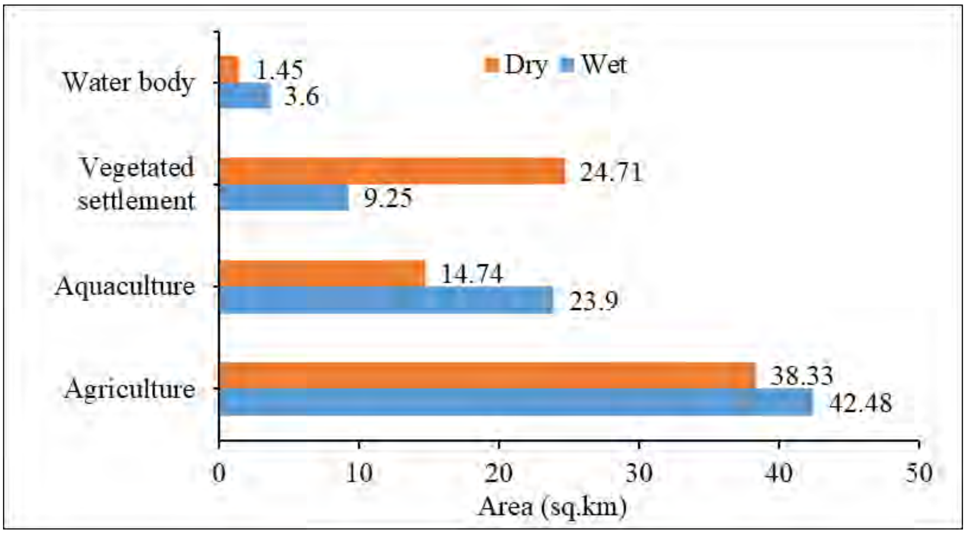

Figure 5.13: Area of different land class in Polder 29

It may be noted here that aquaculture area is often under-reported by the respondents in local government surveys (Figure 5.14). According to the fisheries office of Dumuria, the number of actual gher and registered gher varies for both Bagda and Golda. Gher owners try to hide and do not want to register their new ghers. Besides, among all the unions of Dumuria upazila, Sahas and Sharappur experience brackish gher (Bagda shrimp) farming, where Dumuriya and Vandarpara experience small-scale freshwater (Golda shrimp) farming. FGD respondents of Bakultala, Kanchannagar, Golaimari, Telikhali revealed that these numbers are increasing with a high rate in the recent few years.

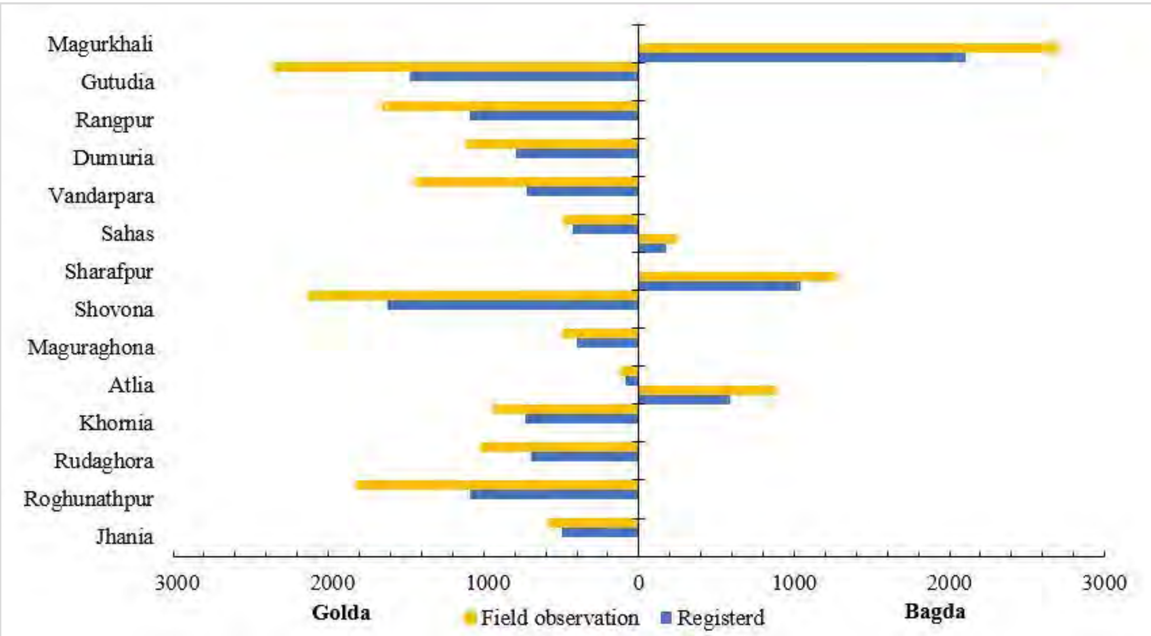

Figure 5.14: Number of gher (Golda shrimp and Bagda shrimp) in Dumuria Upazila (Source: Fisheries Office, Dumuria Upazila)

5.9 Livelihood and ownership status

Livelihood in Polder 29 is constrained, as was found from household survey. About 38% of community struggle a lot for their livelihood, while 7 percent people are unable to meet their needs (Figures 5.15 and 5.16). These areas lie in the high salinity zone and are prone to Bagda shrimp farming by the muscle men and rich landowners (Figure 5.16). The main characteristic of this area is the existence of highly saline water (both in groundwater and surface water). Crop production is greatly hampered due to salinity problem and crop variety is also limited. Only Aman Rice during Monsoon season is cultivated here due to the scarcity of freshwater for cultivation over the year (Source: FGD and IDI). On the other hand, only 44% have their own land for farming, whereas 29% lease in lands from others for cultivation (Figures 5.17 and 5.18).

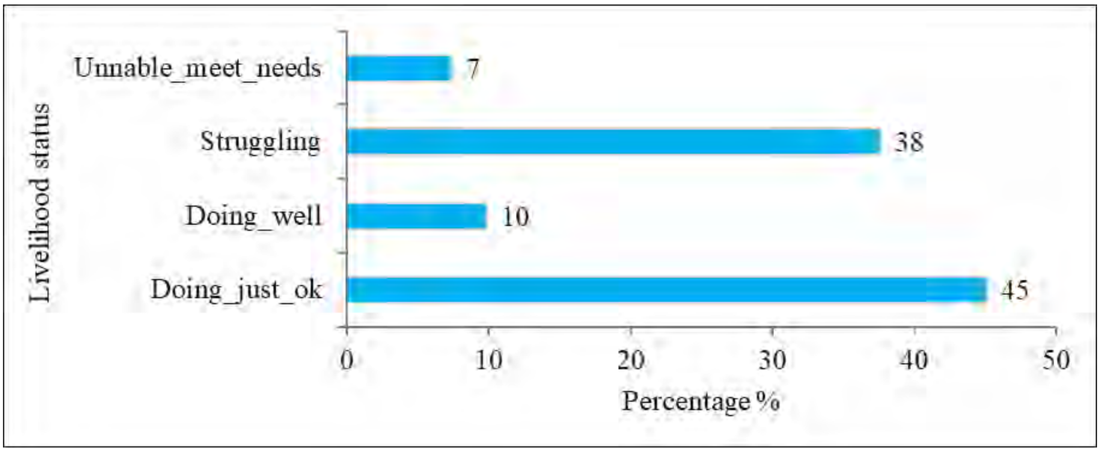

Figure 5.15: Livelihood condition in Polder 29

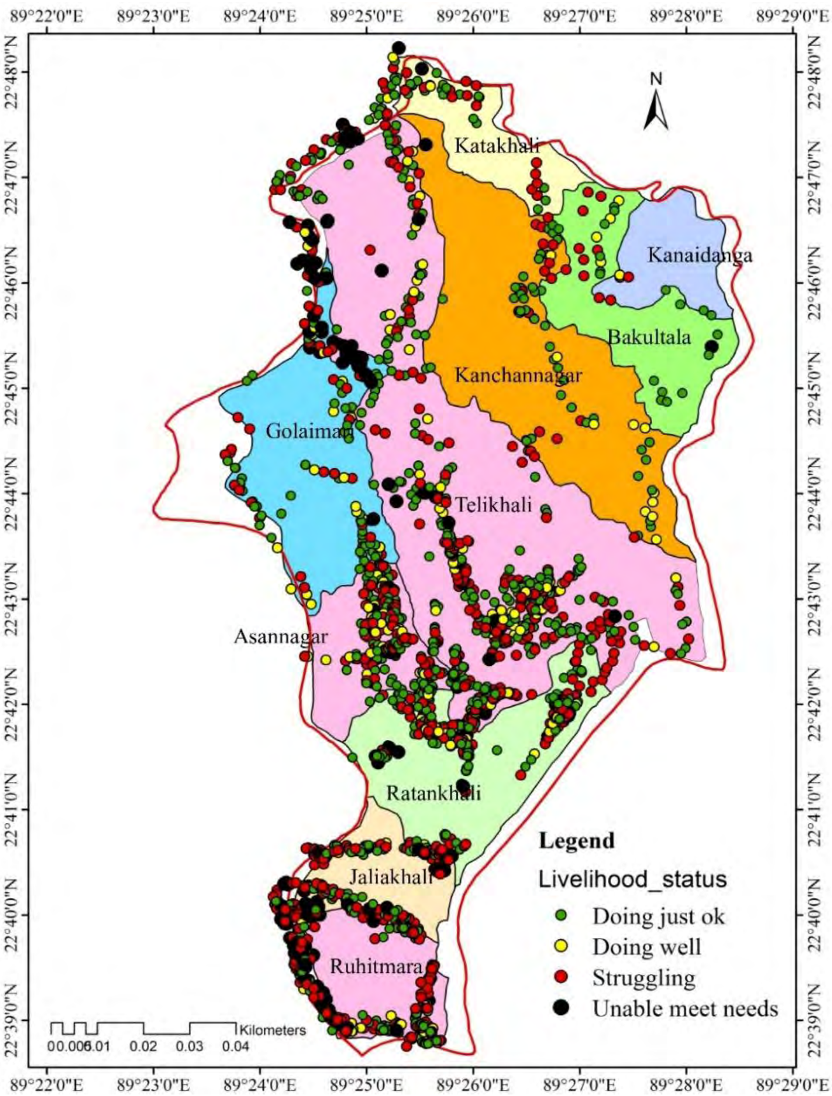

Figure 5.16: Spatial distribution of livelihood condition in Polder 29 (Source: REACH household survey)

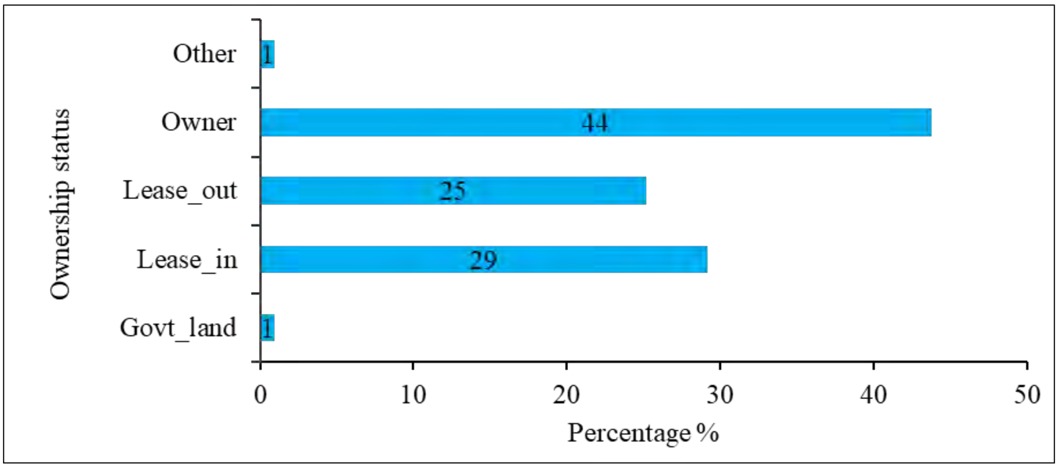

Figure 5.17: Land ownership status in Polder 29

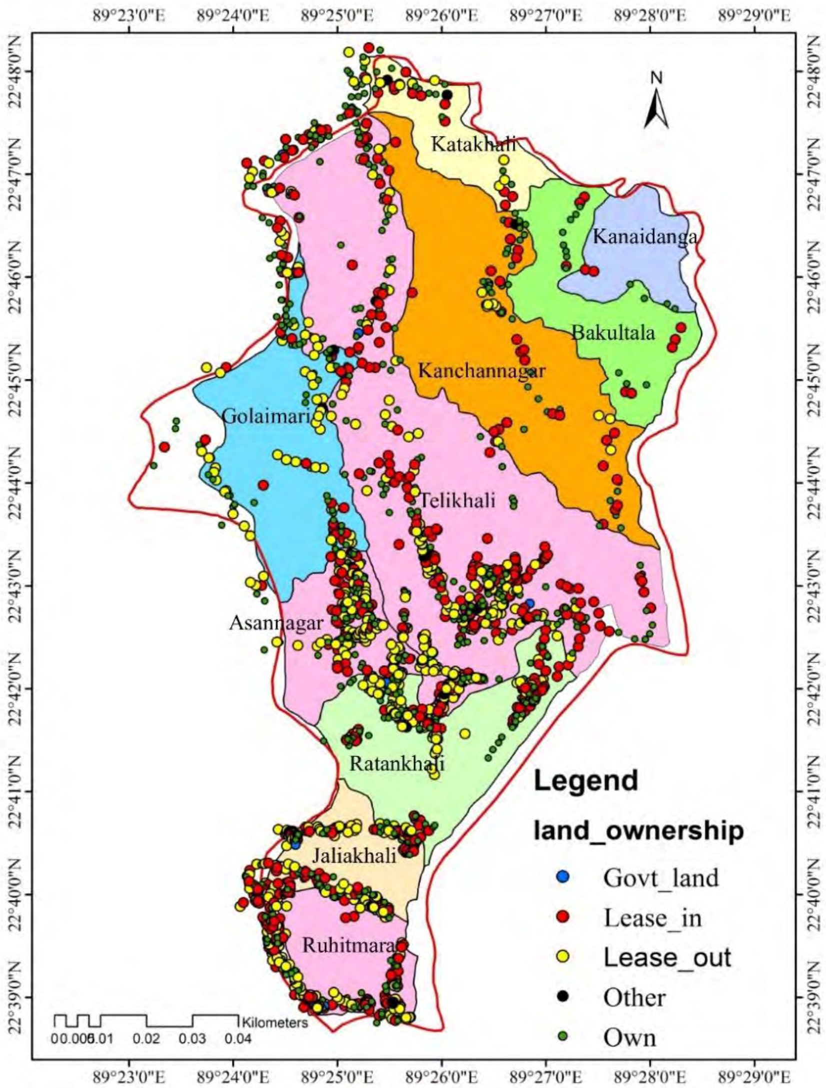

Figure 5.18: Spatial distribution of land ownership status in Polder 29 (Source: REACH household survey)

Chapter Six: Water conflicts and implications for water security in Polder 29

6.1 Introduction

Conflict is a common feature of water management and land use and generally arise from competing interests of various stakeholders. Conflicts do not solely rely on the water management issues, but also depend upon socio-economic situations and environmental conditions (source: KII respondents). A great diversity of opinions was observed over the term "conflict" everywhere in Polder 29. The majority of the respondents mentioned that conflict is essentially a difference of values, ideas, beliefs, opinion, goals and views between individuals or groups. Some of the respondents supported the point of view that conflict is the presence of violence. There was a consensus among respondents that conflict can exist between both individuals as well as groups depending on the nature of conflict. However, respondents from all sub watersheds believed that conflicts were more acute between groups rather than individuals.

Conflicts present in study area are mainly opposing local and exogenous stakeholders regarding competitive interests in the use of the water, and water structures. They concern topography, rights of access and users, regulation of illegal use, water and water structure management, and benefit generation that lead to the change of land use pattern. However, identification of conflicts from different perspectives is very difficult because conflicts are not always apparent. Polder 29 is not an exception. Several major types of conflicts have been identified in the study area resulting from the complex hydrological and socio-economic characteristics. Field investigations were carried out to identify and understand the conflicts and the conflicting situations.

6.2 Identification of conflicts

In Polder 29, the first water issue identified was related to large scale monocentric saltwater farming. With the passage of time this consequence changed its dimension due to the local movement raised by marginal farmers and laborers. The southern parts where this type of conflicts was identified include specifically Ruhitmata, Jaliakhali, Asannagar, and Golaimari. Besides, after the introduction of community-based institutions (WMGs, WMAs) in 2003, institutional issues were seen all over the polder. Sometimes institutional issues led to intra institutional conflicts, for example while forming committee, or inter institutional conflicts among LGIs, WMGs, WMAs, and project implementers like Blue Gold, around decision making, or control of water structures. After 2010, freshwater small-scale ghers became more popular in the northern parts, especially in Bakultala, Kanaidanga, and Katakhali, which eventually contributed to loss of hydrological dis-connectivity making a platform for another type of conflicts. Yet another type of water conflicts in the catchments of the polder is competition for freshwater resources between upstream (u/s) and downstream (d/s) stakeholders. Sometimes these u/s vs d/s issues are amplified by the illegal encroachment of internal canals and sedimentation including inner and outer parts of the sluice gate, resulting in local environmental degradation that leads to environmental conflict with users of that area. Ratankhali, Telikhali, Bakultala, and Kanchannagar catchments are the best examples of the above conflict. The conflicts mentioned above are summarized in Figure 6.1 and are systematically described below.

Large scale shrimp farming vs agriculture:

In the early 80's (i.e., starting from1980), O&M of the sluice gates and the resulting salinity intrusion problem had become a big concern due to political influence and local level power practice by the muscle men. That led to mono-centric brackish shrimp farming with large scale ghers by powerful people resulting less livelihood opportunities for the poor. This remained a source of acute conflict from 1985 to 1992 in Ruhitmara, Jaliakhali, Ratankhali, Asannagar and Golaimari sub-catchments, located in the southern part of Polder 29. The persons who practice large scale gher do not cultivate any other agricultural crops like paddy, vegetables, or grains (like sesame, pulses, etc.). They engage in shrimp production round the year. At present large scale ghers are found in Ruhitmara and Jaliakhali. Even today in Ruhitmara, one person owns 250 acres of brackish gher. Besides, in Golaimari, Asannagar and Ratankhali, large scale brackish farming is found only in periphery areas.

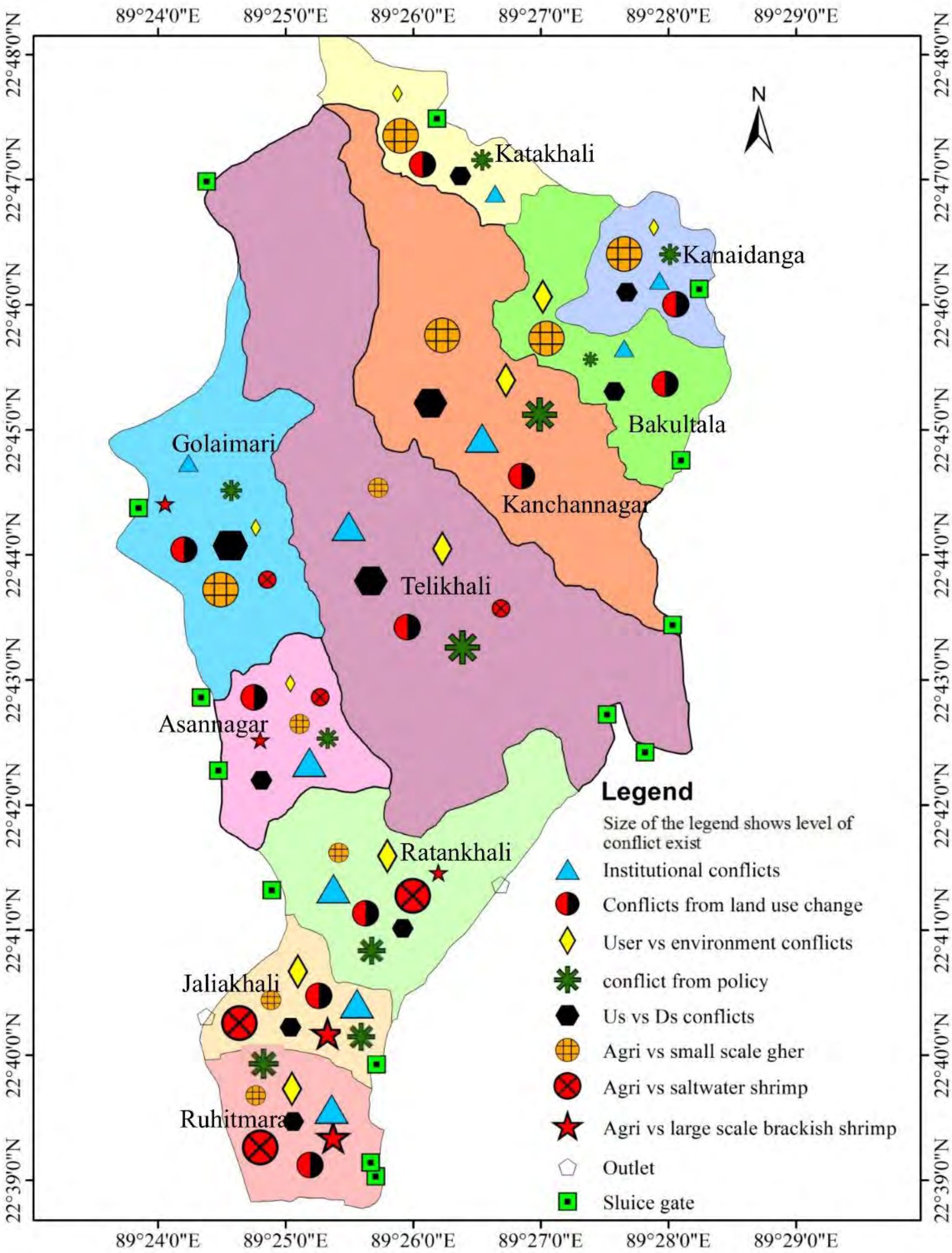

Figure 6.1: Observed spatial water related conflict in Polder 29 (size of symbols indicates the degree of importance)

Agriculture vs saltwater shrimp:

Conflicts are also found between brackish shrimp farming on small-scale and agriculture. Generally, fisheries businessmen tend to engage in saltwater gher farming. They prefer quick economic return. On the other hand, marginal and landless people prefer year-round production to live their livelihood. Some saltwater shrimp farmers try to cultivate seasonal vegetables, grains and pulses, whereas some gher owners lease their ghers to the other marginal farmers for a single season (generally wet season) and again take back that land (preferably in dry season) for shrimp farming (saltwater, i.e., Bagda shrimp). However, during dry season crop cultivation (Boro paddy) by agricultural farmers is affected by the surrounding brackish ghers. Moreover, sometimes the gher owners bring saltwater inside the polder illegally from the peripheral river thus creating trouble for the agriculture farmers. This type of conflict is found at Ruhitmara, Jaliakhali, Ratankhali, some portion of Golaimari, Asannagar and Telikhali (Figure 6.1).

Agriculture vs small-scale freshwater gher:

This conflict is found in the northern part of the polder, especially Telikhali, Kanchannagar, Golaimari, Katakhali, and Bakultala. Around 2010, a more intensive fish farming system has emerged in some small areas, in which rice fields in low lying areas have been converted into ghers. Small-scale freshwater ghers became popular among rich farmers and fishermen. Muscle men group inside the polder leased in and started gher practice. Even today, the practice of small-scale gher in the northern part has an increasing trend. Though initially the construction of gher is costly, freshwater shrimp farming provides high economic benefit later. However, this extensive ghers in the northern parts hamper canal water irrigation for the agricultural land. As, gher owners tend to grab and block the canals.

u/s vs d/s conflict:

The conflicts between the u/s and d/s stakeholders are found all over the polder, especially in Golaimari, Telikhali and Kanchannagar sub-catchments (Figure 6.1). Generally, u/s d/s conflict are generated for topographical difference within the sub-catchment. Natural siltation, manmade siltation process in canals and river encroachment by local instruments (net, pata/kumor; see Figure 5.6), weak water allocation by the O&M committee, lack of community participation, and improper guidelines of O&M are major reasons for this type of conflict.

Conflicts from policy level:

This conflict arises from leasing of sluice gates, khas land and khals, where some local opportunists take lease from the chairman (LGI) or other political and powerful people, though BWDB has opposed to this practice from the very beginning. Though khas land and khal/canal leasing are decreasing, khal/canal grabbing is seen throughout the polder and leasing sluice gate is a common phenomenon in Ruhitmara, Jaliakhli, Asannagar, Telikhali, and Ratankhali sub-catchments. As per BWDB’s policy, no khas land can be leased (both BWDB’s and Govt.

land) and will only be used by the WMOs for their betterment. But according to Government law of “khas land leasing to landless people by DCR 1983”, people mainly ‘muscle men’ take the land (which is sometimes actually a water body e.g., a canal) in the name of landless people and gradually grab more land and adjoining canals which restrict water flow by narrowing down canals and triggering canal siltation.

Institutional conflicts:

Institutional conflicts mainly occur between different institutions (different institutions are listed in section 5.2). If conflicting issues arise between two different bodies, it is considered as inter institutional conflicts. For example, conflicting status between ‘O&M committee’ and ‘beel committee’, conflicts between LGIs and O&M committee (seen at Asannagar and Ratankhali sub-catchments), conflicts between WMG and WMA (seen at Bakultala, Kanchannagar, Telikhali) etc. In 2004, WMGs and WMAs were formed under EPSWAM project. From Blue Gold project onwards, responsibilities of sluice gate, khal/canal management and maintenance, water distribution etc. should be taken by the WMGs and O&M committee.

But it was found that LGIs and locally formed beel committees tend to grab the O&M power. On the other hand, some conflicts are found between two same institutions, for example, conflicts between two WMGs and conflicts among WMG members. This type of conflict is otherwise known as intra-institutional conflict.

There exist some issues among adjacent WMGs and WMGs far from the sluice gate. One of the KII respondent of Blue Gold said:

> “*Everybody wants coordination, but nobody wants to be coordinated. But, to achieve sustainable water management as well as to minimize the conflicts through participatory approach, there is no alternatives but to have coordination among stakeholders and institutions*.”

