



Capital, rules or conflict? Factors affecting livelihood-strategies, infrastructure-resilience, and livelihood-vulnerability in the polders of Bangladesh

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Abstract

Coastal regions are most susceptible to the effects of climate change. To increase infrastructure-resilience of such regions, reduce livelihood-vulnerability of people living in such regions and equip them with appropriate livelihood strategies, governments have invested heavily in coastal infrastructure such as polders. This research is focused on the polders of Bangladesh. The effectiveness of Bangladesh's polders is disputed. No large-scale, evaluative, quantitative analysis of polders has yet been conducted. There is also only a limited number of evaluative studies on the factors which affect livelihood strategies, livelihood-vulnerability or infrastructure-resilience in polders. Therefore, the research question guiding this research is: What factors affect livelihood strategies, infrastructure-resilience, and livelihood-vulnerability in the polders of Bangladesh? These questions are answered by drawing on propositions from the Sustainable Livelihood Approach (SLA) using statistical analysis of a dataset of 137 polders. This dataset has been created from 76 survey-based interviews, secondary research and geo-spatial analysis. It is hypothesized that under different contextual settings, different combinations of livelihood resource endowments, lead to different combinations of livelihood strategies. These combinations of livelihood strategies lead to different outcomes after being moderated by different institutional, and political settings, under different contextual settings. This research demonstrates that various kinds of conflict-related and rule-making variables affect sustainability outcomes. Relationships proposed by the SLA are statistically significant and are generalizable across a large number of heterogeneous sites. Geological, geomorphological, climatic and hydrological conditions also affect livelihood decisions of polder-residents and also affect the condition of polder-infrastructure.

Keywords Institutions · Conflict · Vulnerability · Resilience · Polder · Sustainable livelihood approach

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Introduction

The effects of climate change are being felt across the world (Cheung et al. 2009). Coastal regions are most susceptible to its effects. However, such regions are also densely populated and are an important source of livelihood for the local populace. Therefore, it is necessary to analyze the factors which affect the livelihood strategies adopted by local communities

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in coastal regions. In addition, it is also necessary to analyze if such strategies and other factors are affecting the vulnerability of people whose livelihood depends on the services provided by the world's coastal regions (Renaud et al. 2013).

To reduce the livelihood-vulnerability of people living in such regions, to equip them with appropriate livelihood strategies and to manage land–water dynamics along the coastal belt, governments have invested heavily in coastal infrastructure such as dykes, embankments, *polders* (defined in Section “[Conceptualizing polders](#)”) and other polder-like-structures. Such infrastructure must be resilient to (e.g. climate-change related) shocks, to continue to protect the inhabitants of coastal regions (Renaud et al. 2013).

The first polders and polder-like-structures originated in the Netherlands in the 11th century. Over the years, other countries too have constructed such structures across their coastal regions: Bangladesh, China and India in Asia; Egypt & Morocco in Africa, Belgium & Denmark in Europe; USA in North America; and, Argentina and Venezuela in South America (Inniss and Simcock 2016).

In line with such concerns, this research is focused on the polders of Bangladesh. This is because Bangladesh is amongst the top six countries most affected by extreme weather events (Kreft et al. 2016). For decades it has been plagued by sea-level rise, increasing tidal surges, salt-water intrusion into its downstream riverine system, depleting water levels in its upstream riverine system, coastal flooding, land erosion as-well-as land subsidence, increased incidences of a wide range of extreme events ranging from droughts to cyclones, increasingly erratic precipitation, increasing temperatures, depleting water levels and arsenic contamination (Alam et al. 2017; GED, 2017; Adnan et al. 2019). The coastal belt of Bangladesh is more prone to extreme weather events as compared to the rest of the country (GED 2017).