User vs environment conflicts:

User vs environment conflict in Polder 29 occurs due to the unexpected and undesirable use of river, khal, land, sluice gate and salt water. For example, extensive ghers and unlawful grabbing of river/khal area have disrupted hydrological connectivity resulting in siltation in drainage canals, water congestion, loss of fish species, loss of khals, etc. This has been acute after 2010, especially in Telikhali, Kanchannagar, Katakhali, Bakultala sub-catchments.

Conflicts from land use change:

The most significant land cover changes are a consequence of the expansion of the area under cultivation. This has occurred sequentially over time down the ecological gradient of Polder 29. With rapid population growth, economic and environmental issues (e.g., salinity), cultivation of saltwater shrimp farming had been introduced in the early 80's (1980). After that, aquaculture began to be popular to the people of coastal areas, was extended along river side, internal canals and finally in cultivable land around the polder. This reduced the area available for agriculture and impacted the ease of access to freshwater for agricultural irrigation.

In the study area, from the very beginning (1990-present) the poor wants to use land round the year for year-round benefits, while the rich group wants to be benefited once at a time as economic return is very high. The attitude of monocentric benefit by the rich group is the main driving factor for land use generated conflicts. This conflict was observed in almost every sub-catchment. But in early 1990's, it was acute in the southern parts of polder area, while it started to spread in the northern parts and after 2010.

6.3 Spatial distribution of conflicts

6.3.1 Conflict map from PRA

Conflicting issues between agriculture and large-scale saltwater shrimp farming is much more in the southern part, such as Ruhitmara and Jaliakhali. In Ratankhali, Asannagar and Golaimari, this issue is less acute than the two areas mentioned above (Figure 6.1). Furthermore, institutional conflicts, environmental conflicts for user context and land use land cover change, u/s vs d/s conflicts and conflicts from policy issue are more or less seen all over the polder (source: FGDs and KIIs). Institutional conflicts are found between LGIs and O&M committee, between two WMGs in the same sub-catchment and among WMGs of two different sub-catchment members, and even conflicting interests among WMG members of a single WMG. Besides, there is an institutional conflict among the O&M committee vs powerful groups and LGIs. These three appeared to have similar interests, trying to dominate and maintain water managements activities. On the other hand, due to LULC change, livelihood conflicts and upstream-downstream conflicts are also obvious.

In Kanchannagar and Telikhali sub-catchments, institutional conflicts and u/s vs d/s conflicts are more severe than the other sub-catchments due the catchment size. These two sub-catchments are relatively bigger than the others. As a result, conflicting issues between two

WMGs are found frequently at Telikhali sub-catchment near the new Telikhali sluice gate. Both Telikhali and Uttar Sharappur WMGs in this catchment try to operate sluice gate according to their preference. In this case, other WMGs in Telikhali sub-catchment are divided into two groups. One group supports Uttar Sharappur WMG, while another group supports Telikhali WMG. Again, some peripheral WMGs at Bakultala and Kanchannagar are deprived to use water and irrigation from the sluice gate and canal of that sub-catchment. In Kanchannagar, small-scale freshwater gher farming is notable, while it is less notable in Kanchannagar. There exists saltwater gher at Telikhali sub-catchment but to a small extent.

In Bakultala, Katakhali, Kanaidanga and Golaimari sub-catchments, small-scale ghers are the major land use (more than 77%) (Figure 5.10). According to FGD and IDI respondents of Bakultala, the conversion of the small-scale freshwater gher from agricultural land creates an issue among the local people of this sub-catchment. Marginal people who lived their livelihood through agriculture by leasing in land and agricultural day laborers are facing utmost challenge. According to the household survey, 7% of people in the study area unable to meet their livelihood needs and 45% people are barely managing their day living (Figure 5.12). Besides, the rate of leasing land to the gher farmers on being offered large amount of money is increasing all over the polder area. One of the FGD respondents said:

> "*The persons who lease out their land now a days prefer to lease their land to the relatively rich people/farmers in exchange of large amount of money so that land takers convert their land into ghers. Thus, small and poor landless farmers are deprived of cultivation. Moreover, once the land is turned into gher, adjacent paddy farmers also face a lot of irrigation difficulty, and after a certain period the adjacent agricultural landowners are compelled to also convert their land into a gher or lease out their land to the others for gher culture*."

Some people of *Bakultala* agreed that quick conversion of small-scale freshwater ghers from arable land has accelerated the u/s vs d/s conflict. Though, conflicts from policy level in Bakultala is relatively low, it is found moderately at Katakhali, Kanaidanga and Golaimari sub-catchments. Institutional conflict is highly notable at Golaimari and Katakhali but less in Bakultala. One of the influential WMG members in Bakultala said that the WMG discusses problems related to water management and regulation of sluice gate in monthly meetings and conflicts regarding water sharing issues between different users are often resolved. If they are unable to solve problems locally, they go to the UP Chairman and inform BWDB or Blue Gold officials if required. However, it seemed highly sensitive and was denied by the other respondents of Katakhali, Kanaidanga and Golaimari.

In Asannagar sub-catchment, almost all types of conflicts are found. Though saltwater shrimp farming and large scale ghers are rarely found, some people argued that peripheral ghers of this region contain saltwater shrimp farming. The owner of these ghers often bring saltwater into the catchment by using illegal inlets, which sometimes lead to cracks in the embankment, leaking saltwater to the main agricultural land. While conflicts from policy level and u/s vs d/s conflicts are moderate in Asannagar, institutional conflict is a big issue because of the highly active informal beel committee in parallel to O&M committee, with the beel committee being the dominant body. The coordination of WMG with Blue Gold and LGI is moderately good but not strong enough yet for better water management, as presence of one-sided relationship is claimed by the respondents. Most of the respondents claimed that to get the contribution of LGI, WMG had to knock them several times but that did not ensure their presence in time. FGD respondents in Asannagar also stated that LGIs do not talk to the general people but only to those who can provide financial benefits. Not only in Asannagar but also in most of the places in Polder 29, BWDB are seen to make attempts at prohibiting people to bring saline water into the polder, but they remain powerless against the gher owners.

In Ruhitmara, Jaliakhali and Ratankhali sub-catchments, active saltwater shrimp farming is a big issue. Because brackish gher enhances institutional and u/s vs d/s issues more. Due to saltwater shrimp farming, the production of agricultural land is decreasing. The problem is most prominent in the areas adjacent to the riverside.

With respect to the institutional conflicts, KIIs with the UP members of *Jaliakhali* and *Ratankhali* revealed that Union Parishad is considered as not only the most capable state institution in water management sector but also the most preferred organization. But the committees of WMG do not call them in any of their activities. One of the members of Sarappur Union claimed that they do not get any invitation from the WMG during election of WMG committee, benefit sharing or LCS project activities. They also asserted that present committees of WMGs are totally unwilling to inform the UP about their activity; however, transparency and accountability will be established if WMGs do their activities by informing the UP. On the other side of the coin, committee members of WMGs explain that involvement of LGI may hamper their general activity, which in turn may threaten WMG's own independent identity. However, the general people and the UP totally disagreed with this observation.

FGD and KII at Baro Aria in *Ruhitmara* sub-catchment revealed that coordination and interaction among BWDB, LGIs and WMGs/WMAs is less effective because of less supervision and inspection by the BWDB and LGI. The overall institutional landscape here appears to stumble in respect with actual control and maintenance of water infrastructure. WMGs and the WMA appear to be less effective as the water infrastructures are controlled by either the UP chairman and members or gher owners. Respondents also said that sometimes owners of shrimp ghers are UP members or Chairman himself. Most of the time these two identities are merged, meaning shrimp farming will be the first priority. By taking this advantage, the rich and dominant gher owners fulfill their own interests as sluices are opened or closed as per their instruction. As a result, the operation, maintenance, and infrastructure management plan that should be done by WMGs or WMAs, have been replaced by monopolistic control by the shrimp farming interests. Apart from the coordination gap between WMGs, BWDB and LGI, absence of coordination and interaction within WMG members and WMG committees was also apparent. On the other hand, while river erosion is a big concern here, BWDB or LGI do not take any initiatives or actions unless emergency situations arise.

6.3.2 Conflict mapping from hydrological analysis

Inundation and drainage of the study area

Figure 6.2 illustrates the present condition of the drainage network with the possible inundation area, either from internal rainfall or tidal water intrusion resulting from faulty sluice gate or improper operation of sluice gates. In the figure, DEM ≤ 1 values refer to the low-lying areas with elevation ≤ 1 m MSL, shown in RED colored pixels; DEM ≤ 2 values refer to the areas with elevation ≤ 2 m MSL, shown in LIGHT GREEN colored pixels; and DEM ≤ 3 values refer to the areas with elevation ≤ 3 m MSL, shown in BLUE colored pixels. In the whole Polder 29, DEM ≤ 1 and DEM ≤ 2 Account for about 5% and 20% of area, respectively, as illustrated in Figure 6.3. The area-elevation curve shown in Figure 6.4 illustrates that there are hardly enough areas with high storage.

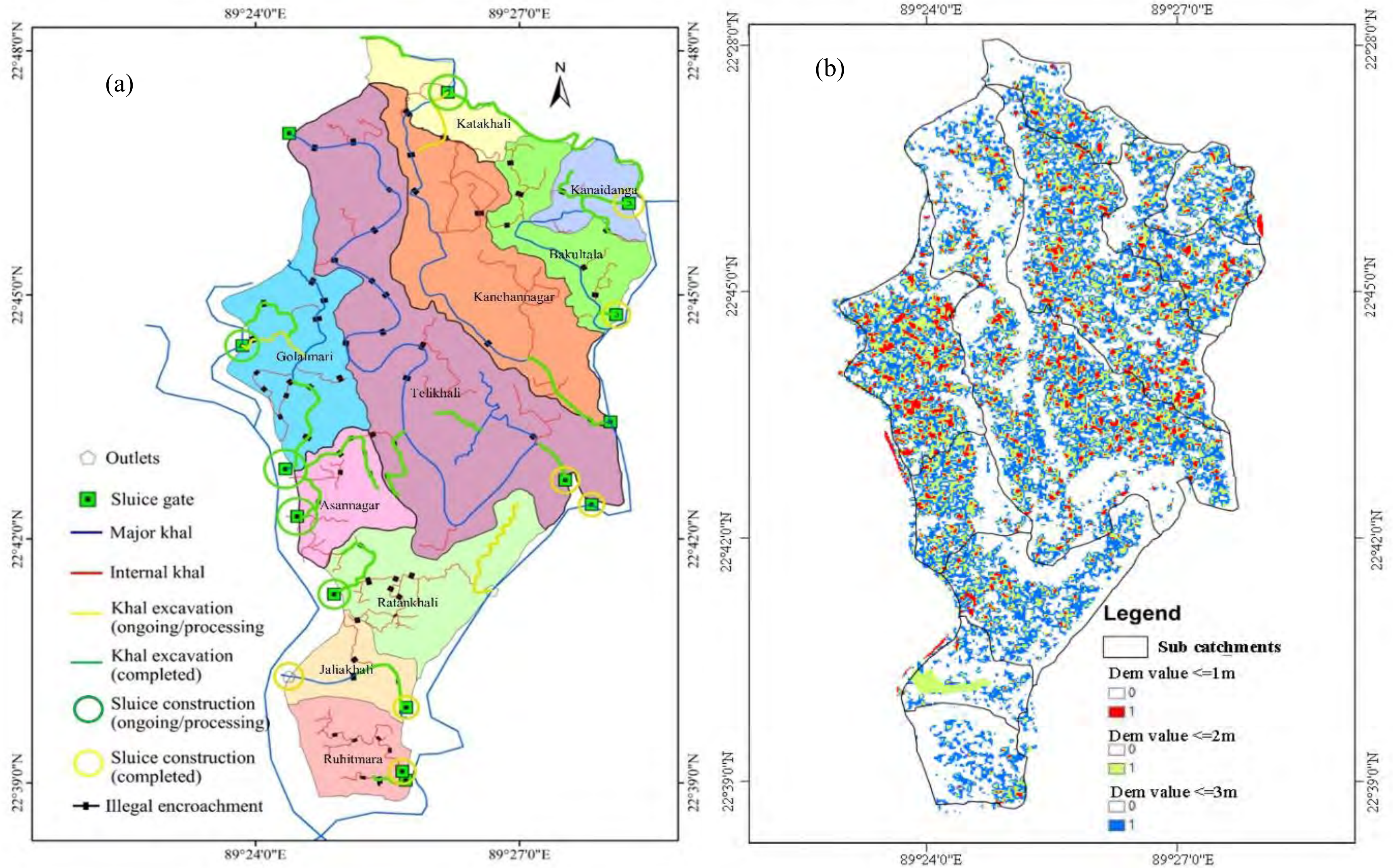

Figure 6.2: Inundation and drainage map of the study area (a) drainage network with khal condition, (b) DEM of the study

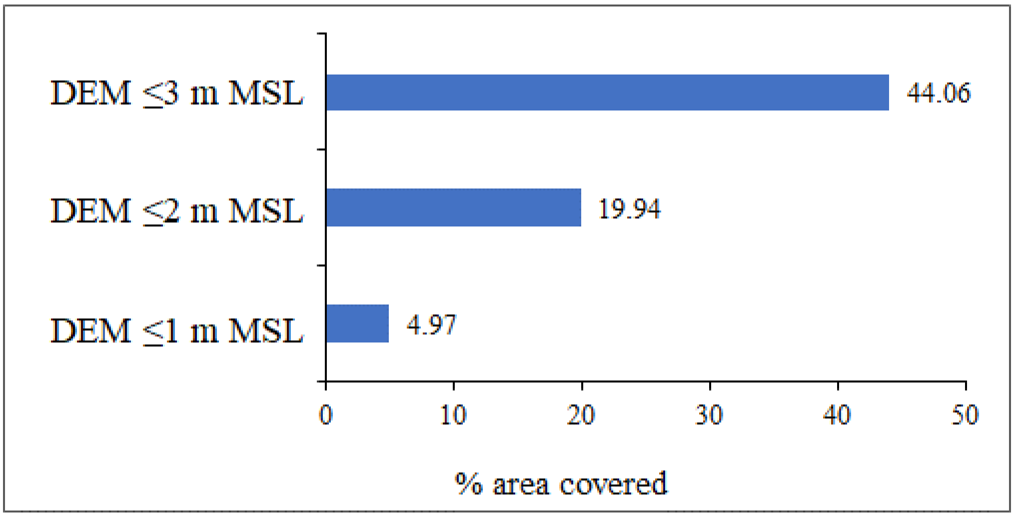

Figure 6.3: Percent area covered by different elevation ranges in Polder 29

As can be seen in Figure 6.2, the Golaimari sub-catchment is relatively more vulnerable to inundation as considerable parts in this area has DEM ≤1 m MSL and DEM ≤2 m MSL. The high concentration of this low elevations even at the upstream part indicate that unless there is adequate and effective drainage system via khals and canals, there is a chance of drainage congestion in the monsoon due to rainfall or pluvial flooding or flooding due to sluice operation. This was also corroborated by field observation and information derived from FGDs and KIIs. It is also seen that some portions of Telikhali, Kanchannagar and Bakultala, especially near the sluice gate, are also inundation prone to heavy rainfall or flooding due to sluice operation. This is further strengthened when the river water level hydrograph along the peripheral river (Figure 6.5) is compared with the topographic map as shown in Figure 6.2.

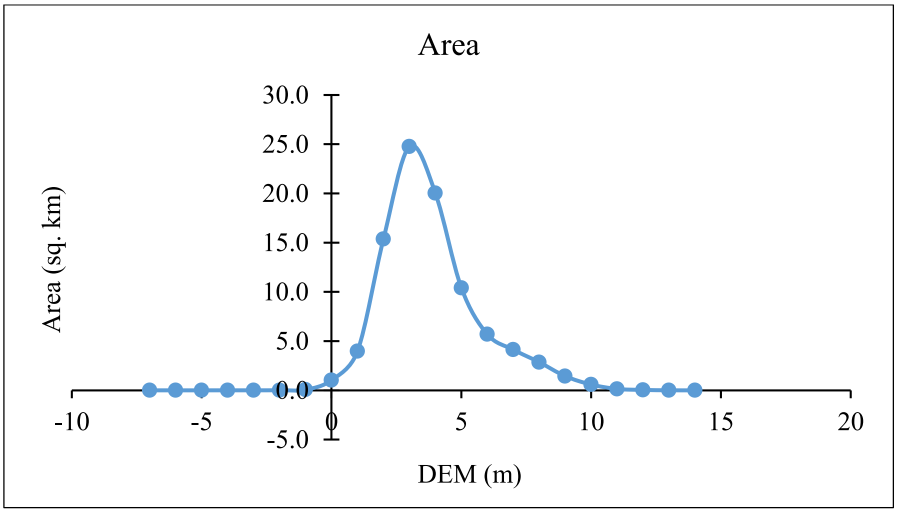

Figure 6.4: Area-elevation curve of the study area

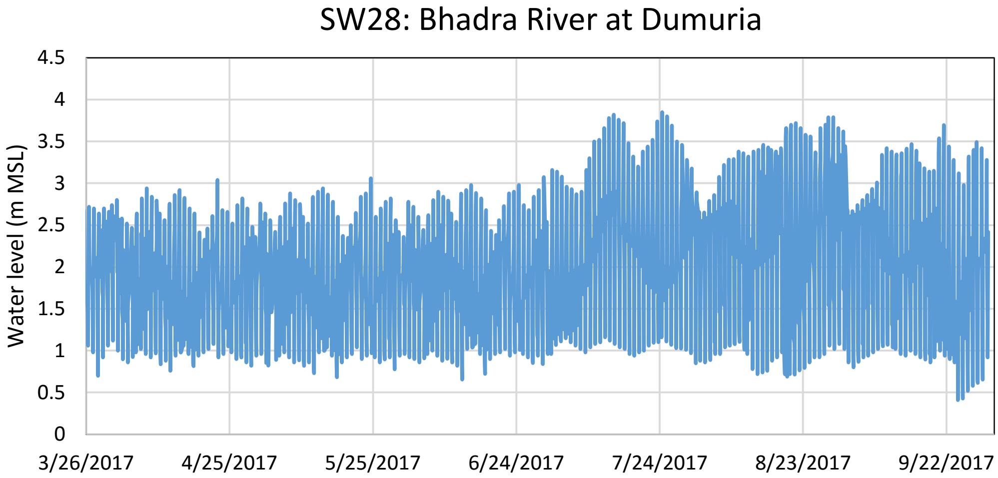

Figure 6.5: Water level hydrograph of Bhadra River at Dumuria (Source of data: BWDB)

Local respondents argued that the northern parts of the study area are inundated due to hydrological disconnectivity, as these areas are small-scale gher centric and a lot of water flow are disrupted by illegal encroachment, as discussed earlier. Moreover, the sluice gates of Golaimari, Telikhali and Kanchannagar were found nonfunctioning for a few years when this study was conducted.

Streamline and catchment delineation

From detail characterization of sub water units of the study area, there are several numbers of major canals in each sub-catchment. Figure 6.6 shows the delineated drainage of the study area from DEM 2012 (left side), and drainage network extracted from Google Earth 2022 (right side). The northern part (especially Bakultala, Katakhali, Kanchannagar and Telikhali) of the polder have higher density of streamlines than the southern part. On the other hand, from field observation, information from KII and IDI respondents, and land use land cover image analysis, it has been found that Bakultala, Katakhali, Kanchannagar and some parts of Telikhali are highly dominated by small-scale gher farming. These types of practice disrupt internal hydrological connectivity that forces reduction of drainage canals and drainage capacity, and changes drainage direction, resulting in u/s and d/s issues, drainage congestion during heavy rain and scarcity of freshwater for harvesting in the dry season.

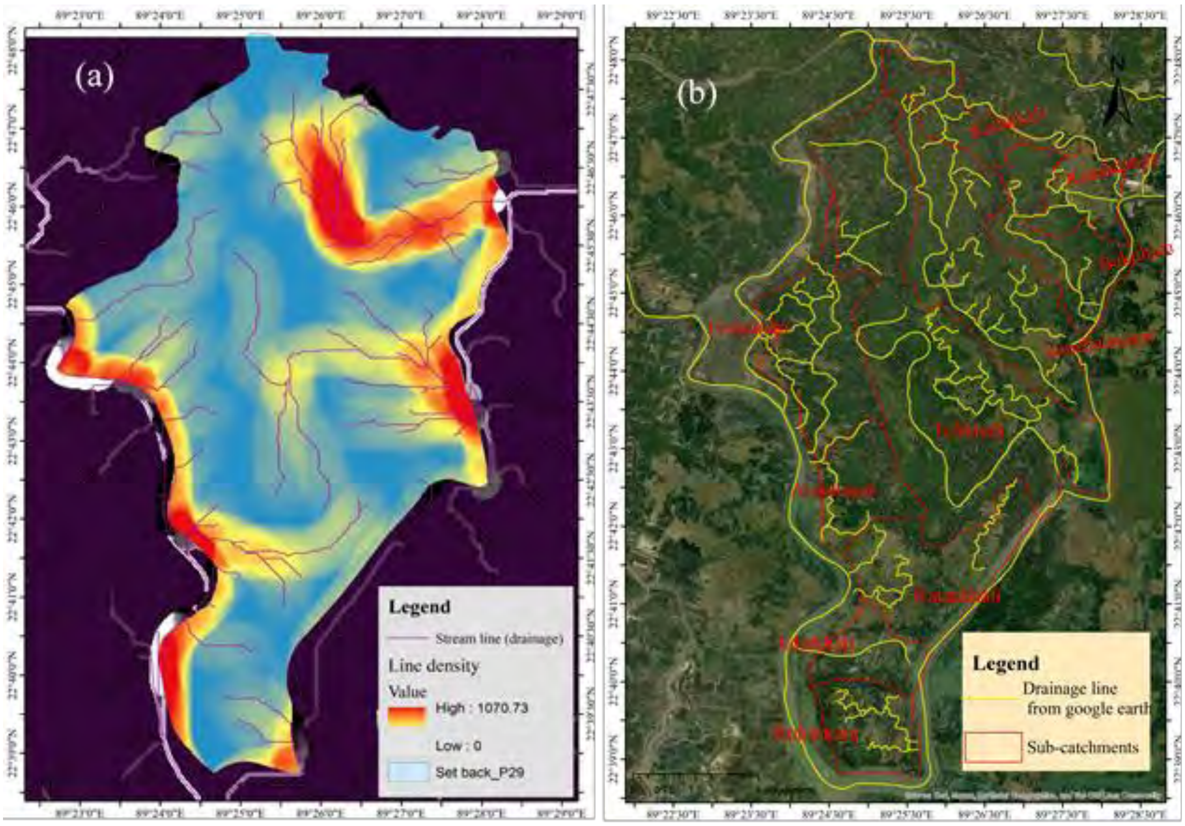

Figure 6.6: Drainage of the study area. (a) delineated drainage line from DEM (b) drainage line extract from google earth image.

Figure 6.7 presents delineated sub-catchment, existing sub catchments and WMGs of Polder 29. As, KII with Blue Gold and BWDB officials mentioned that '*Catchment delineation is not OK. There are two or more WMGs for a single canal and it is very difficult to have them with the same opinion'*. So, catchment delineation is as issue to create conflict between WMGs. There are conflicts between WMGs selecting their boundaries who are in the borderline (according to the Blue Gold catchment delineation). Some of these WMGs cannot use their desired water structures (sluice gate/ canals) while irrigation from the canals or in the opening issues while drainage congestion (Source: FGDs). The study found this problem at WMG named Uttar Sharappur situated at the border line of Telikhali and Ratankhal sub-catchment, Ghona WMG situated between Kanchannagar and Katakhali.

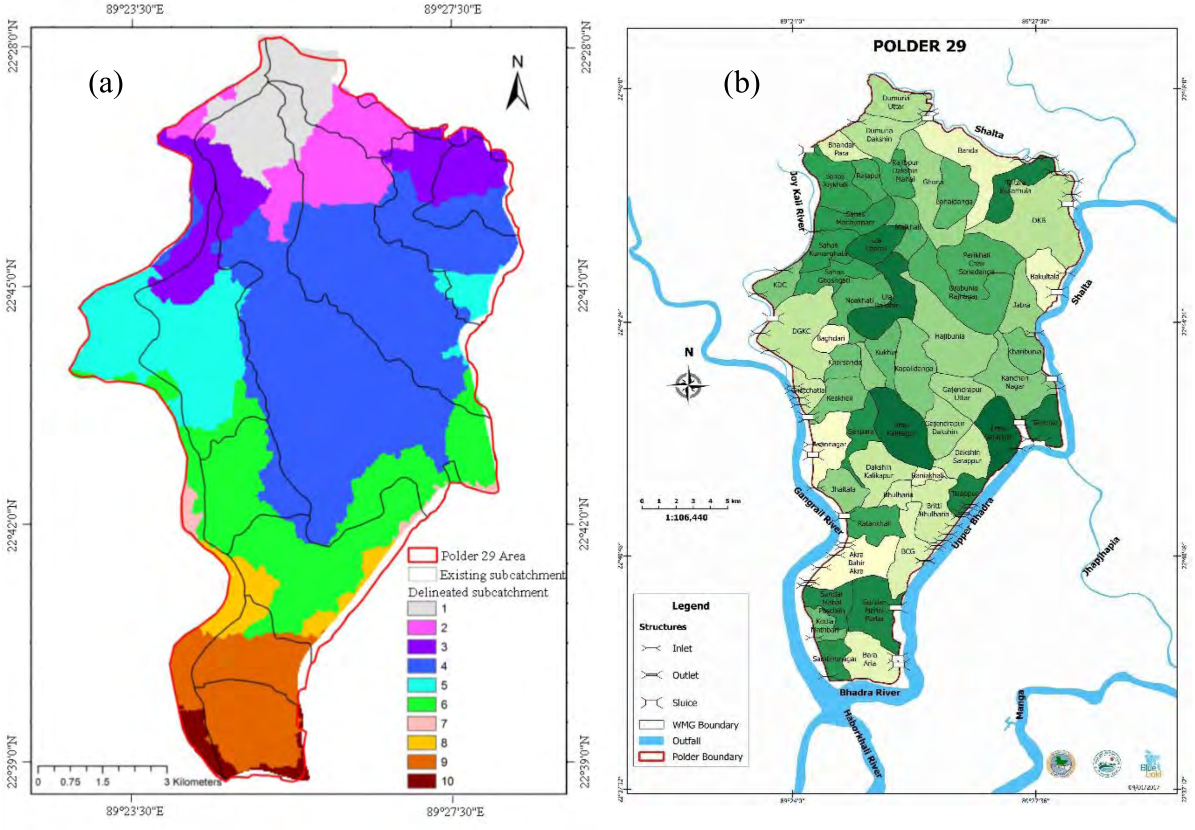

Figure 6.7: Sub-catchment and WMGs of the study area (a) delineated and existing sub catchments (b) existing WMGs of the study.

6.4 Temporal change of water conflicts

6.4.1 Timeline analysis through LULC

Land use land cover change

Table 6.1 and Figure 6.8 show the overall variability of change per land cover type over the study period from 1990 to 2019 where diverse scenarios are observed during both wet and dry seasons. The amount of agricultural land decrease in one season (wet), while a different scenario is observed in another season (dry season). Though, changing trends in vegetated settlements and water body (khal/beel) are negligibly observed, significant change are found in agriculture and aquaculture. Agricultural practice has been decreased by 14.23 sq. km in wet season, whereas it increased by 8.21 sq. km during dry period. The same situation happened for the vegetated settlement in some respects (i.e., 6.4 sq. km decrease and 8.26 sq. km increase in wet and dry seasons, respectively). Contrariwise, aquaculture shows reverse situation, with increase in wet season by 22.06 sq. km and decrease in dry season by 14.71 sq. km. However, a different situation is seen for water bodies, with continuous decrease seen in both wet and dry seasons in the last 20 years. IDI respondents revealed that practice of water use and irrigation, and intervention by water control structures are responsible behind the seasonal variation of agri-shrimp practice. Because water structure and managemental interventions gradually have changed livelihood practices, as mentioned earlier, that has also led to the change of land use pattern, revealed by the IDI and FGD respondents.

Table 6.1: Area of land use class in different years

LULC	1990 (km^2)		2000 (km^2)		2010 (km^2)		2019 (km^2)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Agriculture	56.71	30.12	45.83	31.79	42.09	36.49	42.48	38.33
Aquaculture	1.84	29.45	7.77	20.55	13.16	14.99	23.90	14.74
Vegetated settlement	15.67	16.45	17.85	19.29	17.66	18.93	9.25	24.71
Water body	5.03	3.21	7.78	7.61	6.33	5.79	3.60	1.45

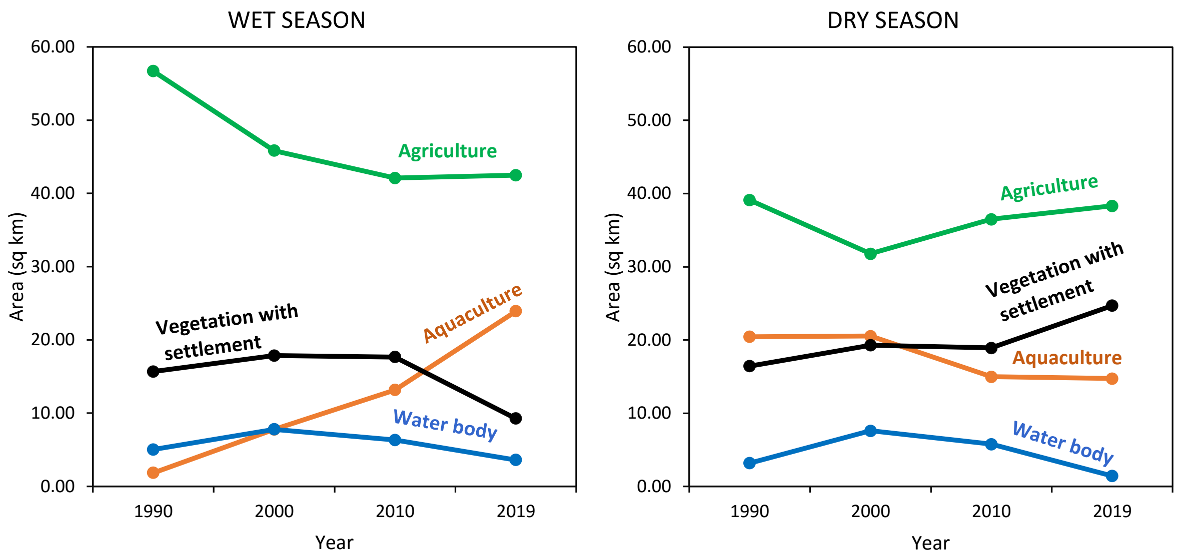

Figure 6.8: Area of land use class in different years

Figure 6.9 presents how LULC changed spatially through three decades from 1990 to 2019 during both wet and dry seasons. Table 6.2 and Figure 6.10 present sub-catchment wise land use change detection in wet season, while Table 6.3 and Figure 6.11 present sub-catchment wise land use change detection in dry season. In wet season, a continuous and substantial change has occurred from 1990 to 2019 in the northern part of the polder (Figure 6.9). Though changes from 1990 to 2000 is not as eye-catching, clearly a huge amount of agricultural land was turned into gher oriented aquaculture in the year of 2010. This trend continuing till 2019 prominently in Katakhali, Kanaidanga, Bakultala, and Kanchannagar areas (Figure 6.10).

At the same time, the southern part of the polder has also experienced substantial land use change during dry season. But the scenario is different from the wet season. From early 1990, saltwater aquaculture was practiced in the southern sub-catchments in Golaimari, Asannagar, Ratankhali, Jaliakhali and Ruhutmara (Figure 6.9 and Table 6.3). During this period, many parts of the polder and the peripheral zone were incorporated into the so-called large scale gher owned by white settlers outside of the polder sheltering political influence. Many of the agricultural land and khas land/khal were sold and leased, and subsequently subdivided into plots for saltwater shrimp farming (Source: IDIs and FGDs). These types of overpopulated saltwater farming areas lying to the south and southwestern parts of the polder resulted a fundamental transformation of the land use system from agriculture to large scale shrimp culture, as opportunity for the surrounding area's economy in salty aquaculture had grown more rapidly than from the rainfed small-scale agriculture. Gradually these transformations in LULC systems are reflected in the present land use patterns in the region. Although this trend decreased in 2000 due to anti-saltwater farming movement, it started increasing again in 2010. There is a trivial change have been observed in Jaliakhali and Ruhitmara sub-catchments in this procession of increase and decrease.

Table 6.2 shows that Kanaidanga (91.39%), Bakultala (88.14%) and Kanchannagar (5.91%) were mostly agriculture dominated sub-catchment in 1990, but over time agricultural land decreased to 41.26%, 8.63% and 28.23% respectively, as most of these lands are turned into gher farming. In sum, aquaculture practice has become dominated land use nowadays and is seeing a continuously increasing trend. Same example goes for the dry season except Bakultala, Kanaidanga, Kanchannagar and Katakhali sub-catchments.

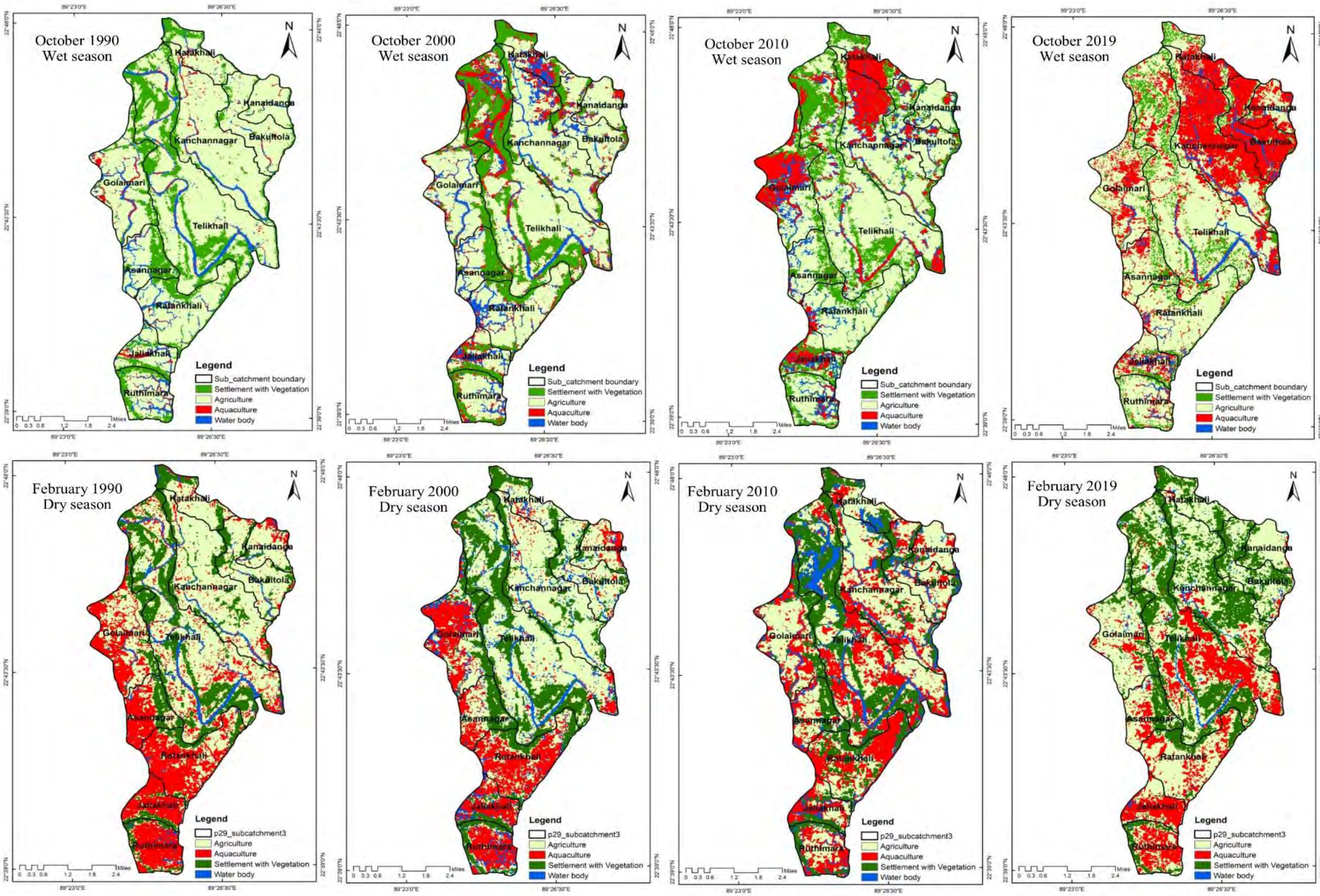

Figure 6.9: LULC of the study area at different years (1990-2019)

Table 6.2: Sub-catchment wise land use change detection in wet season (%)

Year	Land Class	Ruhitmara	Jaliakhali	Ratankhali	Asannagar	Golaimari	Telikhali	Kanchan	Bakultala	Kanaidanga	Katakhali
1990	Agriculture	58.71	60.47	72.15	56.79	71.87	64.00	5.91	88.14	91.30	67.95
	Aquaculture	3.79	7.71	1.35	0.96	5.05	1.32	2.06	1.71	1.40	3.04
	Vegetated settlement	5.99	22.63	19.60	32.38	16.11	28.09	7.75	6.99	4.45	24.07
	Water body	11.51	9.19	6.90	9.86	6.96	6.59	4.28	3.16	2.85	4.94
2000	Agriculture	58.48	44.42	64.39	50.69	67.15	48.12	69.54	69.60	76.79	29.91
	Aquaculture	8.26	16.44	5.37	5.85	7.25	12.37	7.95	7.78	8.72	19.65
	Vegetated settlement	24.17	22.76	17.63	32.87	16.51	31.97	11.64	13.63	9.16	33.58
	Water body	9.09	16.37	12.61	10.59	9.09	7.54	10.87	8.99	5.33	16.86
2010	Agriculture	56.64	25.00	70.88	59.35	33.08	57.54	53.70	57.65	70.24	17.17
	Aquaculture	7.12	30.05	3.80	3.12	38.46	8.99	25.56	12.53	5.16	47.23
	Vegetated settlement	22.49	28.93	18.47	28.74	15.88	28.86	12.86	18.45	16.73	32.07
	Water body	13.74	16.02	6.85	8.78	12.58	4.60	7.88	11.37	7.87	3.53
2019	Agriculture	71.12	46.46	79.99	66.46	64.61	65.58	28.23	8.63	41.26	32.93
	Aquaculture	9.08	26.93	6.67	16.13	24.99	13.22	61.18	77.09	50.56	50.18
	Vegetated settlement	14.51	14.87	10.11	15.31	8.27	16.80	5.73	6.85	3.16	13.69
	Water body	5.29	11.75	3.23	2.10	2.14	4.39	4.86	7.43	5.01	3.20

Table 6.3: Sub-catchment wise land use change detection in dry season (%)

Year	Land Class	Ruhitmara	Jaliakhali	Ratankhali	Asannagar	Golaimari	Telikhali	Kanchan	Bakultala	Kanaidanga	Katakhali
1990	Agriculture	10.23	8.81	27.84	22.25	43.54	50.52	76.42	72.90	70.71	61.08
	Aquaculture	70.24	74.28	58.13	51.83	40.13	11.57	6.21	5.07	15.82	8.18
	Vegetated settlement	15.56	15.26	12.83	24.32	14.30	30.81	14.22	18.71	9.76	27.08
	Water body	3.97	1.65	1.19	1.60	2.03	7.10	3.14	3.32	3.72	3.66
2000	Agriculture	34.59	27.88	23.55	41.86	49.93	30.02	55.45	51.98	67.13	41.84
	Aquaculture	36.90	40.31	43.44	22.81	25.74	23.91	21.91	19.48	16.81	11.65
	Vegetated settlement	20.52	21.38	29.50	28.27	17.31	32.67	13.94	19.10	9.27	33.66
	Water body	7.99	10.44	3.51	7.07	7.02	13.39	8.70	9.44	6.80	12.85
2010	Agriculture	13.72	13.27	25.80	38.66	29.00	52.99	74.14	67.93	64.17	57.23
	Aquaculture	52.92	55.22	53.18	25.67	43.47	3.84	3.72	4.72	22.15	5.90
	Vegetated settlement	22.26	18.08	16.88	32.54	18.01	35.02	15.46	19.44	8.85	31.07
	Water body	11.10	13.44	4.13	3.13	9.51	8.15	6.68	7.90	4.83	5.79
2019	Agriculture	33.10	31.03	59.70	49.22	67.72	37.70	49.77	51.11	73.77	55.48
	Aquaculture	46.83	63.78	23.84	19.54	10.87	22.95	6.86	2.43	2.70	1.56
	Vegetated settlement	19.77	3.66	16.19	30.30	19.67	36.66	41.15	44.10	23.06	41.60
	Water body	0.30	1.53	0.27	0.93	1.74	2.70	2.23	2.36	0.48	1.36

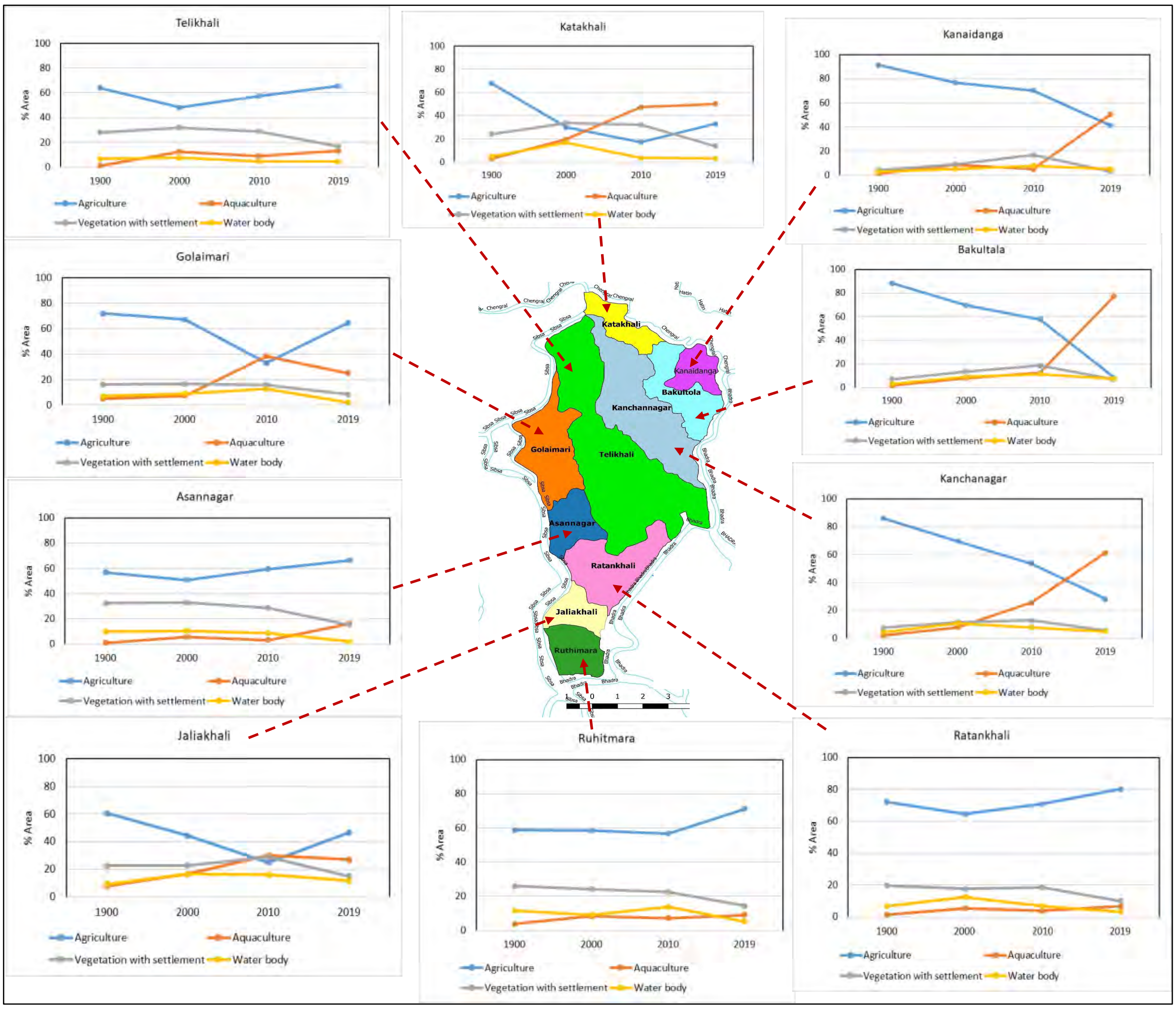

Figure 6.10: Sub-catchment wise land use change detection in wet season

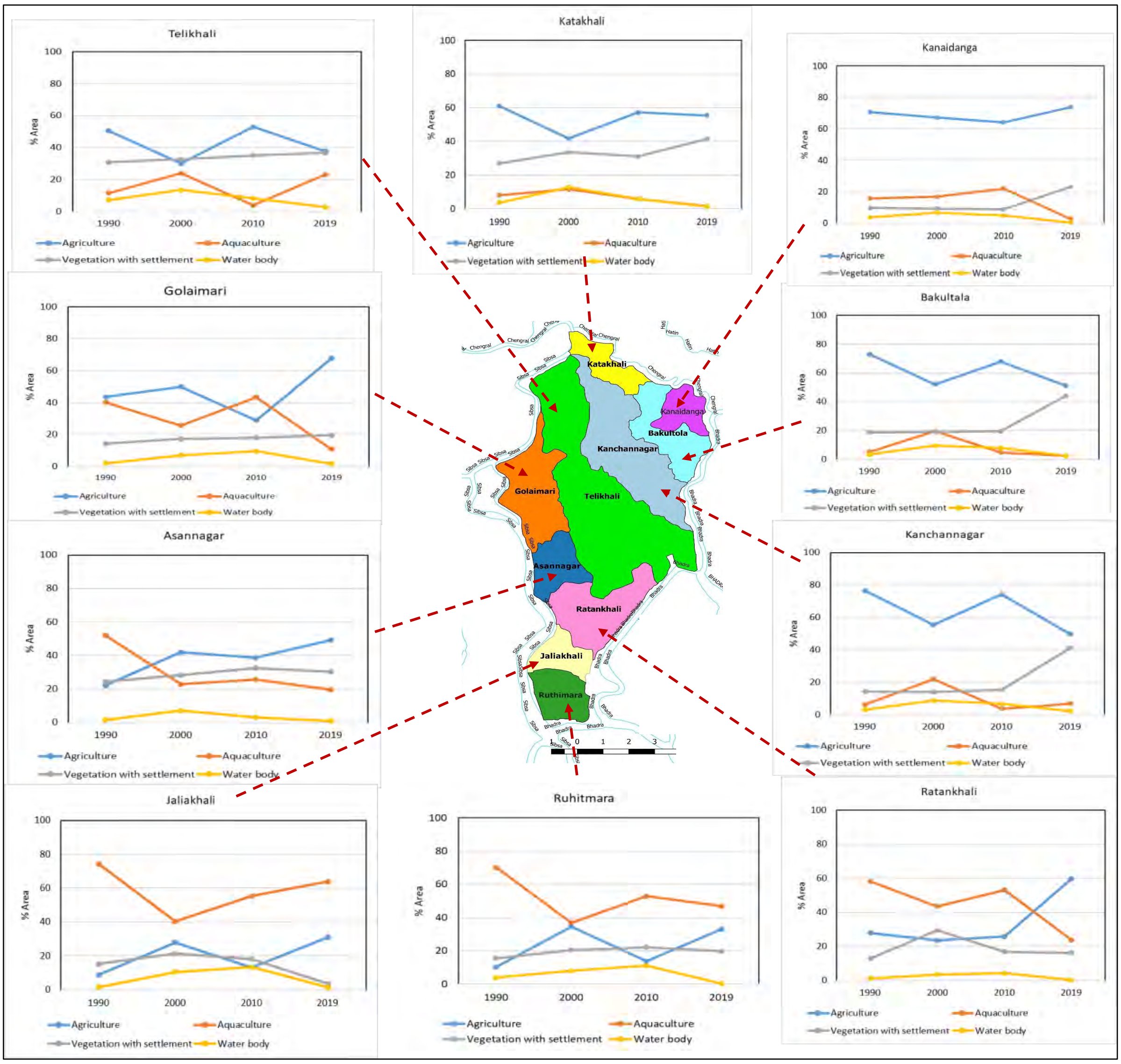

Figure 6.11: Sub-catchment wise land use change detection in dry season

6.4.2 Seasonal change detection and land use conflicts from 1990 to 2019

The results reveal significant modification and conversion of land use and cover over the last three decades (from 1990 to date). Seasonal change in major land use and land cover conversion types were identified (Table 6.4 and Figure 6.12). During the period 1990–2019, around 21% of agricultural land have been converted to aquaculture. Detection of LULC for a period of three decades showed a pick change on agriculture to aquaculture at the northern part in wet season (20.90%) and aquaculture to agriculture at the southern part in dry season (14.46%). The period from 1990 to 2000 saw important changes in water and aquaculture. On the other hand, new land cover types emerged along with the conversion of aquaculture and water in the next 10 years (e.g., conversion of aquaculture to agriculture in the dry season by 24.28%).

Table 6.4: Seasonal change detection of the study area

LULC	1990-2000 %		2000-2010 %		2010-2019 %		1990-2019 %	
	wet	dry	wet	dry	wet	dry	wet	dry
Agri_Aqua	5.43	12.31	6.88	11.47	10.27	9.19	20.90	7.39
Agri_Vegetated sett	4.91	4.01	3.33	0.98	2.35	8.76	2.15	10.88
Agri_Water	4.21	3.52	3.54	3.61	0.74	0.44	1.54	0.56
Aqua_Agri	0.78	9.73	2.61	24.28	4.27	12.04	0.94	14.46
Aqua_ Vegetated sett	0.06	2.25	2.68	2.22	0.29	0.47	0.05	1.79
Aqua_Water	0.96	2.57	1.55	8.37	2.30	0.34	0.50	0.31
Vegetated sett _Agri	1.39	1.55	5.56	2.70	9.70	3.42	8.69	3.14
Vegetated sett _Aqua	1.73	0.70	1.09	1.26	3.49	0.53	1.63	0.70
Vegetated sett _Water	1.13	1.41	0.63	0.60	0.76	0.03	0.39	0.12
Water_Agri	1.31	0.44	1.77	4.00	2.72	3.93	3.42	2.80
Water_Aqua	2.44	4.15	4.05	1.96	4.01	3.52	2.86	4.26
Water_ Vegetated sett	2.13	0.59	1.64	1.53	0.46	1.02	0.88	0.93

Agri= Agriculture, Aqua= Aquaculture, Vegetated sett= Vegetated settlement

Shrimp aquaculture has been a fast-growing industry, albeit with seasonal variation in the study area. The expansion of the industry has raised concerns about its external impacts on the local environment and ecosystems, including agriculture. Moreover, during IDIs people expressed their concerns about the impact of shrimp aquaculture on soil salinity in neighboring paddy farms and how this, in turn, affects paddy farm profits and productions. Results show that the land covered by shrimp ponds almost doubled in terms of percentage of agriculture area, whereas conversion of arable land to aquaculture was 28.3% from 1990 to 2019.

According to one of the FGD respondents:

> "*In the recent decade (2010-2019), agricultural farmers have been demotivated by a downward trend in paddy market prices coupled with higher production costs, frequent disasters, a range of crop diseases, and the need for large amount of freshwater in comparison with gher business. But marginal communities do not have sufficient money involved in gher business or prepare their land as a gher. Additionally, crops are damaged, or production is hampered by leaking of saltwater from adjacent saltwater gher. Thus, people are attempting to sell their land to the gher owners and are trying to change their livelihood.*"

The same sentiment was echoed in the freshwater zone in the north. While conducting KII and FGD at Bakultala, some of the respondents pointed out:

“Within few years the remaining agricultural land of Bakultala will turn into gher. The situation may result in a bigger conflict than now unless alternative livelihoods are introduced”.