The coastal belt of Bangladesh is characterized by more than 140 polders which have been constructed since the late-1960s to protect the region from flooding, tidal surges and water-level rise (Alam et al. 2017). Bangladesh invests less than 2% of its GDP in infrastructure development (WB 2015; GED 2017). Not-surprisingly, Bangladesh was ranked 127th globally in ‘quality of infrastructure’ by the World Economic Forum in its global competitiveness report of 2014–2015 (WB 2015). Therefore, the effectiveness of Bangladesh’s polders is increasingly disputed and the resilience of such infrastructure needs to be studied in greater detail. Auerbach et al. (2015) have argued that hydrological structures (dykes, sluiceways, etc.) associated with these polders are unreliable. They are subject to erosion and sometimes get breached during extreme weather events (Adnan et al. 2019).

Polderization of the coastal belt in Bangladesh has had profound effects on the livelihood strategies of the local

populace. While the amount of land used for agriculture has decreased, the amount of land used for aquaculture has increased (Akber et al. 2018). While contributing to the economic development of the region, these changes may have also led to increasing poverty levels, thus affecting livelihood-vulnerability in the coastal belt of Bangladesh (Mukhopadhyay et al. 2018).

In line with such concerns, the research question guiding this research is: what factors affect livelihood strategies, infrastructure-resilience, and livelihood-vulnerability in the polders of Bangladesh? The objective of this research is to increase our understanding of how livelihood resource endowments, physiographic variables, hydrological variables, institutional variables, political variables, and contextual variables affect livelihood strategies, infrastructure-resilience, and livelihood-vulnerability in the polders of Bangladesh. These questions are answered using statistical analysis of a dataset of 137 polders in Bangladesh.

Literature review and theoretical approach

Conceptualizing polders

A polder can be conceptualized as a piece of land surrounded by embankments (Segeren 1982; Ishtiaque et al. 2017). The embankment separates this piece of land from the surrounding hydrological regime. In polders, embankments protect the enclosed land from flooding. Sluiceways are used to control the flow of water between the polder and the surrounding hydrological regime. Canals convey water to and from the embankment into various sections of the polder (Segeren 1982; Ishtiaque et al. 2017). As most polders are inhabited and are characterized by a wide range of livelihood strategies, they can be theoretically conceptualized as a coupled socio-hydrological system (Di Baldassarre et al. 2013).

The academic disciplines of hydrology and society have traditionally been studied as separate entities. Research in hydrology has often assumed that human agency is exogenous to hydrological or societal change. Similarly, the social sciences have ignored the bi-directional nature of the interaction between societal and hydrological systems (Pande and Sivapalan 2017). However, in a polder, interactions between the social system and the hydrological system are bi-directional. For instance, when an embankment is breached by an extreme event, saline water may flood agricultural lands within the polder, and disrupt the traditional ways of life for the local populace, and increase poverty levels. In contrast, the local populace may deliberately breach their embankment because they may feel that the flow of saline water may increase the aquaculture potential of the region, which in turn may lead to the economic development of the area.

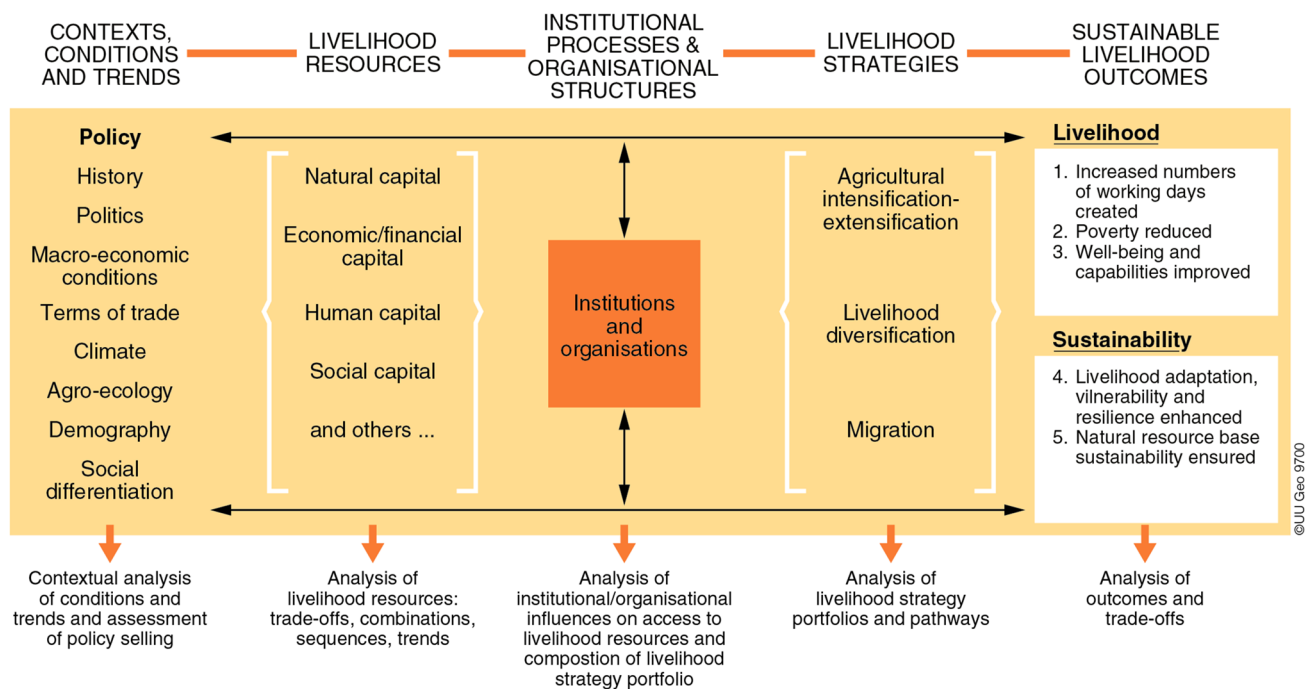


Fig. 1 Variables provided by the Sustainable Livelihood Approach Adapted from Scoones (2015)

In other words, a change in the hydrological system brought about either by the associated social system or the hydrological system itself affects the livelihood-vulnerability and infrastructure-resilience of the region.

Livelihood-vulnerability and infrastructure-resilience

The literature on vulnerability and resilience is characterized by conceptual fuzziness over whether they can be theoretically distinguished from each other (Gallopín 2006). The literature of resilience and the literature on vulnerability are both concerned with understanding how systems respond to stresses and disturbances. Both literatures also acknowledge the role of institutions in ‘buffering’ shocks (Nelson et al. 2007; Miller et al. 2010).

However, based on a comprehensive survey of such literature, Miller et al. (2010) argued resilience and vulnerability are ‘related yet different’ (Turner 2010). Resilience analyzes the effect of socio-ecological, biophysical, geophysical, ecological and engineering factors (and processes) on systemic change. In contrast, vulnerability analyzes the effect of socio-political and socio-economic factors (and processes) on systemic change (Nelson et al. 2007; Miller et al. 2010). Since this article is interested in the resilience of socio-hydrological structures such as polders (and associated infrastructures such as dykes, embankments and sluice-gates), this article is narrowly focused on the concept of infrastructure-resilience. Therefore, as argued by Brand and

Jax (2007), McDaniels et al. (2008), Cutter et al. (2008) and Chang (2014), this article defines infrastructure-resilience as the ability of infrastructure in a system to consistently remain in a stable state or return to a stable state by withstanding, absorbing or adjusting to shocks and disturbances.

This article is interested in the vulnerability of social systems associated with hydrological structures such as polders. In these polders livelihood strategies of the local populace are actively defined by their interactions with polders and associated hydrological structures. Therefore, this article is narrowly focused on the concept of livelihood-vulnerability. As argued by Adger (2006) and Hahn et al. (2009), this article conceives livelihood-vulnerability as a measure of how secure the current livelihood strategies of the designated community are when exposed to various shocks and disturbances, as-well-as the capacity of the community to adapt their livelihood strategies in response to such shocks and disturbances.