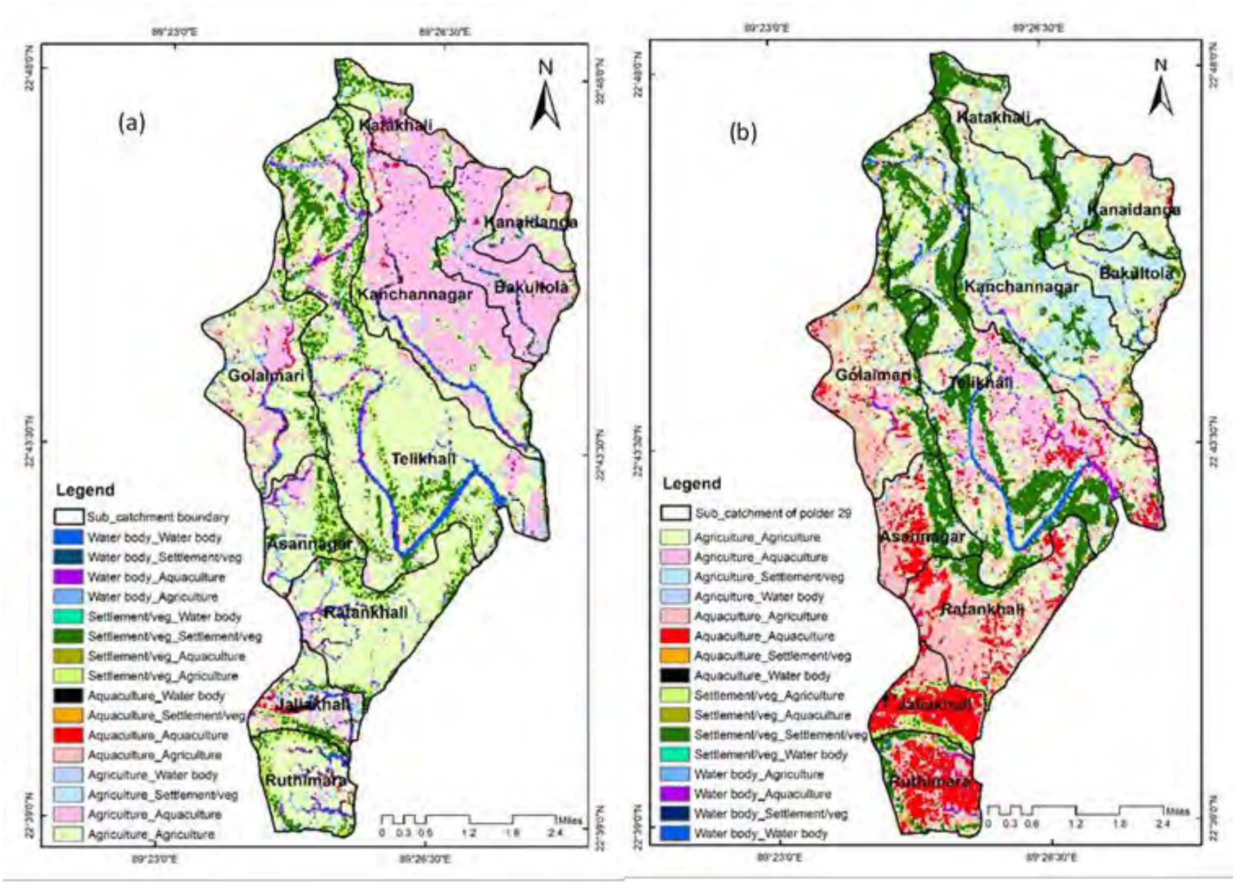

Figure 6.12: LULC detection: Land Use Land Cove change detection of Polder 29 from 1990 to 2019: (a) Wet season; (b) Dry season

6.4.3 Timeline analysis through PRA

Late 90’s to 2000

The term conflict is not an unknown from the beginning of the polder. At the very beginning, there have been contradiction in water management system across the polder due to inconsistency in policy level. This contradiction turned into conflict during the early 90’s when extensive saltwater aquaculture was practiced. People of Polder 29 (source: FGDs and IDIs) mentioned it as ‘saltwater conflicts’ between saltwater shrimp farmer vs people who were directly or indirectly dependent upon agriculture. The reasons of this conflict were: unrestricted free intrusion of saltwater inside the polder, especially in southern and south-western part of the polder, large scale Bagda cultivation by making big enclosure, land grabbing and mono centric saltwater shrimp farming by the people from outside of the polder. As a result, land use pattern of the polder, specifically in the southern part, was highly impacted shown in the Figure 6.9. During 1990-2019, aquaculture has been found as a dominated land use practice in more than two-third areas of Ruhitmara and Jaliakhali in dry season. At the same time significant proportion of Ratankhali (58.13%), Asannagar (51.83%) and Golaimari (40.13%) were also found to be dominated by large scale aquaculture practice. The large scale Bagda farming increased salinity of soil and canal water inside the polder. The people who were directly or indirectly engaged with agriculture faced different types of problems and difficulties, for example reduction in agricultural production, paucity of work as day laborers, decrease in land leasing opportunity for sharecropping for those who used to live their livelihood by leasing agricultural land. Consequently, this became a source of huge conflict among marginal farmers, day laborers and general people of the community.

The ultimate result was the movement in 1995 titled "remove saltwater" from the polder. Basically, this movement existed all over the polder, but it took a sharp turn in Ruhitmara, Jaliakhali, Ratankhali, Asannagar, and Golaimari. Most of these areas were less densely populated and had unoccupied beel areas, which also encouraged large Bagda gher via intentional saltwater intrusion into lands in dry season. FGD and IDI respondent revealed that in 1990, economic profit and political influence were the key factors for this conflict. On the other hand, availability of saltwater was the triggering factor for Bagda culture. Besides, a few years later, environmental factor became a concern due to frequent saltwater intrusion and the resulting salty environment owing to Bagda farming. As a result, reduction of agricultural production and seasonal unemployment became a big concern, creating socio-economic problems inside the polder.

First decade of this century (2000-2010)

From the beginning of first decade in the 21st century, large scale monocentric shrimp farming disappeared due to the movement of 'saltwater removal' mentioned above. But large ghers that were grabbed by the powerful people from outside of the polder started to turn into small ghers owned by elite people and local muscle groups. This started a big increase in land and sluice gate leasing and encroachment of khals/beels and internal drainage canals. Brining in saltwater through inlet-outlets illegally and stealthily by opportunistic people ensued. Although these illegal inlets-outlets were partly stooped by local administrators and authorities (local police, Union and Upazila representatives), yet again conflicts grew between Elite groups and general people, including small, marginal and landless farmers, and day laborers who are dependent upon agriculture.

Besides, this rapidly changing land use pattern caused loss of hydrologic connectivity, which both diversified and intensified conflicts over water resources among the different categories of water users within the highland–lowland systems. Golaimari was the perfect example of highland-lowland conflicts, resulting from dysfunctional sluice gate. On account of ineffective sluice operation, land use practice was disrupted, and even changed from arable land to small-scale ghers. Also, water distribution system was hampered due to highland-lowland discord, leading to user-user conflict, prominently found in Katakhali, Kanchannagar, Telikhali and southern portions of the polder.

Production systems and livelihoods responded to these changes in different ways in different locations. The population engaged in agriculture decreased as critical sources of freshwater and irrigation had been lost to competing land uses. In response, many farmers who had capability, diversified into gher farming. For many, this diversification improved their situations, while the poor's livelihood became more difficult. To overcome these situations, authorities (BWDB, DAE, and others) with the help of international NGOs, initiated water related projects (e.g., IPSWAM) within community level and formed local level institutions (WMOs) (Blue Gold, 2015). But the duality in water management due to the presence of local level informal water management committees (beel committees) was not addressed, which became an issue of conflict, as illustrated by the FGD respondents. From 2000 to 2010, northern parts of the Polder also started to change land use practice. Especially at some portion of Golaimari and upper portion of Telikhali and Katakhali. Because this areas experienced highly canal siltation and non-functionality of sluice gate. Though after IPSWAM project many of the sluice gate had repaired but Golaimari sluice gate was ineffective then that reflect to the image analysis.

The very last decade: Baseline scenario (2010-2019)

Institutional conflicts became a recurrent phenomenon from the beginning of the last decade. Gaps in institutional structures, absence of intra (within same institutions e.g., WMGs, WMAs,) and inter (among different institutions e.g., LGIs, WMOs, Government agencies like BWDB) institutional coordination are the root causes for the institutional conflicts. Although the main purpose of local institutions like WMGs was to ensure proper water management within the sub-catchments, they moved away from their major roles and responsibilities and leaned more towards economic purpose, and got more influenced by political dimensions, as explained by the IDI respondents.

On the other hand, having more than one WMG within the same catchment created problems in sluice gate operation and management and distribution of water distribution, which led to superfluous conflict with high and low land users. Besides, different land use practices are being done within that same sub-catchment, which has accelerated environmental problems and led to user-environment conflict. Moreover, as local elites hold the vital positions of water management organizations, O&M and land use are now dominated by them. This imbalance in power structure is omnipresent everywhere in the polder, drifting some people's interests from sustainable water management and equitable livelihood toward economic gains and power. As understood from one FGD held at Ruhitmara, a person who owned about 400 Bigha (about 248 acres) land is the president of the WMG. Similar scenario is found in some WMGs of Jaliakhali, Telikhali and Kanchannagar catchments. However, there are opposite examples at Golaimari and Bakultala sub-catchments.

Furthermore, many people are currently switching to aquaculture because of the economic benefits or the fact that it is less labor-intensive than agriculture, where workers are paid on a daily basis. Some people appeared to have been forced to switch by the local elites and/or by the unfavorable environment. Tenant farming has also declined as a result of bad tenancy agreements and significant farming risks. People with money can adjust to unexpected changes, but the majority of people in the region are poor, and they have been frequently forced to turn to aquaculture. Because aquaculture is a less labor-intensive industry, many people are left jobless, and they must rely on day jobs or else migrate to adjacent cities or other locations for income. Furthermore, as the literacy rate rises, the changing landscape of LULC and livelihood becomes easier to navigate. People who have earned a university or college diploma are hesitant to work in agriculture. They wish to sell land and start a business.

6.5 Conflicts based on seasonality

Livelihood in Polder 29 can be categorized based on seasonality. The livelihood that is major in the dry season may be a minor livelihood in the wet season. In addition, livelihood practice in the study area varies from catchment to catchment.

In the northern parts of the study area (e.g., Kanchannagar, Bakultala, Kanaidanda, Katakhali), similar livelihoods are seen for both dry and wet seasons (Table 6.5). Here, major and minor livelihoods are very diverse. While shrimp farming (Golda and Bagda) is the major livelihood in wet season, paddy cultivation (Boro variety) is the major livelihood in dry season. According to the people of these areas (source: FGDs and KIIs), rich and wealthy farmers are generally associated with shrimp farming (gher oriented), and they are not interested in paddy cultivation. On the other hand, marginal farmers are mostly dependent on paddy cultivations. One of the FGD respondents revealed:

> *"Poor farmers want to cultivate paddy so that they can sustain the whole year by themselves. On the other hand, the rich people are profit oriented and want to get a lot money within a short time."*

In the middle part of the study area (Golaimari, Asannagar and Ratankhali), major livelihood during both season is paddy. Though shrimp farming in these areas is the minor livelihood, some people are trying to establish shrimp farming (gher oriented) as a dominated livelihood, which seems to be a potential source of imminent conflicts among the water use actors and livelihood groups.

The southern parts (Jaliakhali and Ruhitmara) are basically dominated by large scale gher farmers. Most of the people here, however, are opposed to this practice. But this majority people are in the minority group. A KII respondent in Ruhitmara pointed out:

> *"In Ruhitmara, two-thirds of the land are seized/owned by few people, where they try to exploit the whole water system according to their interests."*

The farmers are facing several problems which are dominating their livelihoods practices. These problems are becoming severe day by day. The overall condition of farmers is not so good as they face improper guidelines of agricultural activities, water scarcity, lack of skilled manpower etc. Until the problems become very severe, they try to continue the farming activity.

In the study area, there is a severe scarcity of irrigation water during the dry season. The farmers do not get sufficient amount of water when it is needed for crop cultivation. Besides, there exists a lack of sufficient number of tube wells as well. Moreover, most of the internal canals, water bodies, and ditches are dried up in summer days. Again, availability of cultivable land is becoming acute day by day in the study area. Since most of the farmers of the area are poor, they do not have own land for farming. They need to provide a major portion of their crops to the landowner in yearly or seasonal basis. However, there are some farmers who own lands and do not practice farming directly. Only these groups are the benefitted. It is found that constraints increased with increasing intensity of salinity. Soil salinity is the most deteriorating factor in the region, especially during the dry season. It affects certain crops at different levels of soil salinity and critical stages of growth, which reduce yield and in severe cases total yield is lost. Saline water also creates severe problems in farming activities.

There are few reasons why poor/marginal people choose agricultural activity, as listed below:

- Expected productivity to meet their personal need of foods
- Income generation via less investment of capital
- No requirement of having own lands
- Personal skill or knowledge in farming
- No requirements of experience
- Opportunity to stay with family and work together with family members
- A chance to perform other's work
- Traditional value of farming

Table 6.5: Major livelihood, conflict and associated drivers in Polder 29

Catchment	**Dry season** (November-May)		**Wet season** (June-October)		Major Conflict
	Major L.	**Minor L.**	**Major L.**	**Minor L.**	
1. Ruhitmara	Bagda Shrimp	Vegetable and agriculture (Boro)	Agriculture (Aman)	Bagda Shrimp	Agri Vs Shrimp (Aman+Boro Vs Bagda+Aman)
2. Jaliakhali	Bagda Shrimp	Boro	Bagda-Golda Shrimp	Agriculture (Aman)	u/s Vs d/s (loss of hydrologic connectivity due to gher and encroachment)
3. Ratankhali	Bagda Shrimp	Bagda Shrimp (u/s)	Agriculture (Aman)	Bagda Shrimp (periphery)	u/s Vs d/s (loss of hydrologic connectivity due to gher and encroachment) Water use conflict (Boro Vs Bagda Shrimp)
4. Asannagar	Vegetable and agriculture (Boro)	Bagda Shrimp	Agriculture (Aman)	Bagda-Golda Shrimp (u/s)	Water use conflict (Boro Vs Bagda Shrimp)
5. Golaimari	Vegetable and agriculture (Boro)	Bagda Shrimp	Agriculture (Aman)	Bagda-Golda Shrimp (u/s)	u/s Vs d/s (loss of hydrologic connectivity due to sedimentation, gher and encroachment) Water use conflict (Boro Vs Bagda Shrimp)
6. Telikhali	-(d/s) Bagda Shrimp -(u/s) Vegetable and Boro	Vegetable	Agriculture (Aman)	Bagda-Golda Shrimp	u/s Vs d/s (loss of hydrologic connectivity due to topology, sedimentation, gher and encroachment)
7. Kanchannagar	Agriculture (Boro) and Vegetable	Bagda Shrimp (periphery)	Golda-Bagda Shrimp	Agriculture (Aman)	u/s Vs d/s (loss of hydrologic connectivity due to topology, sedimentation, gher and encroachment)
8. Bakultala	Agriculture (Boro) and Vegetable	Bagda Shrimp (periphery)	Golda-Bagda Shrimp	Agriculture (Aman)	u/s Vs d/s (loss of hydrologic connectivity due to topology, sedimentation, gher and encroachment)
9. Kanaidanda	Agriculture (Boro) and Vegetable	Bagda Shrimp (periphery)	Golda-Bagda Shrimp	Agriculture (Aman)	No major livelihood conflict but several minor conflict includes u/s Vs d/s and user Vs environment
10. Katakhali	Agriculture (Boro) and Vegetable	Bagda Shrimp (periphery)	Golda-Bagda Shrimp	Agriculture (Aman)	No major livelihood conflict but several minor conflict includes u/s Vs d/s and user Vs environment

6.6 Implications of water conflicts for water security

A summary of the implications of water conflicts for water security for different livelihood activities in the study area is presented in this section. The different types of water conflicts in Polder-29 with spatial and temporal variation have had considerable impacts on water security for agriculture, fisheries, and environment. Livelihoods are closely intertwined with land use practices in both wet and dry seasons.

All over the polder area, currently the coverage under agricultural crop is 42.3% (wet seasonal paddy named Aman) in the wet season and 38.3% (dry seasonal paddy named, Boro) in dry season. In terms of aquaculture, the area coverage is 23.9% in the wet season and 14.7% in the dry season. However, this picture was different some 20 years ago, as there has been substantial transformation of land use patterns in the polder. Agricultural practice has been decreased by 14.23 sq. km in wet season, while it increased by 8.21 sq. km during dry period. In contrast, aquaculture experienced an increase in wet season by 22.06 sq. km and decrease in dry season by 14.71 sq. km. Water bodies were found to have continuously decreased in both wet and dry seasons in the last 20 years. The northern parts and some portions of middle part are gher (sweet water shrimp) dominated, whereas the southern part and some portions of the middle part are agricultural crop (wet season paddy, i.e., Aman) dominated in the wet season. In one sub-catchment in the south (Jaliakhali sub-catchment), however, land use in wet season represents a mix of brackish aquaculture and Aman, although Aman cultivation suffers from water insecurity problems in areas adjacent to the brackish shrimp ghers via saltwater seepage from the brackish shrimp ghers.

Rapid increase in small-scale freshwater shrimp ghers in the northern parts has been a cause for concern for water security for the (small to medium farmers) Aman rice farmers. This was not a major issue about two decades ago as most of the lands in this part was cultivated with Aman rice. However, the land use saw an increase of freshwater shrimp ghers from 2-3% to 50-77% in fur sub-catchments in the north from 1991 to 2019, with a subsequent decline in paddy coverage. This conversion was done mainly by the rich farmers and the local powerful groups. Extensive ghers have been hampering supplementary irrigation from canal water as the gher owners have grabbed and blocked the canals. This has also disrupted hydrological connectivity resulting in siltation in drainage canals, water congestion, loss of khals, and loss of fish species. The loss of hydrological connectivity has also reinforced the u/s vs d/s conflict that were already there to some extent owing to topographical difference within the sub-catchments.

Large scale brackish shrimp farming by external settlers was the most significant threat to water security for agricultural farmers in the southern part of the polder in the 1990's during dry season (70.2% and 74.3% area coverage in two sub-catchments). Many of the agricultural land and khas land/khal were sold and leased, and subsequently subdivided into plots for saltwater shrimp farming. This had a great impact in salinizing the soils, with long term degradation of soils. Although the percentage decreased (46.8% and 63.8% in the two sub-catchments in 2019) after the exodus of large-scale brackish shrimp farming following anti-brackish shrimp movement in the southwest coastal area, these conflicts are still prevalent, mostly in the form of relatively small-sized brackish shrimp ghers.

Marginal and landless people, who are the sharecroppers in the dry season, are the most affected by brackish shrimp farming as the agricultural land is affected by the surrounding brackish ghers, aggravated by the gher owners bringing saltwater inside the polder illegally from the peripheral river. Agricultural farmers have been demotivated by a downward trend in paddy market prices coupled with higher production costs, frequent disasters, and the need for large amount of freshwater in comparison with gher business. But marginal communities do not have sufficient money required for gher business. Moreover, leaking of saltwater from adjacent saltwater ghers damage crops and hamper production, prompting many of them to sell their land to the gher owners and try to shift their livelihood.

Chapter Seven: Drivers of Water conflicts

7.1 Introduction

Water related conflicts in Polder 29 occur due socio-economic and environmental reasons, decision making and power practice, unethical political and power practice and water governance system. Socio economic drivers includes changing water demand, social inequality, water sensitive livelihood etc. Environmental drivers include extensive siltation, illegal encroachments, salinity or natural events. Political and governance drivers includes unequitable power practice, governance issue of water control structures, and week coordination among institutions. Even these drivers are changing the nature of conflict from one dimension to another.

7.2 Identification of drivers

In most FGDs and KIIs, the respondents pointed out that the poorer group (farmers, day laborers) are the prime actors and stakeholders in the local level water management process. But local elite and muscle men including political person, rich farmers and fishermen are found as the key personnel behind local conflicts. On average, farmers group, fisheries group, local elite members are directly or indirectly associated with different conflicting activities. The most significant reasons behind water conflict are lack of economic opportunities (i.e., limited scope to work), unemployment, poverty and social inequity. Besides, there were some backgrounds that worked as catalyst to create conflicting issue in the polder area. For example, large-scale shrimp farming and drastic decline of freshwater in the southern part of Polder 29 creates a conflicting situation between farmers and fisheries. Poor and salinity affected communities are not properly compensated by the large-scale brackish water shrimp farming, causing the increase of poverty among the small farmers and agriculture based lay laborers.

Water conflicts in the study area are driven by socio-economic, environmental, technical and institutional factors (Figure 7.1). Besides, politics and illegal power practice are significant driver of water conflicts in the study area. It was revealed that water management and maintenance of water structures changed in alignment with the change of political parties and local government representatives. In most of the cases, technical and institutional drivers are influenced by these political factors.

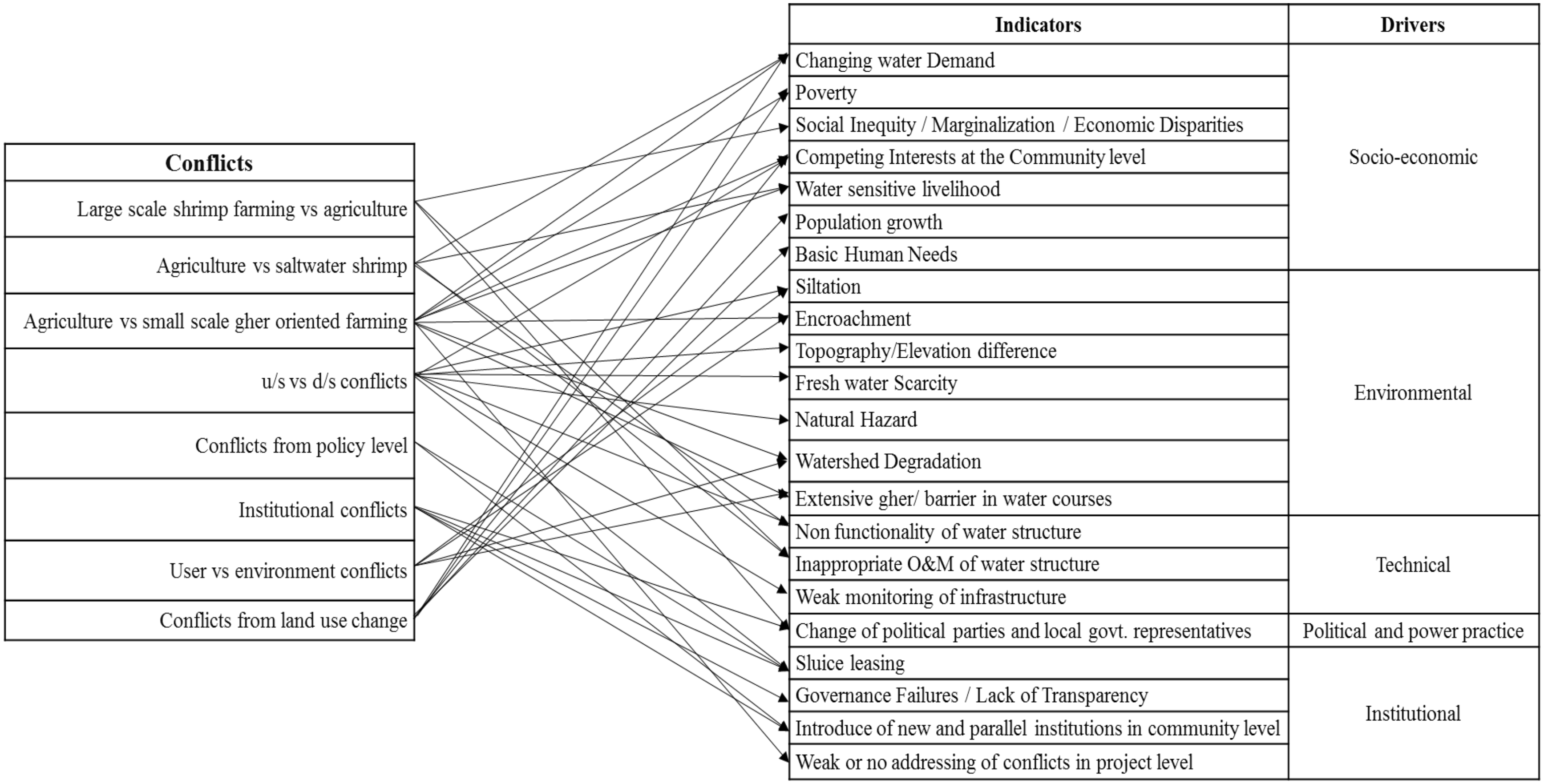

Figure 7.1: The particular drivers behind conflicts

Socio-economic drivers:

Local inequity, marginalization, economic disparities, water sensitive livelihood and population growth can be considered as socio-economic drivers. Competing interests at community level, such as unequal access and distribution of water occurs between u/s and d/s farmers and between agriculture and brackish fishermen create conflict between the sectors. Therefore, those who are "in" (water management decision makers including local elites, muscle men) and those who are "out" (who are excluded but use water, e.g., farmers) cannot get the equal benefit and hence conflicts arise.

Environmental drivers:

There are a lot of environmental drivers that create water conflicts in the study area such as siltation, topography/elevation difference, increased hazard impact, watershed degradation etc. These problems may lead to illegal encroachment into the internal canal/khal/river and extensive gher/barrier in water courses for shrimp farming. Apart from encroachments, ghers made the catchments hydrologically disconnected and disruption of watershed can create drainage congestion which has significant impact on agricultural production and affect the economic condition of agricultural dependent households.

Technical issues:

Due to malfunctioning of water control structures, saline water intrusion, particularly in the peripheral area creates conflict between saltwater and freshwater farmers and fishermen. Besides, the barriers in water flow can create water logging and fluvial flooding inside the polder that create conflict in between the muscle men and the local farmers. Lack of adequate expertise and experienced manpower to carry out the O&M of water infrastructure in the polder along with weak monitoring of infrastructures due to the limited numbers of field staffs in respect to the actual requirement create major water issues.

Political and power practice:

Local powerful persons, including the political leaders illegally interfere on the water control/ management infrastructure and operate to fulfill their own needs. Additionally, illegal grabbing and interference become more acute with change of political parties and local government representatives.

Institutional issues:

Water conflicts are also caused by the way water and its uses are governed. Fragmented institutional structures, and the resulting lack of coordination, are major contributors to water-related conflict. In Polder 29, institutional conflicts arise from sluice leasing, governance failure or lack of transparency. Likewise, existence of new and/or parallel institutions in community level along with LGIs and improper addressing of probable conflicts in the project level are also important reasons for conflict.

7.3 Changing nature of conflicts with associated drivers

Conflicts emerge from the influence of different drivers (social, economic, political, environmental, and institutional). On the other hand, these drivers are dynamic and change over time. Thus, conflicts are inherently dynamic phenomena, and the nature of conflicts is also changing with the changes of drives and associated factors (Figure 7.2).