Studying livelihood-vulnerability and infrastructure-resilience in polders using the Sustainable Livelihood Approach

This article draws on the Sustainable Livelihood Approach (henceforth referred to as SLA) to identify the factors which affect livelihood strategies, livelihood-vulnerability and infrastructure-resilience in polders. This is because, as discussed later, SLA is a useful tool for analyzing how structure (societal or hydrological) interacts with the human

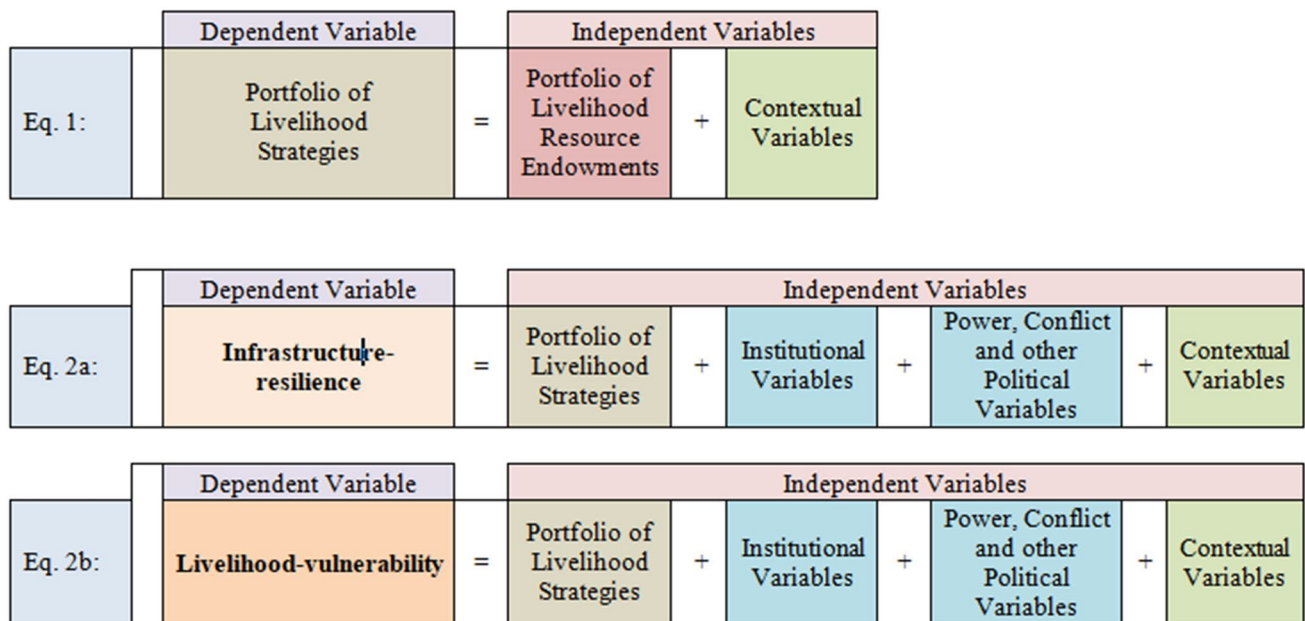


Fig. 2 Theoretical model

agency to affect systemic outcomes (Scoones 1998, 2015). It can be used to study how climate change affects the livelihood strategies of people living in a polder and how such strategies shapes the vulnerability of this population or the resilience of the polder infrastructure (Mersha and van Laerhoven 2016).

The SLA emerged in a working paper by Chambers and Conway (1992). In the decades thereafter, a wide variety of empirical work based on this approach was conducted to understand how communities adapt their livelihood strategies in the face of various shocks and disturbances. This characteristic of the SLA makes it useful for analyzing how variables from both the social as-well-as the natural sciences are associated with livelihood-vulnerability, infrastructure-resilience or adaptive capacity of a coupled system (Mersha and van Laerhoven 2016). Figure 1 illustrates the variables associated with the SLA (Scoones 1998, 2015). Appendix 1 of the Supplementary File lists the definitions of these variables.

According to Scoones (1998, 2015), this framework of variables has been designed to serve as a ‘diagrammatic checklist’ of how various societal as-well-as contextual (hydrological, geographical, ecological, etc.) variables interact with each other. The approach can be applied across a wide range of scales—ranging from the individual-level to more aggregated regional-levels. The starting point of analysis within the approach is the identification of different kinds of resources available for use by the local populace. The framework identifies four main types of resources: natural, economic, social and human. However, other kinds of

capital (such as physical capital) can also be included for analysis. The local population use varied combinations of such resources to develop various kinds of livelihood strategies (such as agricultural intensification/extensification, livelihood diversification or migration). This capability of people to successfully use diverse resources to develop diverse livelihood strategies may explain differences in the livelihood-vulnerability and infrastructure-resilience of the system they are a part of (Morse and McNamara 2013a). Such livelihood strategies when mediated by various institutional (rules, norms, customs, property tenure, markets, etc.) variables, in different contexts (hydrological, geographical, ecological, etc.), produce different kinds of outcomes (Scoones 1998, 2015). Two broad categories of outcomes are possible in the SLA: (a) livelihood-related—i.e. variation in livelihood strategies, variation in poverty-levels etc. and, (b) sustainability-related—i.e. variation in livelihood-vulnerability, infrastructure-resilience or adaptability, etc. The relationship between resources, livelihood strategies, contextual variables and sustainability-related outcomes such vulnerability & resilience is mediated by institutional and political variables (Scoones 1998; McLennan and Garvin 2012; Morse and McNamara 2013b; Scoones 2015).

However, the SLA has its critiques: namely, (a) the political dimensions of human interactions (power, conflict, decision-making, etc.) have not been adequately captured in the approach (Allison and Horemans 2006; Moser 2008; Scoones 2015); (b) institutional variables have also not been fully integrated into it (de Haan and Zoomers 2005; Scoones 2015). In response to such critiques regarding the

underdeveloped attention of SLA to the political and institutional dimension of human interactions, this article draws upon social-scientific empirical work (Naz and Buisson 2015; Ishtiaque et al. 2017) on polders to identify institutional and political variables which may affect outcome variables such as resilience and vulnerability in polders.

Research methodology

Operationalizing variables and hypothesis

The theoretical model guiding this research, as outlined in Fig. 2, has been derived from the Sustainable Livelihood Approach (Scoones 1998, 2015). As outlined by the research question in the Introduction section, there are two dependent variables: (a) Infrastructure-resilience, and (b) Livelihood-vulnerability. A wide range of independent variables are hypothesized to affect these dependent variables: Livelihood strategies, Livelihood resource endowments, Institutional variables, Political variables, and various Contextual variables (Socio-economic, Hydrological, Ecological, Geographic, Geomorphic, etc.). See Table 1 for more details on these variables. It is hypothesized that these independent variables affect the two dependent variables in a 2-staged manner:

- (a) Under different contextual settings, different combinations of livelihood resource endowments, lead to different combinations of livelihood strategies (Eq. 1);

$$\text{Livelihood Strategies} = \beta_1 \times \text{Livelihood Resource Endowments} + \beta_2 \times \text{Contextual Variables} + \text{constant} \quad (1)$$

- (b) These combinations of livelihood strategies, lead to different outcomes after being moderated by different institutional, and political settings, under different contextual settings (Eqs. 2a & 2b)

$$\text{logit}(p) = \beta_1 \times \text{Livelihood Strategies} + \beta_2 \times \text{Institutional Variables} + \beta_3 \times \text{Power, Conflict and other Political Variables} + \beta_4 \times \text{Contextual Variables} + \text{constant} \quad (2a)$$

where p is the probability (Infrastructure-resilience varies between 0 and 1)

$$\text{logit}(p) = \beta_1 \times \text{Livelihood Strategies} + \beta_2 \times \text{Institutional Variables} + \beta_3 \times \text{Power, Conflict and other Political Variables} + \beta_4 \times \text{Contextual Variables} + \text{constant} \quad (2b)$$

where p is the probability (Livelihood-vulnerability varies between 0 and 1)

Study site

The coastal belt of Bangladesh has more than 140 polders (Map 1). The dataset used for this article analyzes information on 137 polders under the administrative control of Bangladesh Water Development Board (BWDB), a public agency responsible for the administration of surface-water and ground-water resources in Bangladesh. Data-availability issues prevented the authors from collecting information on the rest of the polders.