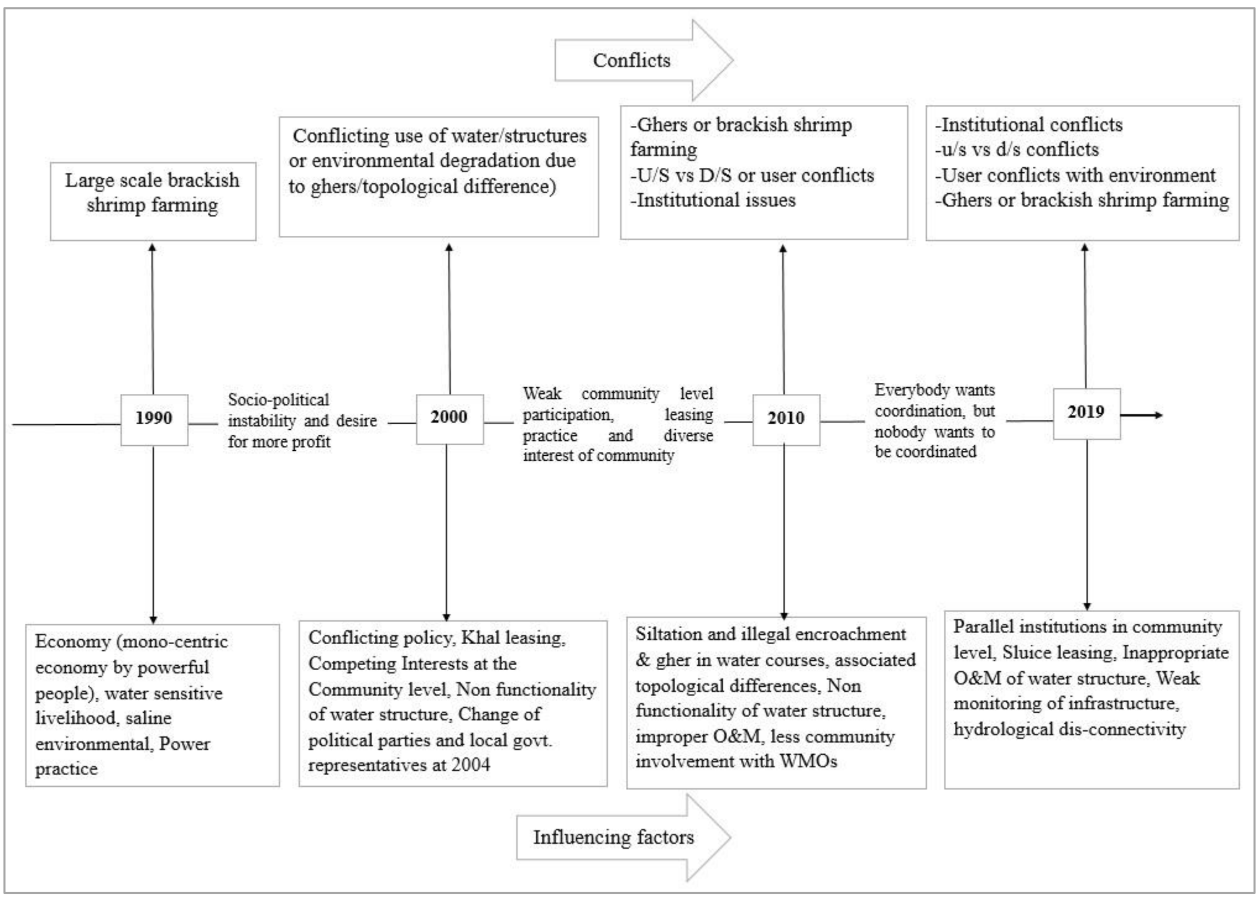

Figure 7.2: Changing issues of conflicts issues with influencing drivers.

In the study area, before 1990, some large and rapid change occurred due to socio political instability (described in section 6.4.3). Since then, socio-economic and political drivers became influential to create water conflict, for example, economic disparities for monocentric large scale aquaculture vs water sensitive livelihood. From 1990 to 2000, conflicting policy with extensive khal/sluice gate leasing and change of political parties increased competitive and competing interest on public water resources. During that time, socio-economic, political and power practice were the dominated drivers. However, in the year of 2004, water management groups and associations were built under IPSWAM project for local level water management. Besides, technical issues became major issue because a lot of questions arose regarding functionality, O&M and monitoring of water infrastructures. Most importantly, the introduction of new water institutions in parallel to LGIs creates institutional conflicts between WMOs and LGIs on the local administration of water structures. That led to the non-functionality of water structures and increased illegal encroachment within the water courses. Therefore, in 2013, Blue Gold project followed the IPSWAM and started to strengthen local level water management institutions that introduced socio-economic development along with water management. However, water management was overlooked in varying degrees at certain places in comparison to the focus the socio-economic development received.

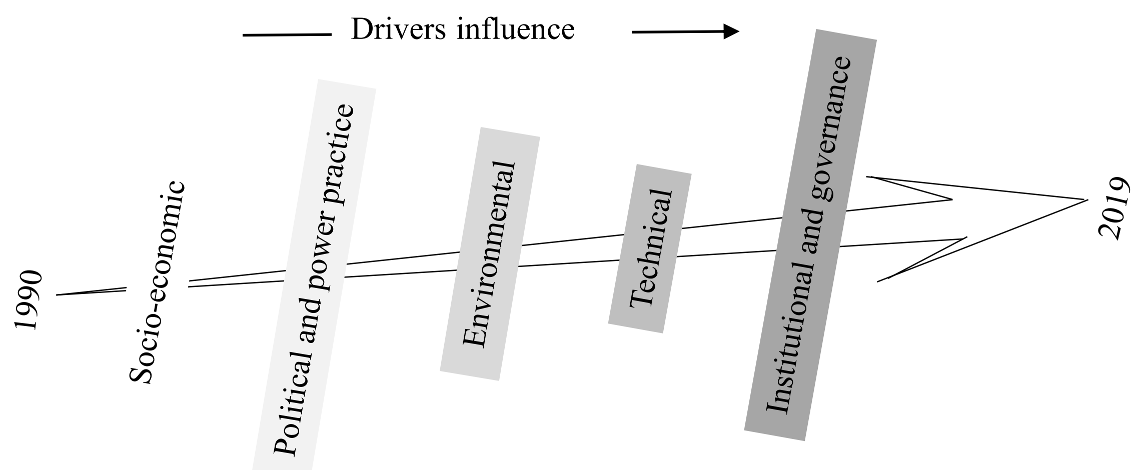

Figure 7.3: Changing influence of drivers over time

In the gap period between two projects, the local level water organizations became inactive. Similarly, present scenario of the study area shows that, institutional and governance issues are now more dominant to create institutional conflicts, u/s vs d/s conflicts, user vs environment conflicts. Figure 7.3 illustrates the scenario of changing drivers' magnitude from 1990 to present.

Chapter Eight: Mitigation of water conflicts

8.1 Introduction

Mitigating water related conflicts is not a straightforward task because of the presence of diverse interest groups, complexity of the processes and drivers behind the conflicting situations, and the way they evolve with time in response to different exogenous and endogenous factors. These are well illustrated in Chapters 5, 6 and 7. Upon understanding the systems and different actors and stakeholders, it is important to map different roles and responsibilities different actors play around local water management systems and the extent of their interests and the capacity to influence processes to mitigate conflicts. This chapter delves into the local governance structure and the opportunities via participatory stakeholder analysis and mapping based on KIIs and FGDs. This involved, in the process, discussions with WMG members, LGI representatives, sluice gate operators, farmers, fishermen, and Blue Gold officials. This also allowed identification of suitable participation of stakeholders and different types of programs that will help to reduce conflicts with their best capacity.

8.2 Role of WMGs in ensuring water security and conflict mitigation

Membership in WMOs is voluntary. Blue Gold wiki report revealed that as of end of 2020, two-thirds (67%) of households were members of at least one type of community institution in the 22 Blue Gold polders surveyed (www.bluegoldwiki.com). However, membership of WMGs was just over half (54%) of sampled households (an increase from 21% in 2017), followed by membership in NGO groups (32%) (largely concerned with micro-finance services and other economic and social development schemes), and farmer groups (17%) (often set up by DAE as a channel for agricultural extension services).

The situation in Polder 29, as of end of 2019 was mixed. Water management organization (WMG) is one of the vital local level stakeholders in the study area. The household survey, conducted in 2018 with a wide scope under the REACH project of IWFM, showed that 75% of households in Polder 29 did not have the WMG membership or any close interaction with WMGs (Figure 8.1). Only 14% male and 8% female held the membership.

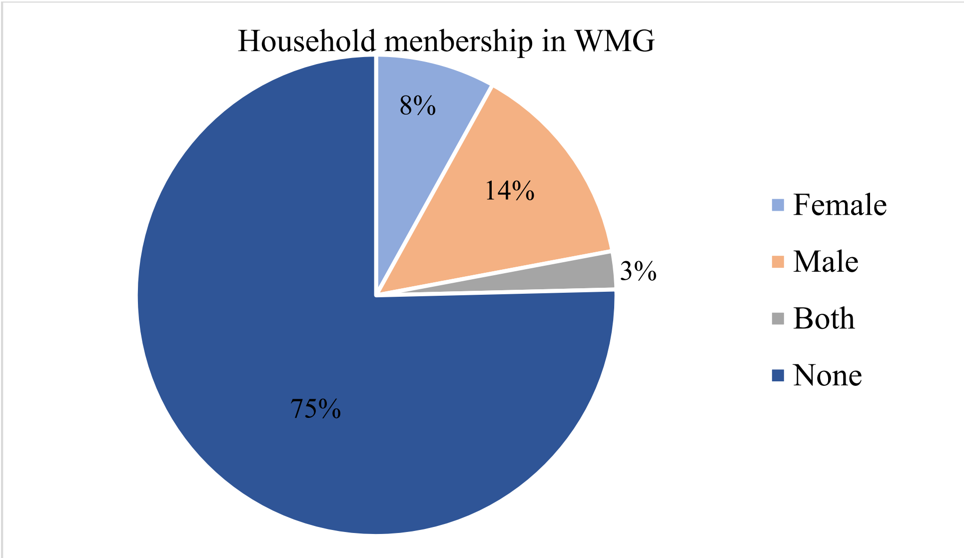

Figure 8.1: Percentage of WMG membership (Source: REACH household survey)

However, mere membership does not guarantee equal opportunity for raising issues or concerns. People become confused while facing problems regarding water management related issues e.g., improper operation of sluice gate, and internal khal grabbing and leasing. More than half of the WMG members revealed that they have no opportunity to raise their voice in the decision-making process while 31.6% acknowledged having opportunities to influence on WMG's decision making process in different water management activities, albeit to a small extent (Figure 8.2). Only 15.4% people admitted that they have a lot of involvement with WMGs. On the contrary, four-fifths of the WMG members (81.2%) opined ineffectiveness of WMGs over water management process in the study area. Inter and intra WMG conflict within catchments have become a major concern and big impediment to ensure local level water security (source: FGDs and KIIs).

FGD respondents near Telikhali sluice gate pointed out:

> *"Most of the WMG members, especially in the leading positions in Telikhaali WMG, belong to the same family and they receive most of the water management training provided by government/NGOs. Even greater number of households in the locality do not know about the existence of WMG committee."*

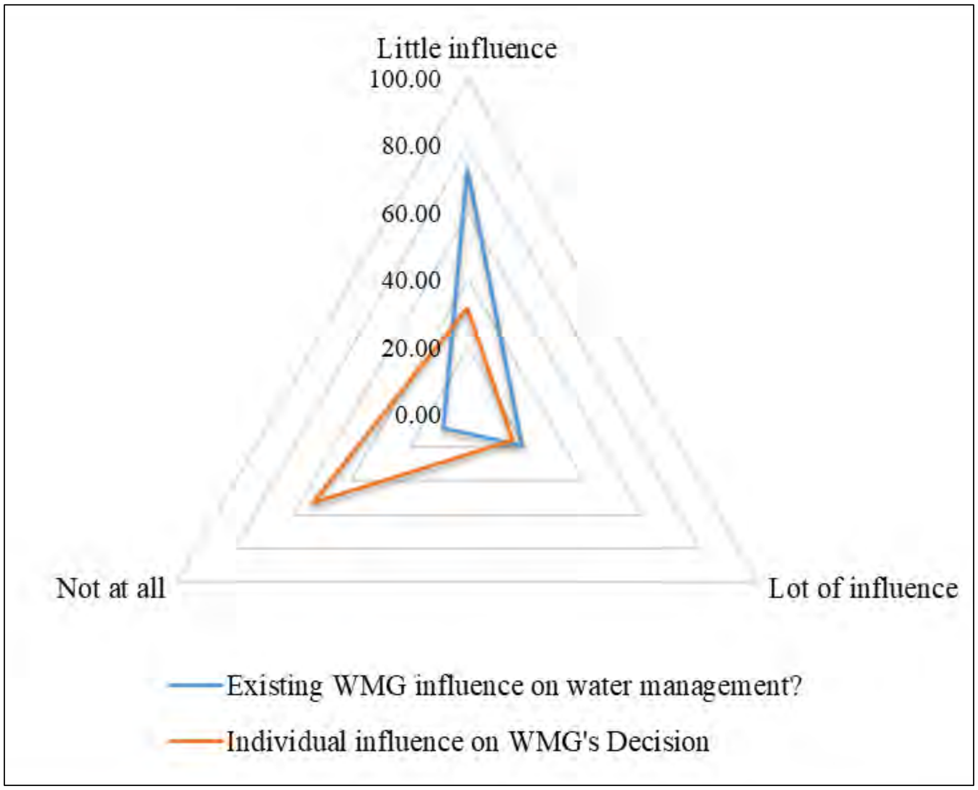

Figure 8.2: Individual role and WMG influence on water management (in percentage)

8.3 Stakeholder diagramming

In the context of this study, stakeholders are those who are involved with and/or are affected by the water management system of Polder 29. The primary stakeholders are people who would be directly benefited or impacted by the water or water structures of the polder. In case of Polder 29, they include farmers, fishers, local business communities, local leaders, representatives of local level groups (for example, WMGs, WMAs, O&M committees), women groups and operators of community properties, e.g., the sluice gate operators. The secondary stakeholders refer to those who may not be directly affected but have interests and may play a role in implementation at some stage or affect decision making on different aspects. From this perspective, NGOs, concerned government departments, Blue Gold program officials, and different agencies fall under this category.

8.3.1 Stakeholder analysis

Stakeholder diagramming has been done, as shown in Figure 8.1, from the field investigation (i.e., from FGDs and KIIs) following the approach suggested by European Commission (EC, 2000; ARB Toolkit, 2002). The process is elaborated in Section 4.2. To re-iterate, the key stakeholders were identified in four groups under three tiers, according to their primary role in influencing local water conflicts and their alleviation. The explanations of the groups and tiers are given below:

<u>Groups</u>

- Decision makers: who take decisions
- Users: who use the result of decision or are affected by it
- Implementers: who implement the decision/ policy
- Experts: who offer information, expertise, or means

<u>Tiers</u>

- Co-operating stakeholders: They are the most closely involved in the issue, through active participation in the process and interaction with the other stakeholders (i.e., active involvement).
- Co-thinking stakeholders: They take part in passive consultation with other stakeholders but do not interact actively with others (i.e., consultation).
- Co-knowing stakeholders: They are only aware of the issue and do not actively participate in the interactions but may be informed of the process and progress.

Field investigation revealed that BWDB and its water security related project Blue Gold, LGIs, Fishermen and Farmers are the only primary actors. LGIs can be categorized as cooperating-decision makers because of their influence on local water management system, as they are the principal sources of elite capture (Figure 8.3). Moreover, there exists an informal body named 'beel committee', which is formed by the presence of elite and influential LGI members, thus directly influencing maintenance of water structures and water allocation decisions. On the other hand, formal registered local level institutions, WMGs and WMAs, with little influence over decision making process, are categorized as co-thinking and co-knowing actors, respectively. Furthermore, only BWDB acts as implementing authority and Blue Gold project as expert leading from the first tier. Officers from different ministries, for example Agricultural Officers (AOs) and

Fisheries Officers (FOs), are in the second tier of expertise, and NGOs, Media, and universities are regarded as co-knowing experts.

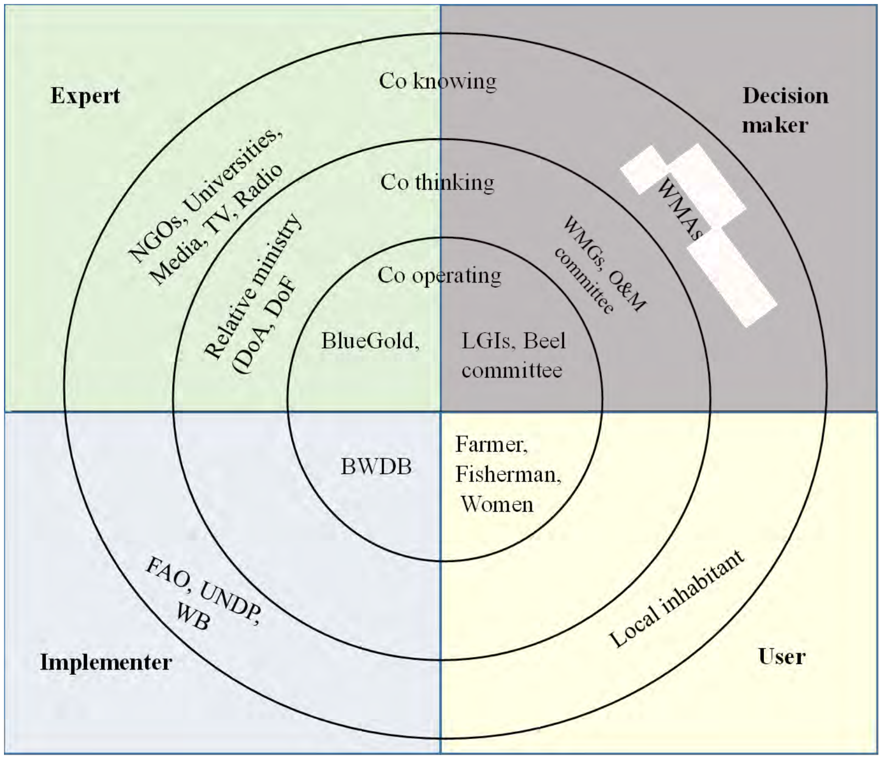

Figure 8.3: Stakeholders stage diagram

8.3.2 Stakeholder's influence within community

A considerable number of institutions within and outside the study area have direct and indirect influences over the water community. To identify interactive linkages between water management community and institutions, a Venn Diagram (Figure 8.4) has been produced with the help of local stakeholders through FGDs. The radius of the circle demonstrates community influence of a particular institution, whereas the increasing width of the lines reveals level of interaction between community and the particular stakeholder. On the other hand, very low interaction and influence are illustrated by the dotted lines or dotted circles.

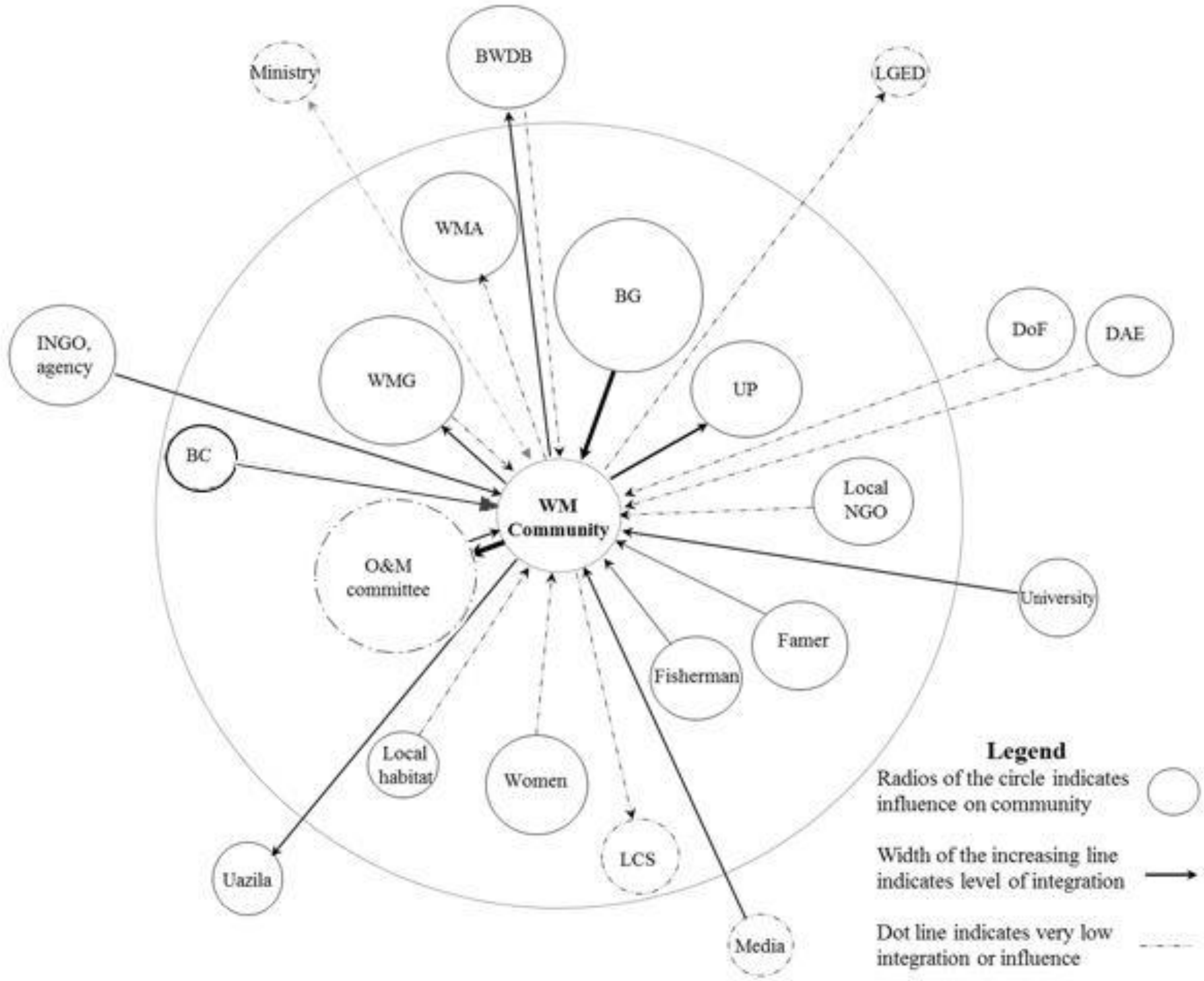

Figure 8.4: Stakeholders Ven Diagram of the study area

It is evident from Figure 8.4 that some institutions have influence and try to coordinate with the water management system from outside the area, considered as external players, as they are regional, national, or international actors. There are few active community-based organizations (CBOs), namely the O&M committee, water management organizations (WMGs) and water management associations (WMAs). Among these the activity of O&M committee is notable regarding water management inside the polder though it is considered as an informal institution having no registration like WMG or WMA does. The O&M committee has a both-way interaction but has less influence on the community than WMG or WMA. On the other hand, beel committee, also an informal body formed earlier, has a strong one-way influence over the water management system. Similarly, local livelihood groups and stakeholders, for instance women, farmers, fishermen, and labor contracting society (LCS) have one way interaction with less community influence over water management. The Blue Gold (BG) project led by the BWDB is considered as the internal institution having strong influence with a one-way interaction, while Union Parishad (UP) under Local government institution (LGI) and local NGOs show a reverse scenario with medium or low interaction. In the case of external institutions, only BWDB has relatively more and two-way interaction, whereas DAE, DoF, universities and other agencies have low and one-way integration.

8.3.3 Opportunities for mitigating conflicts

According to the key informant interviews with Blue Gold officials, both way interaction between water management community and associated institutions who are directly involved with the water management process is essential to establish sustainable water management community and to avoid local level water conflicts. One of the vital WMA members (President, WMA) in Polder 29 said that committee members of Bakultala WMG try to arrange monthly meetings with local people, farmers, and women to share their activities, progress and/or other water related issues (e.g., sluice gate operation). They also arrange six monthly meetings in a year where they invite UP chairman, BWDB, Blue Gold, DoA and DoF officials to interact with them. He also argued that this type of initiatives is rarely found in other WMGs of Polder 29.

The stakeholder diagramming exercise (Figure 8.3) and the synthesis of findings of the field research provide indication how a change in the stakeholder's roles and responsibilities via moving across 'groups' and/or 'tier' can address water issues cum conflicts and ensure sustainable water secured community. It can be argued that implementing and decision-making process is more vital where active and responsible stakeholders should be considered properly.

In decision making process, WMOs should be given priority as a co-operating body, as both decision-makers and implementers, while LGIs may support as co-thinking stakeholders. LGIs should play a vital role both in decision making and implementing process from the second tier but will need to do so involving local people and local organizations to prevent rise of any conflicts. They will play supporting roles in decision making on water related issues, working with WMOs and local people, and try to avoid or limit conflicting issues.

BWDB should continue playing their role as implementer from the first tier (i.e., co-operating), helping with major repairs and required components such as excavation of new and re-excavation of old khals and drainage canals, introducing new inlets or outlets, if required, etc. On the other hand, local and international NGOs should work with local people and WMOs in the expert domain moving from co-knowing tier to co-thinking tier, i.e., having stronger interactions with them (Table 8.1).

Table 8.1: Stakeholder's possible role and stage to address water conflicts and ensure water security.

Involvement / Approach	User	Expert	Decision maker	Implementer
Co operating	Farmer, Fisherman, Women	Blue Gold,	WMOs	BWDB, WMOs
Co thinking		NGOs, INGOs, Concerned departments (DoA, DoF, DoC), Universities	LGIs	LGIs, LGED
Co knowing	Local inhabitant	Media, TV, Radio	MoLGRDC (DPHE)	International agencies like FAO, UNDP, WB

8.4 Local level stakeholder power mapping and the degree of importance

The stakeholders in the study area can be classified into six groups based on their current status in water related activities. There are opposition (active and passive), supporter (active and passive), fence-sitters or neutral groups based on their livelihood and water management activities (Figure 8.5). Large gher owners, local elites, social and political leaders, and khal leasers are under the active opposition group. On the other hand, influential members of WMG are found to play passive opposition roles. Marginal farmers and fishermen, laborer community and low land communities are active supporters who want to establish an agriculture-based society, whereas medium agriculture farmers are passive supporters (source: FGDs and KIIs). Though they are the most important and vital water users of the study area, they are the prime victims and are suffering a lot due to water issues and conflicts.

LGIs and WMOs in Polder 29 are found almost neutral since their little initiatives are very insignificant in mitigating the substantial water related conflicts that are present in the study area. On the other hand, BWDB and Blue Gold are the fence sitters as they are not committed to get involved in mitigating any local level conflicting issues.

Stakeholders	**Present status**	**Involvement in water activities**	**Remarks**
Large gher owner		High	Dominative
Marginal farmers and fishermen		High	Most victim group, want agriculture dominated livelihood
Laborer community		High	Victim group, and allies with the labor flow society
LGIs		Medium	Mediator in-between
Large/medium farmer		Medium	Most victim group but want agriculture dominated livelihood
Elite and political leaders		Medium	Might be mediator in-between
Low land community		Medium	Victim group
Khal leaser		Medium	Power dominative and economically tempted
BWDB		Medium	Mediator in-between
Other dwellers		Low	Agriculture supportive audience
WMA, O&M committee		Low	Water manager and might be mediator in-between
Influential members of WMG		Low	Mostly involved in situation-control
Blue Gold		Low	Expertise and water manager

Legend	Active Opposition	Active Support	Passive Opposition	Passive Support	Fence-sitters	Neutral

Figure 8.5: Stakeholders present status and their involvement in water activities

Figure 8.6 presents importance and influence of different stakeholders. The marginal and landless farmers and fishermen are the main victims though their importance in water management activities is high. Besides, elite persons and political leaders, and informal beel committee are the most opportunists and have influence on the community but they have less importance than the others in the perspective of water activities. These groups exert power and dominate operation and maintenance in water management. In this regard, LGIs, formal WMOs like WMGs, O&M committee of the study area and BWDB are the most important bodies to mitigate conflicts.

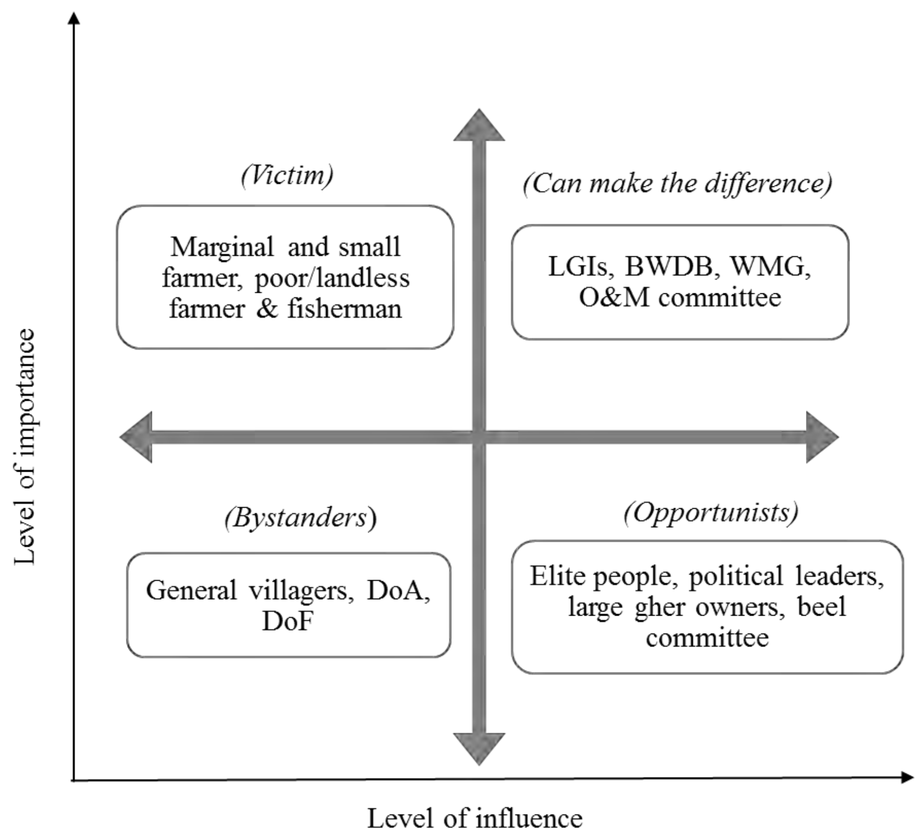

Figure 8.6: Importance vs influence matrix of water stakeholders in Polder 29

8.5 Bridging the gaps in institutional system

Figure 8.7 presents the level of contributions from different institutions that are needed to bridge the gaps and mitigate the local level conflicting issues in water management. Field research in the current study revealed that all water management infrastructures (sluice, embankment, and canal) should be well-functioning and controlled and operated by WMGs and WMAs for good water resources management with reduced conflicts. This was also acknowledged in earlier Blue Gold project survey (Blue Gold, 2019), which observed that having functional sluices and sluices controlled by WMGs, not by other influential people, is linked to reduced water management problems. As of 2019, WMGs had control of 31% sluice gates in Khulna and 39% in Satkhira, while the control of 53% and 33% of sluices was with external people in Khulna and Satkhira, respectively (Blue Gold, 2019).

BWDB is the prime entity to ensure the functionality of the water infrastructure. While the routine and periodic maintenance activities can be done through O&M committee, but the major maintenance need will require BWDB's direct involvement. According to Bangladesh Water Act (2013), the major responsibilities of BWDB include construction and O&M of water control structures like embankment, polder, and water control structures (regulators and sluices), along with dredging and re-excavation of river/canal, land reclamation and river training. BWDB (with Blue Gold) have been the dominant implementer of embankment (70%) and khal excavation (73%) as well as 37% of sluice works with the help of WMGs and another 40% of sluice works without the help of WMGs (Blue Gold, 2021; 2019). It is clear that the role of BWDB is essential, yet it is faced with constraints in procedures and staffing, according to the Key Informants of BWDB. Similar observation was made in the Blue Gold mid-term review report (Memoire, 2015).

The O&M committee needs to be more operationally considered as the base unit of water management instead of WMG, although this committee is not a formal body, rather works as a sub-committee under WMA, comprising of representatives of several WMGs in a single sub-catchment, given the role of operating sluice gates and water allocation through canals between agriculture and fisheries. The WMAs need to continually coordinate with the O&M committee for effective management of catchment. Also, they need to be supported with funds without interruption as they do not have their own funds (dependent on WMGs for funds) to utilize in O&M activities.

LGI representatives are identified as advisor to the WMOs. On the one hand, the definition does not give any further clarification of what being advisor entails. On the other hand, this also gives flexibility for the WMOs (WMGs and WMAs) and LGI to develop a mutually beneficial relationship based on own insights. LGIs have ample opportunities to contribute to efficient water resources management within the polders, and instead of some unwanted roles of some of the LGI members in getting involved in unlawful control of water structures with local elites, they can play a big role in minimizing water related conflicts.

LGIs can help in WMGs' getting control over all sluices. The field investigation in this study revealed considerable issues with khal or canal encroachment and the barriers to cleaning or re-excavation of them in Polder 29. Even if in the cases the sluice gate is under WMG's control, the internal khals are encroached by the powerful groups, including the 'gher' owners, thus causing considerable negative impact on drainage of run-off during monsoon. It was clear from the KIIs and FGDs that LGIs, being the legal authority, can help the WMGs in getting the cleaning or Khal re-excavation activities done. WMG members opined that their voices become stronger with UP support.

Similar observations were also made in evaluation by Blue Gold project itself earlier (Blue Gold, 2021; 2019). In their 22 surveyed polders, WMGs have been responsible for Khal cleaning (about 61%) and sluice operation (66%) in the surveyed coastal polders. Where WMGs are good at articulating the aspirations of communities with respect to water management, the UPs were able to help resolve conflicts in the case of obstructed drainage flows and provide authority to WMG action such as canal cleaning. As the khals are leased out by the Upazila administration, there may be better coordination between them and the WMGs to stop problematic lease and help the WMGs clean the khals (www.bluegoldwiki.com).

Besides, partnership of WMGs and WMAs with Local Government Institutions (LGIs) at Upazila and Union Parishad levels should be strengthened or established (in case of absence of partnership), specifically in the formulation of Village Action Plans and Polder Development Plan (e.g., in the budget/planning processes). Coordination can be further strengthened to enable WMGs to take active participation in disaster risk reduction and sustainable environment management. When the embankment erosion frequently threatened at Jaliakhali and Ruhitmara sub-catchments, the UP Chairman has been instrumental in mobilizing resources and local action, and together with WMGs the UP jointly prevented the breaching of the embankment. There have been several examples of successful emergency protection of embankment through joint initiatives at local level in some other polders (www.bluegoldwiki.com). The collaboration between Unions and WMGs in the Union Disaster Management Committees has been a clear example of investing in a constructive relationship during good times, so that cooperation is easier during crises. This was also echoed in earlier Blue Gold assessment (Blue Gold, 2014a). Besides, LGIs can also help mobilize resources for investment in small-scale infrastructure.

One of the KII respondents mentioned that,

> *"Because the role and responsibilities of both LGIs and WMOs are not specific. But specific advisory and monitoring role of LGIs will make a difference in better water management and mitigating water issues."*

The roles and responsibilities of and coordination among BWDB, LGIs and WMGs/WMAs, in the light of above discussions, are not adequately made clear in the guidelines for participatory water management. These discussions may be synthesized and possibly brought into the guidelines as a part of modification.

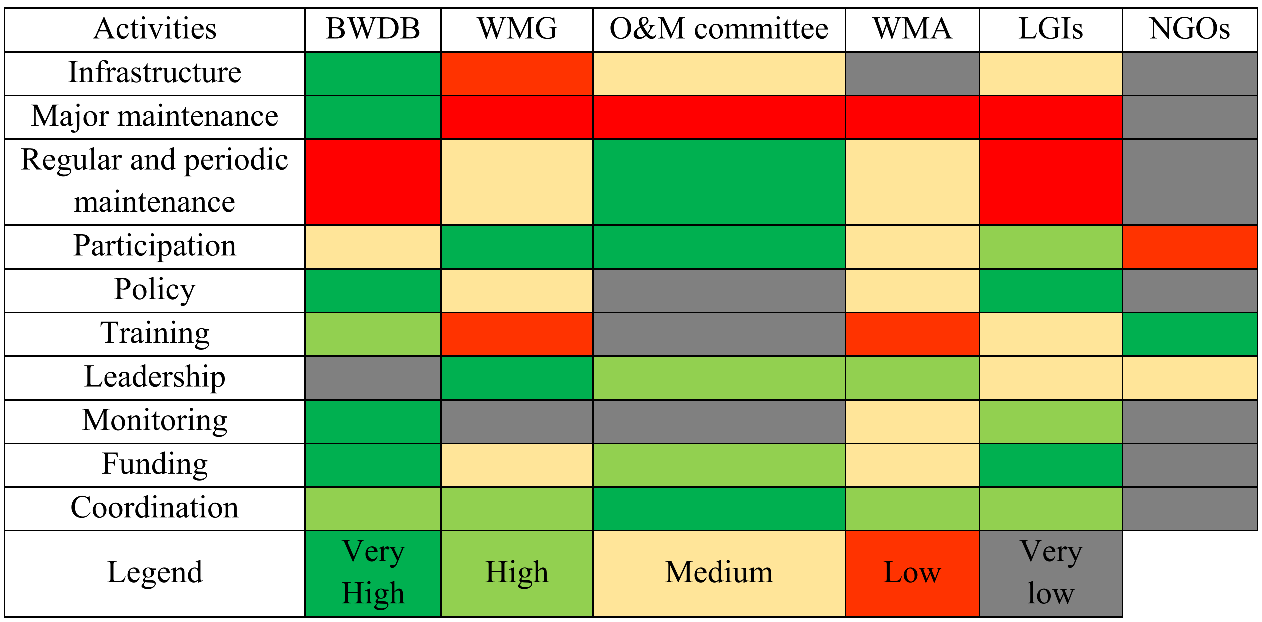

Figure 8.7: The level of contributions from different institutions to bridge the gaps and mitigate the local level conflicting issues in water management.

Additionally, conflicting policy of water management among different agencies need to be addressed. For example, conflict regarding leasing public land should be resolved in policy level. No O&M committee in Polder 29 can utilize BWDB accrued land and other khas land for generating O&M fund.

Secondly, ensuring universal participation in WMOs means each individual households irrespective to their socio-economic condition in the community should engage in WMOs. Besides, WMGs must focus on water management; however, water management has not received as much attention as other economic activities (e.g., micro-credit) did in Polder 29. In Blue Gold program, it was envisaged that strong WMGs form the basis for effective and sustainable water management and ultimately overall polder development. Based on the experiences from IPSWAM, it was inferred that a village is the best organizational unit for a WMG, as it is usually a relatively homogeneous group of households or families that have some cohesion among the different stakeholder groups, which brings with its elements of "social control" and "confidence and trust", that are the corner stones of a successful social organization process. The spontaneous development of saving and micro-credit groups as part of the WMG development is the result and evidence of this conducive environment. In sum, WMGs were thought to be strong and cohesive, having trust for savings, microcredit, income generating activities and business development (Blue Gold, 2014).

However, because of the disconnect with water management, many WMGs are locally known as only a micro credit business institute (Samiti) to many villagers; consequently, they do not know why they are in the WMG and what their responsibility is in terms of water management. One of the KII respondents said that,

> *"Successfulness of WMG in many cases is not measured by how excellent water management is, but rather by how much fund has been generated through micro credit business. So, it is better to incorporate income generating activities with water management. As most of the WMGs do not have any O&M fund, this should be the prime mandate of each WMG in the first place."*

It is generally expected that strong WMGs, strengthened by abilities of generating funds via micro-credit as well as income generating activities, will be contributing to effective and sustainable water management and overall polder development. Besides, financial sustainability of WMOs need to be ensured through utilizing the public water resources and other income generating activities (described in more details in section 8.6).

Thirdly, monitoring and coordination need to be inclusive, improved and better structured. Continuous monitoring of WMOs should be conducted by the mother agency (i.e., BWDB) with the help of LGIs. FGD participants and KII respondents in Baro Aria (Ruthimara sub-catchment) argued that coordination and interaction of WMOs with BWDB and LGIs is not up to the mark because of less supervision and inspection by the BWDB and LGIs. Besides, absence of required coordination and interaction within WMG members and WMG committees are evident. WMG and WMA appear to lack independent identities when it comes to water and/or water infrastructure management; as a result, control of O&M of water structures is often dominated by either political groups or powerful gher owners.

Moreover, without the supportive role of LGIs (UP and UZP), it is difficult to implement WMOs' mandates in water management and water conflicts mitigation. LGIs' participation and involvement in WMOs' activities are less than expected because the committee members of WMOs do not prefer the inclusion of LGI in their activities in anticipation of possible interference of LGIs in their other economic activities. However, successful story of LGI's involvement has been found in Bakultala at Bakultala WMG (Source: KIIs 2019).

It is clear that (also supported by KII and FGD respondents) without sharing information with LGI's, the WMOs will not be able to make effective planning and design of water management. On the other hand, administrative support from UZP level (e.g., from UNO) needs to be incorporated within WMOs to utilize the public water resources and to stop illegal leasing of sluice gates and khas canal/land.

Lastly, leadership in WMOs should be selected based on the people's need and leader's interest. In the leading position, executive committee should be selected on the basis of both need and interest. If one has interest but does not have needs, then his/her contribution will not be in that level who has both need and interest. Selection rather than election in formation of WMG committee has been found in many areas. This selection process gives opportunity to the local elite/influential/political persons to grab the leading positions and do water management activities in favor of their personal purposes. Field research even found several WMG committees represented by members of a single family.

The farmers as local beneficiaries have the right to know why and what decisions are made by the WMG committee and whether they would be positively or negatively affected by the decisions. If the WMG Committee leaders and general members do not share the process of their activities, general members will remain unaware about it and thus in most cases the overall capacity building of local communities through community-based organizations will not be possible. Therefore, accountability and liability should be major criteria for selecting executive committee and in implementing their tasks.

8.6 Water conflict mitigating programs

To mitigate water conflicts, several major programs were identified from stakeholder analysis (Figure 8.8) which are illustrated below.

a) ***Proper positioning of stakeholders*** by including the water management stakeholders according to their priority, roles, and responsibility in mitigating conflicts.

Institutional issues mainly occur when the question arises on who will take the responsibility for water resources management. To solve the issue proper positioning of stakeholders with defined roles and responsibilities is required. The major duty of O&M committee should be routine O&M of water structures. Routine O&M should include clearing weeds and other obstacles from secondary and tertiary canals as well as from sluice gates; painting and minor repair of sluice gates; and monitoring and taking necessary steps to remove illegal encroachments (net, pata, kumor) from the canal. Besides, WMGs should assign specific groups of people from general members to participate in different stages of project cycle, e.g., prepare annual crop plan, prepare O&M plans, help the concerned authority and O&M committee by providing manpower, collect beneficiary contribution towards scheme investment and O&M cost, keep books of account for record and auditing, identify local issues and solve them as soon as possible with the help of WMA and LGIs, and observe overall O&M of sub-catchments.

On the other hand, WMAs should prepare budget and participate in all water management activities, review and resolve conflicts or issues referred from WMGs, liaise with the implementing agency, LGI's, NGOs and community groups who are concerned of various issues, prepare annual O&M plan, collect crop/other production plan prepared by WMGs, collect O&M cost and beneficiary contribution from WMGs for the investment and O&M maintenance cost, and assist in arranging training and other services from govt and non-govt organizations for various stakeholder groups.

For major operation of hydraulic structures, BWDB should discuss with LGIs and WMOs and address the issue. For medium and small operational activity, BWDB should provide technical advice and training to the O&M committee, so that the local body can solve their problem by themselves. Major and periodic maintenance (after 3/4 years) of embankment, secondary canal, and flood emergency work, repair of major flood/erosion damage, and reconstruction and/or rehabilitation of infrastructure as per stakeholders' demand should be led by BWDB with the help and advice of LGIs.

b) ***Strengthening financial ability*** of WMOs through income generating activities (e.g., microcredit program focusing on water management), utilization of khas land by WMOs instead of elite capture, government projects (e.g., earthen work), and subscription from beneficiaries including farmers and fishermen.

Income Generating Activities mainly, microcredit program of WMG is a vital source of generating fund and benefit sharing. The committee of WMG charges a monthly payable amount to each general member of WMG to offer loan to local farmers with the fund thus created, irrespective of their membership in the WMG, with a fixed interest rate. Most of the WMGs do not have O&M fund and are not willing to provide fund to WMA and/or O&M committee, making it very challenging for the WMA or O&M committee to manage water management activities. Currently, Bakultala WMG had a total amount of fund of 16 lakhs 20 thousand BDT (at the end of 2019). But they had no specific fund for O&M of water structures; moreover, they were not interested to spend their money in water management purpose. Because they thought that fund required for water management should come from the government.

At Bakultala, Ruhitmara, Asannagar, Chatchatia, and Golaimari, WMGs have reserve funds, but only Asannagar and Bakultala WMGs spend their fund to repair sluices and in other social welfare activities (installing lamp posts, helping the poor regarding marriage, etc). But most of the time they could not collect money from the farmers who are benefited by the sluices. Sometimes the WMG leaders had to spend from their own source (Source: KIIs).

In this backdrop, it seems reasonable that to strengthen financial ability in water management activities, WMG should raise a O&M related fund from their income. Earthen works such as khal excavation and repair of embankment, sluice, regulator, and bridge/culvert, are to be implemented by WMGs and WMAs through LCS (Labor Contracting Society) project carried out by BWDB (in this case the Blue Gold program of BWDB). WMOs should get the top priority in allocation of LCS funds, which has not been the case in several cases (Source: KII). This will enhance the financial ability of the WMOs.

c) ***Strengthening human capacity*** by improving the knowledge of water management through proper training to wider populations including the marginal groups, so that communities can not only identify the water conflicts but also take appropriate measures to resolve the issues.

All the local institutions engaged in water management are not well trained. FGDs have revealed that there have been unequal opportunities in training; the same people were found to be taking training (mainly few leaders of WMOs) in most of the cases with others left behind. Although most the of WMGs got training regarding water management by Blue Gold program, their outcome has not been satisfactory enough (source: FGDs). The training recipients do not usually share their learnings with others; hence, general members and other project beneficiaries remain less informed. However, there are few exceptions; for example, Maikhali WMG facilitates a lottery system to select who will participate in the training and ensure that no one can go to the training twice.

Besides, information dissemination is a basic requirement for participatory water resource management. It is an activity through which information, skills and expertise is transferred from the national level institutions to local level organizations and vice versa. For the sustainability of WMOs, it is essential to spread the basic information of projects and related information among all stakeholders. Training and meeting at the field level are effective tools used by the project leaders for transferring all required knowledge among local stakeholders. It develops capacity of the institutions as well as communities to increase functionality more effectively. Besides, meeting is a useful tool for intra-institutional knowledge dissemination.

d) ***Enhancing physical and technical strength*** through proper maintenance of water structures (i.e., sluice gate, irrigation network, embankments, inlets, outlets, regulators, etc.), removing barriers from internal canals for smooth water flow, and conducting different technical training programs (by BWDB) on canal excavation, embankment/sluice repair, etc.

In Asannagar, Chatchatia, Telikhali and Ruhitmara, the physical condition of sluices was very poor in the recent past. By the initiative of BWDB, Blue Gold repaired most of the sluices. Respondents of FGDs and KIIs informed that BWDB does not maintain the khals and canals inside the polder on a periodic basis. On the other hand, KII respondents of WMG said that no initiatives to maintain khals and canals from WMOs have been taken on a regular basis (Source: KIIs and FGDs). One of the FGD respondent in Ruhitmara WMG said,

> *"Proper O&M of sluice and canals will not bring any benefits and facilities, if embankment is not fixed to protect river erosion".*

However, different technical trainings will help to mitigate conflicting issues among user groups. For example, due to elevation difference between the u/s and the d/s, there are some problems with providing water for irrigation in the dry season or draining out water in the monsoon through the sluice gate. Low areas become flooded in the monsoon because of drainage congestion, while high areas do not receive water for irrigation through canals during the dry season. To address these issues, about 15 days back and forth irrigation considering low and high land is a good idea extracted from local knowledge (Source: FGD and KII).

e) ***Strengthening social groups*** by ensuring participation in WMGs from farmers, fishermen, women, and others livelihood groups, and selecting appropriate committee members and leaders.

The main aim of participatory water management is ensuring equitable distribution of water resources and services which involves all stakeholder's participation in decision making and planning. To satisfy all stakeholders with a sustainable institutional system, it is essential to involve all kinds of project beneficiaries in planning and decision-making process. Field data revealed that local elites, some leaders of WMOs and LGI representatives are the dominant group in Polder 29 in planning and decision-making considering their interest. As a result, poor farmers and fishermen cannot raise their voice, and hence remain excluded in decision-making process and from the mainstreaming of water management.

Several success stories of strengthening social groups by ensuring participation in WMGs have been found in the study area. FGD respondents of Golaimari, Chatchatia and Asannagar WMGs delightfully expressed that during the period from 2008 to 2010 local small farmers raised their voice against shrimp gher owners with the help of the Upazila Chairman and police and were able to free some canals and khals from the blockage of ghers. They were also able to stop saline water intrusion through inlets by demolishing the inlets. An NGO named Uttaran helped local farmers a lot to raise this movement. In Jaliakhali and Ruhitmara, some pipes appear to have been removed by local people with the help of UP and police but still some gher owners continue with this practice illegally. By engaging local stakeholders in every activity according to their ability may help to embed decentralized water governance system, thus reducing illegal power practice at the local level.

The programs described above have different levels of importance to mitigate different types of conflicts (Figure 8.8). For example, in mitigating agriculture vs small scale gher conflict, strengthening physical and technical strength and strengthening social groups are vital while proper positioning of stakeholders is moderately important. Agriculture vs small brackish shrimp farming conflict can be addressed by ensuring physical and technical potency of the study area. In this regard, increasing physical and technical capacity and strengthening social groups are moderately important. But to address large scale saltwater shrimp farming proper stakeholders positioning is of utmost importance. Besides, financial abilities of WMOs along with proper stakeholders' position should be addressed in mitigating institutional issues. On the other hand, land use conflicts, u/s vs d/s conflicts and user-environmental conflicts can be minimized by increasing physical and technical potency. Strengthening human capacity and social groups are moderately and highly important for land use conflicts and vice versa for u/s vs d/s issues.

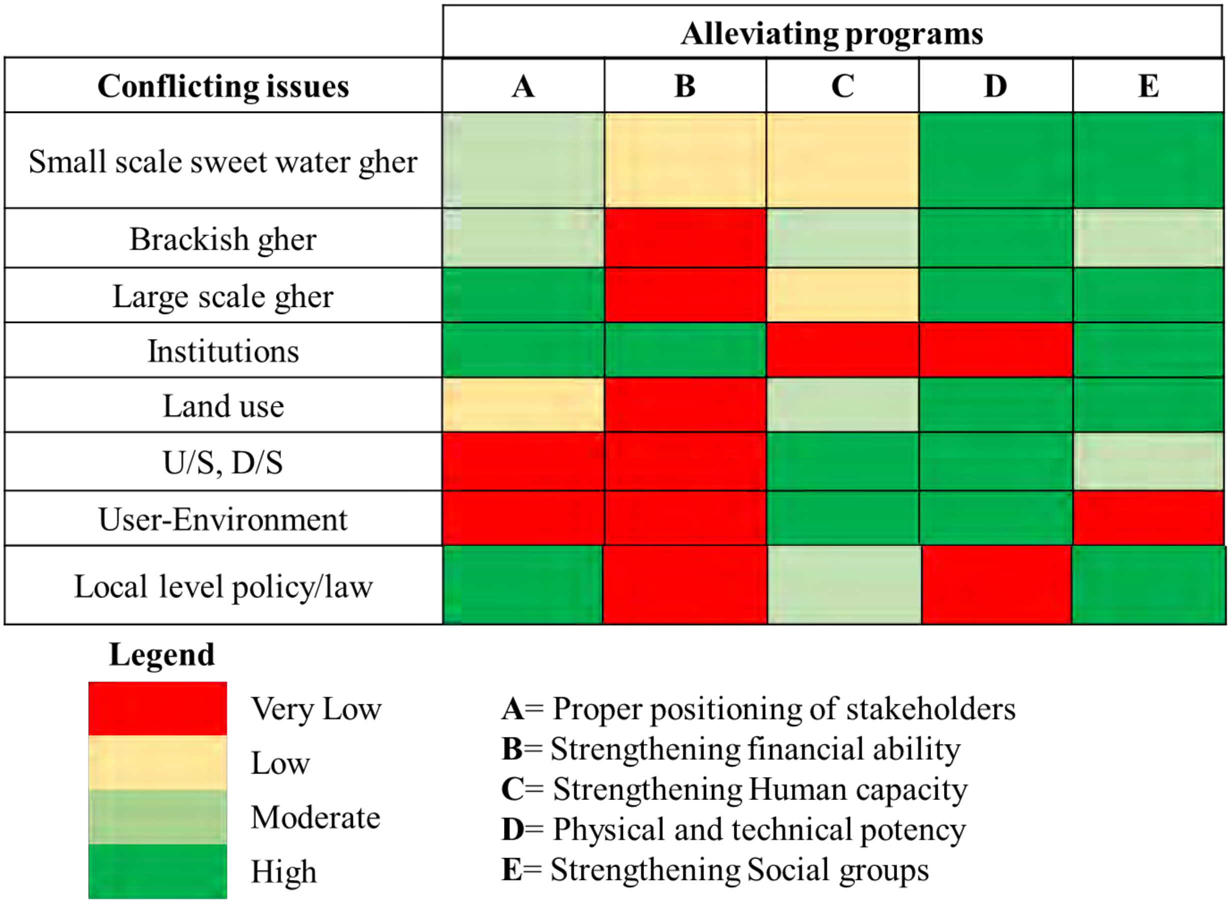

Figure 8.8: Local level water conflict mitigation programs

Chapter Nine: Conclusions and Recommendations

9.1 Introduction

The study aimed to investigate the complex nature of different water related conflicts and how they evolved with time in response to different drivers in a southwest coastal polder, namely Polder-29. Besides, it captured the dynamics of the changing nature of conflicts under changing environmental and anthropogenic stresses and evaluated roles of water security programs and institutional/management systems in mitigating conflicts.

9.2 Major conclusions from the study

9.2.1 Spatial and temporal characteristics and drivers of conflicts

Major conclusions on spatial and temporal characteristics and drivers of conflicts are listed below:

- Polder 29, consisting of ten sub-catchments, is characterised as a multi-hazard (tidal flooding, water logging, cyclone, embankment breaching) area with different water interventions from water control structures to water management institutions with different types of livelihoods. The southern sub-catchments (i.e., Ruhitmara, Jaliakhali, Ratankhali, Asannagar and southern part of Golaimari and Telikhali) are relatively more dominated by brackish shrimp farming, while the northern sub-catchments (Katakhali, Kanaidanga, Bakultala, Kanchannagar and upper portion of Telikhali and Golaimari) are dominated by small gher oriented shrimp farming and agriculture.
- There exist different types of water conflicts, which have evolved with time under various drivers in Polder 29 in response to changing environmental and anthropogenic stresses. Siltation, river erosion, saltwater intrusion, water congestion, non-functionality of water infrastructure, and ineffective water institutions reinforce existing water conflicts in the region.
- Large scale shrimp farming vs agriculture, agriculture vs saltwater shrimp, agriculture vs small-scale freshwater gher, u/s vs d/s conflict, conflicts from policy level, institutional conflicts, user vs environment conflicts, and conflicts due to land use change are the major sources of discord in the polder. These water conflicts are highly diverse in nature and significantly vary spatially and temporally with different livelihood and land use practices.

- For example, agriculture vs large scale brackish shrimp farming was the dominant conflict earlier in 1990s, with aquaculture covering 70.2% and 74.3% area in the south at Ruhitmara and Jaliakhali during dry season. The percentage decreased to 46.83% and 63.78% in 2019. These conflicts are still prevalent, and newer conflicts such as agriculture vs small scale saltwater shrimp, institutional conflicts, user vs environment conflicts, and conflicts due to land use change have emerged with time.
- Marginal and landless people, who are the sharecroppers in the dry season, are the most affected by brackish shrimp farming as the agricultural land is affected by the surrounding brackish ghers, aggravated by the gher owners bringing saltwater inside the polder illegally from the peripheral river.
- On the other hand, in the northern part, the conflicts are not same as in the southern part, where extensive increase in small-scale freshwater ghers, from 2.06%, 1.71%, 1.40% and 3.04% in 1990 to 61.18%, 77.09%, 50.56% and 50.18% in 2019, respectively in Kanchannagar, Bakultala, Kanaidanga and Katakhali) creates several conflicts like agriculture vs small-scale freshwater gher, u/s vs d/s conflict, user vs environment conflicts, and conflicts due to land use change. Extensive ghers hamper canal water irrigation for the agricultural land as the gher owners (consisting of rich farmers and local powerful groups) tend to grab and block the canals. This has also disrupted hydrological connectivity resulting in siltation in drainage canals, water congestion, loss of khals, and loss of fish species. This also reinforces the u/s vs d/s conflict generated by topographical difference within the sub-catchments.
- Institutional conflicts mainly occur between different institutions, for example, conflicting status between 'O&M committee' and 'beel committee' and conflicts between LGIs and O&M committee (seen at Asannagar and Ratankhali sub-catchments), and conflicts between WMG and WMA (seen at Bakultala, Kanchannagar, Telikhali).
- These conflicts mainly stem from the control of sluice gates and the drainage canals. The WMGs were still yet to get control of sluice gates in several sub-catchments (e.g., Chatchatia, Asannagar and Telikhali), with LGIs and local powerful groups getting involved in leasing the sluice gate. The leaseholders control the sluice according to their benefit, for example via intentional obstruction of drainage during heavy rainfall events and catching fish from canals and at the sluice mouth washed away from small ghers. The issues are accentuated by leasing

of khals (by LGIs, with lack of coordination between LGIs and BWDB) and subsequent obstruction of the canals for catching fish (notably in Telikhali, Kanchannagar and Golaimari).

- While strong WMGs form the basis for effective and sustainable water management and ultimately overall polder development, engagement of WMGs in micro-credit activities is also important for the sustainability of the WMOs, with WMGs considered as strong and cohesive, having trust for savings, microcredit, income generating activities and business development. However, in several cases in Polder 29, water management has not received as much attention as other economic activities (including micro-credit) did. This disconnect with water management has left many members of WMGs unaware of their roles and responsibilities in terms of water management.
- LGIs' participation and involvement in WMOs' activities are less than expected because of the reluctance of the WMO members in anticipation of possible interference of LGIs in their other economic activities. However, there is a successful story of LGI's involvement I Polder 29 (i.e., at Bakultala at Bakultala), with evidence of sharing information with LGI's contributing to more effective planning and design of water management.

9.2.2 Recommendations for conflict mitigation

- To understand water management system and mitigate local level water conflicts, it is important to map different roles and responsibilities of different actors and stakeholders. A both way interaction between water management community and associated institutions who are directly involved with the water management process is very essential.
- The study has mapped key stakeholders, their involvement in water management and mitigating roles, influence within community, and possible opportunities in addressing conflicts through different stakeholder's analysis and power-influence mapping. It was revealed that mitigating conflicting situations may be achieved by shifting of roles and activities of key stakeholders, in alignment with the expected involvement at different levels. The WMGs, O&M committee and WMAs, the prime actors in Polder 29, are currently in a 'co-thinking' stage (i.e., passive interaction with others) and need to act as co-operating stakeholders (i.e., more closely involved in decision-making and other important processes and interacting with other stakeholders). Influence of Beel committee along with other opportunist groups over water management system should be addressed. Giving priority of WMOs as a co-

operating body in decision making process is needed. In this regard LGI should support both in decision making and implementing process from the co-thinking tier.

- To mitigate local water conflicts, bridging the gaps in institutional system is thus of utmost importance. Water management infrastructures should be well-functioning and BWDB is the prime entity to ensure functionality. The routine and periodic maintenance activities can be done through O&M committee but the major maintenance needs BWDB's direct involvement.
- Besides, formal approval of O&M committee is needed, and it must be considered as the base unit of water management instead of WMG. Additionally, conflicting policy of water management among different agencies need to be addressed.
- The WMOs must re-focus considerably on water management apart from important socio-economic development activities. Their financial sustainability also needs to be ensured. Each WMO should have a self-financial mechanism generated from the existing public water resources. The O&M committee should be in charge of the resource utilization system.
- Monitoring and coordination need to be inclusive, improved, and better structured. Continuous monitoring of WMOs should be conducted by BWDB with the help of local government. Moreover, without supportive role of LGIs (UP and UZP), WMA and O&M committee are unable to implement their mandates of water management. Leadership roles in WMOs should be selected based on the people's need and leader's interest, where election of WMG leaders rather than selection process is needed. A technical body needs to be established through proper training to respond to O&M difficulties and make routine O&M feasible by WMOs.
- Finally, water conflict mitigating programs should be taken according to their importance for a particular identified conflict. Proper positioning of stakeholders according to their priority, roles and responsibility is important to mitigate agriculture vs shrimp farming conflicts, institutional conflicts and conflicts from policy level. Strengthening financial ability through different income generating activities will help to address institutional conflicts but are found less effective in mitigating other conflicts.
- Besides, strengthening human capacity through proper training to wider populations is essential in mitigating u/s vs d/s conflict, user-environment conflicts, conflict from land use change and policy level conflicts. Though enhancing physical and technical strength (e.g., proper maintenance of water structures, conducting different technical training programs) is found less important to manage institutional and policy issues, is considered to be utmost

important for other conflicts. Likewise, strengthening social groups (e.g., universal participation of different livelihood groups, selecting appropriate leaders) will play substantial role in mitigating water conflicts.

9.3 Recommendations for future research

The study recommends the following as potential areas where research could be carried out in the future for more comprehensive understanding of conflicting issues and their dynamics at the local level and removing barriers in implementation of participatory water management at the polder level.

(1) The study was conducted in only one polder (i.e., Polder 29). Given the complexity and heterogeneity across the coastal polders, often characterized as different social-ecological systems (SESs) based on geo-hydrological, environmental and socio-economic characteristics, future exploration of local water conflicts in other polders, representing different SESs, will provide a more through and complete picture.

(2) The study should inform the recent initiatives in Bangladesh to try to identify the motivations and abilities of the stakeholders involved in bottom-up water resource planning contexts, i.e., participatory water management (PWM)), and in subsequently providing insight into the types of capacity- or consent-building strategies needed for effective implementation (Sadik et al., 2022).

It is now recognized that implementation failure is a major impediment to the success of water resource plans and/or projects; successful implementation largely depends upon the motivation and abilities of various key stakeholders to see the plan to fruition (Phi et al., 2015). This requires proactive approaches for analyzing potential implementation issues during the planning stage. While a range of useful decision support techniques are available to assess the performance of plans and policies, e.g., Multi-Criteria Analysis, Cost Benefit Analysis, Robust Decision Making and Environmental Impact Assessment (Quan et al., 2019; Drèze and Stern, 1987), which can provide useful information on performance indicators, performance-based techniques are not sufficient for determining whether a project will actually be adopted by local stakeholders and/or implemented by the appropriate institutions (Quan et al., 2019).

The motivations and abilities (MOTA) framework (or MOTA analysis) developed in 2015 by Phi et al. (2015) provides a multi-stakeholder and multi-level approach for assessing the implementation feasibility of projects and plans (Conallin et al., 2021). It takes the motivation and ability of actors involved in plan implementation as central and links these to the actors' perceptions of threats and opportunities. Previous research shows that the MOTA framework can be very useful in identifying the motivations and abilities of the stakeholders involved in a range of bottom-up water resource planning contexts, and in subsequently providing insight into the types of capacity- or consent-building strategies needed for effective implementation (Conallin et al., 2021). The reliability of the MOTA framework has been tested through its application in case studies on human behaviours to support policy analysis in VMD and Vietnam (Phi et al. 2015, Nguyen et al. 2019a, 2019b, 2020) and in Bangladesh (Kulsum 2020).

Sadik et al (2022) recently extended the framework in the context of PWM reforms for coastal communities in Bangladesh. They found that the MOTA framework is capable of informing policymakers and implementing agencies about how to enhance the stakeholders' motivation and ability to ensure an enduring implementation of PWM reforms. They argue that the MOTA framework can be adjusted and extended to address the implementation feasibility of institutional measures, which is needed in the BDP 2100 (Bangladesh Water Management Rules 2018 as well), i.e., PWM reform.

References

Abdullah, A. N., Myers, B., Stacey, N., Zander, K. K., & Garnett, S. T. (2017). The impact of the expansion of shrimp aquaculture on livelihoods in coastal Bangladesh. *Environment, Development and Sustainability*, *19*(5), 2093–2114.

Acuña, R. M. (2015). The politics of extractive governance: Indigenous peoples and socio-environmental conflicts. *Extractive Industries and Society*, *2*(1), 85–92. https://doi.org/10.1016/j.exis.2014.11.007

Adams, A., & Cox, A. L. (2008). *Questionnaires, in-depth interviews and focus groups* (pp. 17-34). Cambridge University Press.

Adger, W. N., Kelly, P. M., & Ninh, N. H. (2001). *Living with environmental change*. Routledge London, United Kingdom.

Afroz, S., Cramb, R., & Grunbuhel, C. (2016). Collective management of water resources in Coastal Bangladesh: formal and substantive approaches. *Human Ecology*, *44*(1), 17–31.

Agardy et al. (2005). *Coastal Systems. Ecosystems and Human Well-being: Current State and Trends*. Island press.

Ahmad, H. (2019). Bangladesh coastal zone management status and future trends. *Journal of Coastal Zone Management*, *22*(1), 1–7.

Ahmed, N., Allison, E. H., & Muir, J. F. (2010a). Rice fields to prawn farms: A blue revolution in southwest Bangladesh? Aquaculture International, 18, 555–574.

Ahmed, N., Troell, M., Allison, E. H., & Muir, J. F. (2010b). Prawn post larvae fishing in coastal Bangladesh:Challenges for sustainable livelihoods. Marine Policy, 34, 218–227.

Ahmad, Q. K., Biswas, A. K., Rangachari, R., & Sainju, M. M. (2001). Ganges–Brahmaputra–Meghna Region: A Framework for Sustainable Development. *University Press Limited, Dhaka, Bangladesh*.

Ahmed, S. A., Mallick, D. L., Ali, M. L., & Rahman, A. A. (2002). Literature review on Bangladesh shrimp. Individual partner report for the project ''Policy Research for Sustainable Shrimp Farming''. Dhaka: University of Portsmouth and Bangladesh Centre for Advanced Studies (BCAS).

Ahmed, A. F., & Rahman, M. M. (2010). *Water Supply and Sanitation: Rural and Low income urban countries, Fourth Edition, ITN, BUET, Dhaka*.

Alam, M.K., Hasan, A.K.M.S., Khan, M.R. and Whitney, J.W.(1990), Geological Map of Bangladesh, Geological Survey of Bangladesh, Dhaka.

Alamanos, A., Rolston, A., & Papaioannou, G. (2021). Development of a decision support system for sustainable environmental management and stakeholder engagement. *Hydrology*, *8*(1), 40.

Alauddin, M. & Tisdell, C. A., (1998) The environment and economic development in South Asia: An overview concentrating on Bangladesh. Macmillan Press Ltd.

Ali, A. M. S. (2006). Rice to shrimp: Land use/land cover changes and soil degradation in Southwestern Bangladesh. *Land Use Policy*, *23*(4), 421–435.

Ali, M.Y. (1994), Fisheries and Environment, in Environment and Development in Bangladesh, ed. A.A. Rahman, S. Huq, R. Haider and E.G. Jansen, University Publishers Limited, Dhaka.

Ali, M. Y. (1990), Open water Fisheries and Environmental Changes in Environmental Aspects of Surface Water Systems of Bangladesh, Ed. by A.A. Rahman, S. Huq, G.R. Conway, University Press Limited, Dhaka.

Antonio, B. Q., Pagsanghan, J., & Marquez, N. D. (2019). *In Defense of Land Rights: A Monitoring Report on Land Conflicts in Six Asian Countries. Asian NGO Coalition for Agrarian Reform and Rural Development – ANGOC.*

Azman, N., Halim, S. A., & Komoo, I. (2009). Integrated public education for heritage conservation: A case for Langkawi Global Geopark. *Dalam RIMBA: Sustainable Forest Livelihoods in Malaysia and Australia. Ainsworth, G. & Garnett, S.(Eds.)*, 151–156.

BBS. (2018). *Report on Agriculture and Rural Statistics.* Bangladesh Bureau of Statistics. Statistics and Informatics Division (SID), Ministry of Planning. Government of the People's Republic of Bangladesh.

BBS. (2011a). *Bangladesh national portan, the People's Republic of Bangladesh*. Bangladesh Bureau of Statistics. Statistics and Informatics Division (SID), Ministry of Planning. Government of the People's Republic of Bangladesh.

BBS. (2011b). *District statistics.* Bangladesh Bureau of Statistics. Statistics and Informatics Division (SID), Ministry of Planning. Government of the People's Republic of Bangladesh.

Bansil, P. C. (2004). Water management in India. *Concept Publishing Company*.

Barnett, J., & Adger, W. N. (2007). Climate change, human security and violent conflict. *Political geography*, *26*(6), 639-655.

Batista, M. I., Henriques, S., Pais, M. P., & Cabral, H. N. (2014). Assessment of cumulative human pressures on a coastal area: integrating information for MPA planning and management. *Ocean & Coastal Management*, *102*, 248–257.

Belton, B., Ahmed, N., & Murshed-e-Jahan, K. (2015). *Aquaculture, employment, poverty, food security and well-being in Bangladesh: A comparative study*. WorldFish.

Bernier, Q., Sultana, P., Bell, A. R., & Ringler, C. (2016). Water management and livelihood choices in southwestern Bangladesh. *Journal of Rural Studies*, *45*, 134–145.

Blue Gold. (2021). Blue Gold Lessons Learnt Wiki. https://www.bluegoldwiki.com/index.php?title=Blue_Gold_Lessons_Learnt_Wiki

Blue Gold. (2019). *Technical report 26.* Inproving the productivity of land in coastal Bangladesh: Outcomes of Blue Gold interventions, WMG survey 2019.

Blue Gold. (2016). *Environmental Impact Assessment (EIA) on Rehabilitation of Polder 29.* Ministry of Water Resources, Government of the People's Republic of Bangladesh.

Blue Gold. (2015). *Technical Report 13.* Engaging Local Government Institutions In Water Management. Ministry of Water Resources, Government of the People's Republic of Bangladesh.

Blue Gold. (2014a). *Blue Gold Program Technical Report No. 10.* Outcome of Functionality Assessment for Water Management Organizations. Ministry of Water Resources, Government of the People's Republic of Bangladesh.

Blue Gold. (2014b). *Technical Report 09.* Water Management Organizations – Comparative Analysis. Ministry of Water Resources, Government of the People's Republic of Bangladesh.

Brown, G., & Raymond, C. M. (2014). Methods for identifying land use conflict potential using participatory mapping. *Landscape and Urban Planning*, *122*, 196–208.

Buisson, M.-C., Das, A. & Mukherji, A. (2017). Where river meets the sea: Participatory Water Management in Coastal Bangladesh. *Review of Market Integration* 9(1–2), 45–65. https://doi.org/10.1177/0974929217717528.

Bulleri, F., & Chapman, M. G. (2010). The introduction of coastal infrastructure as a driver of change in marine environments. *Journal of Applied Ecology*, *47*(1), 26–35.

Campbell, D. J., Gichohi, H., Mwangi, A., & Chege, L. (2000). Land use conflict in Kajiado District, Kenya. *Land Use Policy*, *17*(4), 337–348. https://doi.org/10.1016/S0264-8377(00)00038-7

CEGIS. (2012). *Master plan of haor area, Bangladesh Haor and Wetland Development Board*

(BHWDB). Summary Report, Volume II, Ministry of Water Resources, Government of the People's Republic of Bangladesh.

CEGIS. (2016). *"Environmental Impact Assessment (EIA) on Rehabilitation of Polder 29."* Centre for Environmental and Geographic Information Services, Dhaka.

Chavez, P. S. (1996). Image-based atmospheric corrections-revisited and improved. *Photogrammetric Engineering and Remote Sensing*, 62(9), 1025–1035.

Chu, T. H. (2006). *Environment and livelihoods in tropical coastal zones: managing agriculture-fishery-aquaculture conflicts* (Vol. 2). CABI.

Chowdhury, J. U., Rahman, M. R., & Salehin, M. (1997). Flood Control in a Floodplain Country: Experiences of Bangladesh, Institute of Flood Control and Drainage Research. *Islamic Education, Scientific and Cultural Organization (ISESCO),* Rabat, Morocco.

Crow, B., & Sultana, F. (2002). Gender, class, and access to water: Three cases in a poor and crowded delta. *Society &Natural Resources*, *15*(8), 709-724.

Conallin, J., Ning, N., Bond, J., Pawsey, N., Baumgartner, L.J., Atminarso, D., McPherson, H., Robinson, W., Thorncraft, G. (2021). A review of the applicability of the Motivations and Abilities (MOTA) framework for assessing the implementation success of water resources management plans and policies. *Hydrology and Earth System Sciences*, Preprint. Discussion started: 10 November 2021, https://doi.org/10.5194/hess-2021-545.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R. V, & Paruelo, J. (1997). The value of the world's ecosystem services and natural capital. *Nature*, *387*(6630), 253–260.

Damonte, G., & Glave, M. (2012). Rent distribution and extractive industry conflict: the Latin American approach. *ELLA: Economic Development, Extractive Industries and Conflict Management*, 3.

Datta, A. K. (1997). *Planning and management of water resources-lessons from two decades of early implementation projects, Bangladesh.* In A. K. Datta (Ed.), Dhaka, Bangladesh: The University Press Limited.

De Groot, R., Brander, L., Van Der Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M., Crossman, N., Ghermandi, A., & Hein, L. (2012). Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem Services*, *1*(1), 50–61.

Dewan, C. (2012). Review of the historical evolution of policies and institutions of community based management in coastal Bangladesh. *G3: Water Governance and Community Based Management*.

Dewan, C., Buisson, M.-C., & Mukherji, A. (2014). The Imposition of Participation? The Case of Participatory Water Management in Coastal Bangladesh. *Water Alternatives*, *7*(2), 342–366.

Dewan, C., Mukherji, A., & Buisson, M.-C. (2015). Evolution of water management in coastal Bangladesh: from temporary earthen embankments to depoliticized community-managed polders. *Water International*, *40*(3), 401–416. https://doi.org/10.1080/02508060.2015.1025196.

DHV. (1989). *Final Report.* Bangladesh Inland Water Transport Master plan. Vol. 1, pp.70-71, Bangladesh Inland Water Transport Authority, Dhaka.

Duyne, J. E. (1998). Local initiatives: People's water management practices in rural Bangladesh. *Development Policy Review*, *16*(3), 265–280.

EC (2003). Common Implementation Strategy for the Water Framework Directive (2000/60/EC): Guidance Document No 8 Public Participation in Relation to the Water Framework Directive, European Commission

Ehler, C., & Douvere, F. (2009). *Marine Spatial Planning: a step-by-step approach toward ecosystem-based management.* Intergovernmental Oceanographic Commission and Man and the Biosphere Programme.

Eric, F. et. al. (2001). *The causes of land-use and land-cover change: moving beyond the myths. , 11(4), 0–269.* doi:10.1016/s0959-3780(01)00007-3

Engel, A., & Korf, B. (2005). Negotiation and mediation techniques for natural resource management. *Rome: Food and Agriculture Organization of the United Nations*, *3*.

FAO. (2015). *UN Food and Agricultural Organization. Per capital renewable freshwater resources. AQUASTAT Database*. http://www.fao.org/nr/water/aquastat/main/index.stm

Falkenmark, M. (2000). Competing freshwater and ecological services in the river basin perspective: an expanded conceptual framework. *Water international*, *25*(2), 172-177.

Faruque, S. B. (2009). *Multipurpose use of Hazir khal by making provision for community proposed flow control gate at a culvert*.

Firoze, A. (2003). The southwest coastal region: problems and potentials. *The Daily Star*, 25.

Fleiss, J. L., Levin, B., & Paik, M. C. (2004). The Measurement of Interrater Agreement. *Statistical Methods for Rates and Proportions*, 598–626. https://doi.org/10.1002/0471445428.ch18

Fonji, S. F., & Taff, G. N. (2014). Using satellite data to monitor land-use land-cover change in North-eastern Latvia. *SpringerPlus*, *3*(61), 1–15. https://doi.org/10.1186/2193-1801-3-61.

Frederick, K. D. (1996). Water as a source of international conflict. *Resources for the Future*, *123*.

Funder, M., Bustamante, R., Cossio Rojas, V., Huong, B.T.M., van Koppen, B., Mweemba, C., Nyambe, I., Phuong, L.T.T. & Skielboe T. (2012) 'Strategies of the poorest in local water conflict and cooperation: evidence from Zambia, Vietnam and Bolivia', Water Alternatives 5,1: 20–36

Funder, M., Mweemba, C., Nyambe, I., van Koppen, B. & Ravnborg, H.M. (2010a) 'Understanding local water conflict and cooperation: evidence from Zambia', Journal of Physics and Chemistry of the Earth 35, 13–14: 758–764.

Funder, M. & Mweemba, C. (2010b) 'The case of the Mbeza irrigation scheme, Zambia'. Case Studies of Local Water Conflict and Cooperation. Report 12: Copenhagen: Danish Institute for International Studies.

Gain, A. K., Mondal, M. S., & Rahman, R. (2017). From flood control to water management: a journey of Bangladesh towards integrated water resources management. *Water*, *9*(1), 55.

Gammage, S., Swanburg, K., Khandkar, M., Islam, M. Z., Zobair, M., & Muzareba, A. M. (2006). A gendered analysis of the shrimp sector in Bangladesh. *Greater access to trade and expansion. USAID, Bangladesh*.

Garg, S. K. (2005). *Irrigation Engineering and Hydraulic Structures".* Chapter 7, pp 379, Khanna Publishers, 19th edition.

Giordano, M., Giordano, M., & Wolf, A. (2002). The geography of water conflict and cooperation: internal pressures and international manifestations. *Geographical Journal*, *168*(4), 293-312

Gizelis, T. I., & Amanda, E. W. (2010). Water Resources, Institutions, & Intrastate Conflict. *Political Geography*, *29*(8), 444-53.

GoB. (2013). *Bangladesh Water Act, 2013.* Government of Bangladesh, Dhaka. Available at: http://warpo.gov.bd/index.php/home/act (accessed 11 November 2020).

GoB. (2018). *Bangladesh Water Rules, 2018.* Government of Bangladesh, Dhaka. Available at: http://warpo.gov.bd/index.php/home/act (accessed 11 November 2020).

GPWM (2000). *Guidelines for Participatory Water Management*. Ministry of Water Resources. Government of the People's Republic of Bangladesh.

Guion, L. A., Diehl, D. C., & McDonald, D. (2011). Conducting an In-depth Interview:

FCS6012/FY393, rev. 8/2011. *EDIS*, *2011*(8).

Gupta, A. (2020). The Politicization of Water: Transboundary Water-Conflict in the Indian Subcontinent. *Honors Papers.* 690. https://digitalcommons.oberlin.edu/honors/690.

GWP. (2003). *"Sharing knowledge for equitable, efficient and sustainable water management".* Toolbox for Integrated Water Resources Management, Global Water Partnership.

Haider, M. Z., & Akter, R. (2018). Shrimp paddy conflict in the South-West coastal region of Bangladesh. *International Journal of Agricultural Economics*, *3*(1), 9–13.

Halpern, B. S., Ebert, C. M., Kappel, C. V, Madin, E. M. P., Micheli, F., Perry, M., Selkoe, K. A., & Walbridge, S. (2009). Global priority areas for incorporating land–sea connections in marine conservation. *Conservation Letters*, *2*(4), 189–196.

Halcrow, S. W. & Partners Ltd. and others (1993), *Final Report of Southwest Area Water Resources Management Project*, FAP4, Vol.1, p.13, 37, 38, FPCO, Dhaka.

Halpern, B. S., Selkoe, K. A., Micheli, F., & Kappel, C. V. (2007). Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. *Conservation Biology*, *21*(5), 1301–1315.

Hamid, M. A., & Alauddin, M. (1998). Coming out of their homesteads? Employment for rural women in shrimp aquaculture in coastal Bangladesh. *International Journal of Social Economics*, *25*(2/3/4), 314-337.

Hanchett, S., Akhter, J., & Akhter, K. R. (1998). Gender and society in Bangladesh's flood action plan. *Donahue, JM, and BR Johnston*.

Harun, A. Y. (2005). *Effects of Small-Scale Water Development Project, on Fisheries*. Bangladesh University of Engineering and Technology (BUET).

Hasan, M. H., Hossain, M. J., Chowdhury, M. A., & Billah, M. (2020). Salinity intrusion in southwest coastal Bangladesh: an insight from land use change. In *Water, Flood Management and Water Security Under a Changing Climate* (pp. 125–140). Springer.

Hassan, M., Mahmud-ul-Islam, S., & Rahman, M. M. (2022). Perception of Vulnerable Ultra-Poor Women on Climate Change Impacts and Local Adaptation in a High Flood Prone Area of Bangladesh. In *Disaster Risk Reduction for Resilience* (pp. 431-449). Springer, Cham.

Heady, C. (1998). Natural resource management and poverty reduction. *Fondazione Eni Enrico Mattei, Working Paper*, (63.98).

Heinz, I. (2002). Voluntary agreements as an instrument to solve conflicts between farmers and water suppliers. *IAHS-AISH Publication*, *273*, 11–16.

Hoanh, C. T., Tuong, T. P., Gowing, J. W., & Hardy, B. (2006). *Environment and Livelihoods in Tropical Coastal Zones*. CAB International.

Hunting, T. S. L. (1992), FCD/I Agricultural Study, FAP-12, Main Report, Vol. 1, FPCO, Dhaka.

Huntjens, P., Pahl-Wostl, C., Rihoux, B., Schlüter, M., Flachner, Z., Neto, S., & Nabide, K. I. (2011). Adaptive water management and policy learning in a changing climate: a formal comparative analysis of eight water management regimes in Europe, Africa and Asia. *Environmental Policy and Governance*, *21*(3), 145–163.

Islam, G. M. T., Islam, A. S., Shopan, A. A., Rahman, M. M., Lázár, A. N., & Mukhopadhyay, A. (2015). Implications of agricultural land use change to ecosystem services in the Ganges delta. *Journal of Environmental Management*, *161*, 443–452. https://doi.org/https://doi.org/10.1016/j.jenvman.2014.11.018

Islam, K., Jashimuddin, M., Nath, B., & Nath, T. K. (2018). Land use classification and change detection by using multi-temporal remotely sensed imagery: The case of Chunati wildlife sanctuary, Bangladesh. *The Egyptian Journal of Remote Sensing and Space Science*, *21*(1), 37–47. https://doi.org/10.1016/j.ejrs.2016.12.005

Islam, M. R. (2006). 18 Managing diverse land uses in coastal Bangladesh: institutional approaches. *Environment and livelihoods in tropical coastal zones*, 237.

Islam, M. R., & Tabeta, S. (2019). Shrimp vs prawn-rice farming in Bangladesh: A comparative impacts study on local environments and livelihoods. *Ocean & Coastal Management*, *168*, 167–176.

Islam, W., & Sarker, S. C. (2016). Monitoring the Changing Pattern of Land Use in the Rangpur City Corporation Using Remote Sensing and GIS. *Journal of Geographic Information System*, *08*(04), 537–545. https://doi.org/10.4236/jgis.2016.84045

Jacob, D. P., Jennifer C. Veilleux & Aaron, T. W. (2017): International water conflict and cooperation: challenges and opportunities, *Water International*, DOI: 10.1080/02508060.2017.1276041.

Jahan, K. M., Ahmed, M., & Belton, B. (2010). The impacts of aquaculture development on food security: Lessons from Bangladesh. *Aquaculture Research*, 41, 481–495.

Jahan, K. M., Belton, B., & Vishwanathan, K. (2014). Communication strategies for managing coastal fisheries conflicts in Bangladesh. *Ocean & Coastal Management*, 92, 65–73.

Jenson, S. K., & Domingue, J. O. (1988). Extracting topographic structure from digital elevation data for geographic information system analysis. *Hotogrammetric Engineering and Remote Sensing*, *54(11)*, 1593–1600.

Jansen, E.G., Dolman, A.J., Jerve, A.M. & Rahman, N.(1994), The Country Boats of Bangladesh, Social and Economic Development and Decision Making in Inland Water Transport, 3rd impression, pp. 54, University Press Limited, Dhaka.

Jonathan, S. (2015). *"Conflict Transformation", Key Concepts in Intercultural Dialogue*.

Juul, K. 2001. Power, pastures and politics: Boreholes and decentralisation of local resource management in northern Senegal. In Benjaminsen, T.A. and Lund, C. (Eds), Politics, property and production in West African Sahel: Approaches to natural resource management, pp: 57-74.

Karim, M., Meisner, C. A., & Phillips, M. (2013). Shrimp (Penaeus monodon) farming in the coastal areas of Bangladesh: Challenges and prospects towards sustainable development.

Karim, M., & Stellwagen, J. (1998). Final Report on Fourth Fisheries Projects: Shrimp Aquaculture (Preparatory Phase for National Development Program). Department of Fisheries, Ministry of Fisheries & Livestock, Bangladesh.

Khalequzzaman, M. (2019). Transboundary river flow: The future of Bangladesh depends on it. *The Daily Star*.

Khan, A., & Awan, N. (2020). Inter-provincial water conflicts in Pakistan: a critical analysis. *Journal of South Asian and Middle Eastern Studies*, *43*(2), 42-53.

Kiousopoulos, J. (2008). Methodological approach of coastal areas concerning typology and spatial indicators, in the context of integrated management and environmental assessment. *Journal of Coastal Conservation*, *12*, 19–25. https://doi.org/10.1007/s11852-008-0019-6

Kramer, A. (2004). Water and conflict (Policy briefing for USAID). Berlin, Bogor, Washington, DC: Adelphi Research, Center for International Forestry Research, Woodrow Wilson International Center for Scholars.

Krug, J. A. (1957). *Water and Power Development in East Pakistan.* Report of a UN Technical Assistance Mission, New York.

Kulsum, U., (2020). Supporting adaptive delta management: systematic exploration of community livelihood adaptation as uncertainty. Delft, The Netherlands: Delft University of Technology.

Kumar, K. (1989). *Conducting key informant interviews in developing countries*. Agency for

International Development Washington DC.

Lambin, E. F.; Geist, H. J.; Lepers, E. (2003). Dynamics of Land use and land cover change in tropical regions. *Annual Review of Environment and Resources,* 28(1), 205–241. doi:10.1146/annurev.energy.28.050302.105459

Lecoutere, E. (2011). Institutions under construction: resolving resource conflicts in Tanzanian irrigation schemes. *Journal of Eastern African Studies*, *5*(2), 252–273.

Lenton, R., & Muller, M. (2012). Integrated water resources management in practice: Better water management for development. *Routledge*.

López-Serrano, P. M., Corral-Rivas, J. J., Díaz-Varela, R. A., Álvarez-González, J. G., & López-Sánchez, C. A. (2016). Evaluation of radiometric and atmospheric correction algorithms for aboveground forest biomass estimation using Landsat 5 TM data. *Remote Sensing*, *8*(5), 369.

Lu, D., Mausel, P., Brondízio, E., & Moran, E. (2004). Change detection techniques. *International Journal of Remote Sensing*, *25*(12), 2365–2401. https://doi.org/10.1080/0143116031000139863

Madulu, N., & Zaba, B. (1998). Water availability and rural migration in Mwanza region, Tanzania. *Tanzanian Journal of Population Studies and Development*, *5*(1 and 2), 23–38.

Marschke, M. (2012). *Life, fish and mangroves: Resource governance in coastal Cambodia*. University of Ottawa Press/Les Presses de l'Université d'Ottawa.

Mas, J. F. (1999). Monitoring land-cover changes: A comparison of change detection techniques. *Int. J. Remote Sens*, *20*, 139–152. https://doi.org/https://doi.org/10.1080/014311699213659

Mbonile, M. J. (2005). Migration and intensification of water conflicts in the Pangani Basin, Tanzania. *Habitat International*, *29*(1), 41–67.

Mehta, L. 2005. The politics and poetics of water: Naturalising scarcity in Western India. New Delhi: Orient Longman.

Memoire A. (2015). Mid Term Review Blue Gold Program Updated. Mid Term Review Mission (MTR) of the Blue Gold Program. (BGP)https://mail.google.com/mail/u/0/?tab=rm&ogbl#sent/FMfcgzGrbHwllgSQlBKWMVtdFCBkdCJC?projector=1&messagePartId=0.5

Mirza, M.M.Q & Ericksen, N.J. (1996), Impact of Water Control Projects on Fisheries Resources in Bangladesh, *Environmental Management*, 20(4), 523-539.

Mitchell, C. (2002). Beyond resolution: what does conflict transformation actually transform?

Peace and Conflict Studies, *9*(1), 1–23.

MoWR. (2000). *Guidelines for Participatory Water Management.* Ministry of Water Resources. Government of the People's Republic of Bangladesh.

MoWR. (2001). *Summary of National Water Management Plan 2001.* Ministry of Water Resources. Government of People's Republic of Bangladesh.

MoWR. (2015). *National WaterbPolicy, 1999.* Ministry of Water Resources. Government of People's Republic of Bangladesh. *Available at:* https://mowr.gov.bd/site/files/328fb561-f1db-4c88-97f1-04ac01eaf851/National-Water-Policy-1999 (accessed 11 November 2020).

Mozahedy, A. B. M. K. (2011). *Social perceptions and technical evaluation of performance of selected water control structures in Narail district*.

Mujwahuzi, M. R. (2001). Water use conflicts in the Pangani Basin. *Water Resources Management in the Pangani River Basin*, 128–137.

Murshed-e-Jahan, K., Belton, B., & Viswanathan, K. K. (2014). Communication strategies for managing coastal fisheries conflicts in Bangladesh. *Ocean and Coastal Management*, *92*, 65–73. https://doi.org/10.1016/j.ocecoaman.2014.01.003

Murshed, S. B & Khan, M. S. A. (2009). Water Use Conflict between Agriculture and Fisheries in a Selected Water Resources Development Project in Bangladesh. *South Asia Water Journal*, *1*(2), 159–183.

Murshed, S. B. (2009). *Management of conflicts between irrigation and fisheries in a selected water resources project.* MSc in Water Resources Development. Bangladesh University of Engineering and Technology.

Mutahara, M., Warner, J. F., & Khan, M. S. A. (2020). Multi-stakeholder participation for sustainable delta management: a challenge of the socio-technical transformation in the management practices in Bangladesh. *International Journal of Sustainable Development & World Ecology*, *27*(7), 611–624.

Nath, S., van Laerhoven, F., Driessen, P., & Nadiruzzaman, M. (2020). Capital, rules or conflict? Factors affecting livelihood-strategies, infrastructure-resilience, and livelihood-vulnerability in the polders of Bangladesh. *Sustainability Science*, *15*(4), 1169–1183.

Naz, F., & Buisson, M. C. (2015). Multiple actors, conflicting roles and perverse incentives: the case of poor operation and maintenance of coastal polders in Bangladesh. *Revitalizing the Ganges Coastal Zone: Turning Science into Policy and Practices Conference Proceedings.*

Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food (CPWF). 600pp, 147.

Nguyen, H.Q., et al., (2020a). Socio-ecological resilience of mangrove-shrimp models under various threats exacerbated from salinity intrusion in coastal area of the Vietnamese Mekong Delta. *International Journal of Sustainable Development & World Ecology*, 4509, 1–14. doi:10.1080/13504509.2020.1731859

Nguyen, H.Q., et al., (2019a). Farmer adoptability for livelihood transformations in the Mekong Delta: a case in Ben Tre province. *Journal of Environmental Planning and Management*, 62 (9), 1603–1618. doi:10.1080/09640568.2019.1568768

Nguyen, H.Q., et al., (2019b). Evaluation of retrofitting responses on urban flood in Ho Chi Minh City using Motivation and Ability (MOTA) framework. Sustainable cities and Society, 47, 101465. doi:10.1016/j. scs.2019.101465. Nguyen, H.Q., et al., 2020. Land use dynamics in the Mekong delta: from national policy to livelihood sustainability. *Sustainable development*. doi:10.1002/SD.2036.

Nguyen-Khoa, S., & Smith, L. E. D. (2004). Irrigation and fisheries: irreconcilable conflicts or potential synergies? *Irrigation and Drainage: The Journal of the International Commission on Irrigation and Drainage*, 53(4), 415–427.

Noshab, F., & Mushtaq, N. (2001). Water disputes in South Asia. Strategic Studies, 21(3), 78-104.

Noor, S. (2018). *Investigation on polderization indiced water logging and feasible adaptation measures in Dumuria Upazulla under Khulna District.* MSc in Water Resources Development, Bangladesh University of Engineering and Technology.

O'Callaghan, J. F., & Mark, D. M. (1984). The extraction of drainage networks from digital elevation data. *Computer Vision, Graphics, and Image Processing*, *28(3)*, 323–344.

ODA. (1995) *Fisheries Studies and Pilot Project*. Final Report, FAP – 17. Overseas Development Administration, UK.

Odhiambo, G. O. (2017). Water scarcity in the Arabian Peninsula and socio-economic implications. *Applied Water Science*, *7*(5), 2479–2492.

Pahl-Wostl, C., Conca, K., Kramer, A., Maestu, J., & Schmidt, F. (2013). Missing links in global water governance: a processes-oriented analysis. *Ecology and Society*, *18*(2).

Pani, N. (2010). The place of the tribunal in inter-state water disputes. *South Asian Water Studies Journal SAWAS*, *2*(1), 37-48.

Paprocki, K., & Cons, J. (2014). Life in a shrimp zone: aqua-and other cultures of Bangladesh's coastal landscape. *Journal of Peasant Studies*, *41*(6), 1109-1130.

Parven, A., & Hasan, M. S. (2018). Trans-boundary water conflicts between Bangladesh and India: water governance practice for conflict resolution. *International Journal of Agricultural Research, Innovation and Technology*, *8*(1), 79–84.

Parvin, G. A., Ali, M., Fujita, K., Abedin, M., Habiba, U., & Shaw, R. (2017). Land use change in southwestern coastal Bangladesh: Consequence to food and water supply. In *Land use management in disaster risk reduction* (pp. 381–401). Springer.

Paul, A. K. & Røskaft, E. (2013). Environmental degradation and loss of traditional agriculture as two causes of conflicts in shrimp farming in the southwestern coastal Bangladesh: Present status and probable solutions. *Ocean & Coastal Management,* p 19–28. doi:10.1016/j.ocecoaman.2013.08.015

Paul, M. T. (1996) Operation and Maintenance Performance and Conflicts in Flood-control Projects in Bangladesh. *International Journal of Water Resources Development*, 12:3, 311-328, DOI: 10.1080/07900629650196

Peters, C. N., Baroud, H., & Hornberger, G. M. (2019). Multicriteria decision analysis of drinking water source selection in southwestern Bangladesh. *Journal of Water Resources Planning and Management*, *145*(4), 5019004.

Peters, P. 1984. Struggles over access, struggles over meaning: Cattle, water and the state in Botswana. Africa 54(3): 29-50.

Phi, H. L., et al. (2015). A framework to assess plan implementation maturity with an application to flood management in Vietnam. *Water International*, 40 (7), 984–1003. doi:10.1080/02508060. 2015.1101528

Pokrant, B., & Reeves, P. (2001). Putting globalisation in its place: Globalisation, liberalisation and export-orientated aquaculure in West Bengal and Bangladesh. *South Asia: Journal of South Asian Studies*, *24*(1), 159-184.

Quan, N., Guerra, J., Korbee, D., Luan, P., Dung, T., Hung, D., Loc, H., & Hermans, L. (2019). Manual for Application of the MOTA Framework: Theory and Practice, Center of Water Management and Climate Change, Vietnam National University, Ho Chi Minh City, Vietnam.

Rahman, A. (1995). *Beel Dakatia: The environmental consequences of a development disaster, Dhaka*. Bangladesh: University Press Limited (UPL).

Rahman, M. H., Lund, T., & Bryceson, I. (2011). Salinity impacts on agro-biodiversity in three coastal, rural villages of Bangladesh. *Ocean & Coastal Management*, *54*(6), 455–468.

Rahman, M. M., Giedraitis, V. R., Lieberman, L. S., Akhtar, T., & Taminskiene, V. (2013). Shrimp cultivation with water salinity in Bangladesh: The implications of an ecological model. *Universal Journal of Public Health*, *1*(3), 131–142.

Rahman, M. M., Imam, M. H., Roy, S., Hoque, F., & Ahsan, U. (2021). *Analysis of Long-term Rainfall Trends in Bangladesh*.

Rahman, M.S., Salehin, M. (2009). Water management of integrated rice-fish farming in inundated floodplains: A case study. *Journal of Agricultural Engineering*, The Institution of Engineers, Bangladesh, Vol. 37/AE, December 2009.

Ramirez, R. (1999). Stakeholder analysis and conflict management. In *Cultivating peace: conflict and collaboration in natural resource management*. IDRC, Ottawa, ON, CA.

Rasheed, K.B.S. (1995), Potentials and Constraints of Inland Water Transport Development in Bangladesh, *Asia Pacific Journal on Environment and Development*, Bangladesh Unnayan Parishad, 2(1), 40-52.

Renner, J., & Opiyo, F. (2021). Stakeholders' interactions in managing water resources conflicts: a case of Lake Naivasha, Kenya. *Zeitschrift Für Wirtschaftsgeographie*, *65*(3–4), 165–181.

Rijsberman, F. R. (2006). Water scarcity: fact or fiction? *Agricultural Water Management*, 80(1–3), 5–22.

Rwanga, S. S., & Ndambuki, J. M. (2017). Accuracy assessment of land use/land cover classification using remote sensing and GIS. *International Journal of Geosciences*, *8*(04), 611.

Sadik, M.S., Hermans, L.M., Evers, J., Nguyend, H.Q., Khan, M.F.A., & Ahmed, S. (2022). Assessing the societal adoptability of participatory water management: an application of the Motivation and Ability (MOTA) framework. *Water Policy*, Vol 24, No 5, 729, doi: 10.2166/wp.2021.255.

Sanchayan, N., Driessen, P., & Md, N. (2020). Capital, rules or conflict? Factors affecting livelihood-strategies, infrastructure-resilience, and livelihood-vulnerability in the polders of Bangladesh. *Sustainability Science*, *15*(4), 1169–1183.

Saumyarathna, N. G. R., Gunawardena, E. R. N., & Dayawansa, N. D. K. (2016). Water conflicts among different water users and uses in the Hakwatuna Oya watershed in the Deduru Oya basin, Sri Lanka.

Seter, H., Theisen, O. M., & Schilling, J. (2018). All about water and land? Resource-related conflicts in East and West Africa revisited. *GeoJournal*, *83*(1), 169-187.

Shafi, M. (2003). Impact of Flood Control Drainage and Irrigation (FCDl) on Inland Fisheries of Bangladesh, In: *Bangladesh Fisheries, Academic Press and Publisher, Ltd.,* Dhaka.

Sharmin, S., & Ali, R. N. (2005). Socioeconomic analysis on factors contributing to household income of the stakeholders involved in shrimp industry of Bangladesh. *Bangladesh Journal of Agricultural Economics*, 28(454-2016-36536), 85-96.

Shawinigan Lavalin Inc. (1993), Water Transport Study, Northeast Regional Water Management Project, FAP-6, FPCO.

Silva, S. de. (2012). *Literature Review: The Experiences of Water Management Organizations in Bangladesh*.

Skarlato, O. (2013). *Environmental and resource conflicts and conflict resolution practices in coastal areas of the North American Great Lakes: towards an integrated approach for policymaking*.

Stanghellini, P. S. L. (2010). Stakeholder involvement in water management: the role of the stakeholder analysis within participatory processes. *Water Policy*, *12*(5), 675–694.

Stetter, S., Herschinger, E., Teichler, T., & Albert, M. (2011). Conflicts about water: Securitizations in a global context. *Cooperation and Conflict*, *46*(4), 441-459.

Subramanya, K. (2013). *Engineering hydrology, 4e*. Tata McGraw-Hill Education.

Sultana, P., & Thompson, P. M. (2017). Adaptation or conflict? Responses to climate change in water management in Bangladesh. *Environmental Science & Policy*, *78*, 149-156.

Sultana, P., Thompson, P. M., & Daplyn, M. G. (1995). Impact of surface water management projects on agriculture in Bangladesh. *Project Appraisal*, *10*(4), 243–259.

Sultana, P., Thompson, P. M., Paudel, N. S., Pariyar, M., & Rahman, M. (2019). Transforming local natural resource conflicts to cooperation in a changing climate: Bangladesh and Nepal lessons. *Climate Policy*, *19*(sup1), S94–S106.

Swarnokar, S. C., Ashik-Ur-Rahman, M., & Mou, S. I. (2020). Conflict of resource use among different livelihood group in coastal villages of SouthWestern Bengal Delta, Bangladesh. *Int J Sustain Dev Plan*, *15*, 1089–1099.

Swatuk, L.A and Wirkus, L. (Eds). 2009. Transboundary water governance in Southern Africa: Examining underexplored dimensions. Bonn: Nomos Press.

Tamas, P. (2003). Water resource scarcity and conflict: Review of applicable indicators and systems of reference. *Unesco*, *1*(75), 15.

TCWT. (2011). *Run Off Coefficient. The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment State Water Resources Control Board 5.1.3 FS-(RC)* (Issue C).

Teillet, P. M. (1986). Image correction for radiometric effects in remote sensing. *Int. J. Remote Sens*, *7*, 1637–1651. https://doi.org/https://doi.org/10.1080/01431168608948958

Toufique, K. A., & Belton, B. (2014). Is aquaculture pro-poor? Empirical evidence of impacts on fish consumption in Bangladesh. *World Development*, *64*, 609-620.

Tsilimigkas, G., & Rempis, N. (2018). Marine uses, synergies and conflicts. Evidence from Crete Island, Greece. *Journal of Coastal Conservation*, *22*(2), 235–245. https://doi.org/10.1007/s11852-017-0568-7

Turner, B. L., Lambin, E. F., & Verburg, P. H. (2021). *From land-use/land-cover to land system science*. Ambio. https://doi:10.1007/s13280-021-01510-4

Turker, M., & Asik, O. (2002). Detecting land use changes at the urban fringe from remotely sensed images in Ankara, Turkey. *Geocarto Int.*, *17*, 47–52. https://doi.org/https://doi.org/10.1080/10106040208542243

UNFAO. (2010). *United Nations Food and Agricultural Organization.* Municipal water withdrawal. AQUASTAT Database. http://www.fao.org/nr/water/aquastat/data/query/results.html

Uprety, D. R. (2006). Conflicts in natural resource management - Examples from community forestry. *Journal of the Austrian Society of Agricultural Economics*, *15*, 143–155.

USAID. (2006). A pro-poor analysis of the shrimp sector in Bangladesh. Greater access to trade expansion (GATE) project. Development and Training Services, Inc. (DTS), Office of Women in Development, US Agency for International Development.

Van Eeuwijk, P., & Angehrn, Z. (2017). *How to… Conduct a Focus Group Discussion (FGD). Methodological Manual*.

Vidal, A., Harrington, L. W., & Fisher, M. J. (2014). Water scarcity and abundance, water productivity and their relation to poverty. In *Water scarcity, livelihoods and Food Security* (pp. 29–58). Routledge.

Wang, R. Y., Ng, C. N., Lenzer Jr, J. H., Dang, H., Liu, T., & Yao, S. (2017). Unpacking water conflicts: A reinterpretation of coordination problems in China's water-governance system. *International Journal of Water Resources Development*, 33(4), 553–569.

Wennersten, R. (2008). *Conflict Resolution in Coastal Zone Management*. Peter Lang Publications, Frankfurt.

Wolf, A. T., Stahl, K., & Macomber, M. F. (2003). Conflict and cooperation within international river basins: The importance of institutional capacity. *Water Resources Update*, *125*(1), 31-40.

Wolf, A. T., Yoffe, S. B., & Giordano, M. (2003). International waters: identifying basins at risk. *Water policy*, *5*(1), 29-60.

Wolf, A. T. (2007). Shared waters: Conflict and cooperation. *Annual review of Environment and resources*, *32*(1), 241-269.

Yapa et al., (2020). Head-tail disparity in irrigation management in Sri Lanka: A review of empirical evidence. *Malaysian Journal of Society and Space*, *16*(4), 45-55.

Zeitoun, M. and Allan, J.A. 2008. Applying hegemony and power theory to transboundary water analysis. *Water Policy* 10(S2): 3-12.