Research design

Scoones (2015) argues that a wide range of research methods (quantitative, qualitative, deliberative and participatory) can be used to study the relationships encapsulated in the SLA. These relationships are ‘linear in style’ and have been formulated in a ‘mechanical cause-effect’ manner (Morse and McNamara 2013b). However, most studies using this approach have been qualitative in nature. Scoones (2015) therefore calls for more quantitative studies using this approach to statistically evaluate whether the relationships proposed by the approach hold across larger data-sets. In addition, Scoones (1998) argues that such relationships can be best tested by combining ‘survey tools’ with other qualitative and quantitative instruments for data collection and analysis. Therefore, survey-based interviews, secondary data collection and GIS (& spatial) tools are used for data collection and processing. This article then uses multiple regression techniques on generalized linear models to evaluate the relationships proposed by the SLA for analyzing the factors which affect livelihood-vulnerability and infrastructure-resilience of polders.

This article is the first-ever attempt at using regression techniques for analyzing broad & generalizable findings about the various factors which affect resilience and vulnerability in polders. A detailed review of the literature using the string “polders regression OR statistics” on Google Scholar & Scopus reveals that no such large-scale, cross-sectional, quantitative analysis of polders has yet been conducted—neither for Bangladesh nor globally.

Data collection and processing

Three kinds of data collection and data processing techniques have been used in this article: surveys, secondary research and GIS (& spatial) analysis. Data was collected for only those variables identified by the theoretical model outlined earlier. The data collection process was

Table 1 Definitions and source—dependent and independent variables

Type of Variable	Variable Name	Definition	Source
All dependent and independent variables have been normalized to vary within the range 0–1			
Dependent Variables	Dependent variable for Eq. 1		
	Livelihood Strategies	This variable answers the question: What kind of livelihood strategies are adapted by the residents of this polder? This variable ranks polders according to the livelihood strategy. It can take 12 values. (0.00, 0.09, 0.18, 0.27, 0.36, 0.45, 0.55, 0.64, 0.73, 0.82, 0.91, 1.00). Lower values of this variable represent those polders associated with low levels of migration and traditional forms of livelihood such as agriculture. Higher values are associated with polders with a higher level of migration and non-traditional forms of livelihoods such as services etc.	BBS (2011), BBS (2014a, b), BBS (2015)
	Dependent variable for Eq. 2a		
	Infrastructure-resilience	This variable answers the question: How resilient to the effects of climate change is the polder infrastructure? It can take 5 values (0, 0.25, 0.5, 0.75, 1) where, 0 represents 'Very resilient'; 1 represents 'Not resilient at all'	Surveys
Independent variables for all three equations	Dependent variable for Eq. 2b		
	Livelihood-vulnerability	This variable answers the question: How vulnerable is the livelihood of people living in this polder to the effects of climate change? It can take 5 values (0, 0.25, 0.5, 0.75, 1) where, 0 represents 'Not vulnerable at all'; 1 represents 'Severely vulnerable'	Surveys
	Livelihood Strategies	This variable answers the question: What kind of livelihood strategies are adapted by the residents of this polder? This variable ranks polders according to the livelihood strategy. It can take 12 values. Lower values of this variable represent those polders associated with low levels of migration and traditional forms of livelihood such as agriculture. Higher values are associated with polders with a higher level of migration and non-traditional forms of livelihoods such as services etc.	BBS (2011), BBS (2014a, b), BBS (2015)
	Physiographic Region	This variable answers the question: Which physiographic region does this polder predominantly lie in? It can take 17 values depending on the region in which the polder lies.	GIS and spatial analysis, Brammer (2012)
Physiographic Variables			

Table 1 (continued)

Type of Variable	Variable Name	Definition	Source
Hydrological variables	Type of Dyke	This variable answers the question: What kind of dyke characterizes this polder? It can take 3 values: 0 = Interior dyke only; 0.5 = Interior dyke & Sea dyke; 1 = Sea dyke only	Dasgupta et al. (2010), BWDB (2012a, b, 2013)
	Unplanned Inlets	This variable answers the question: How many 'unplanned cuts, gates or pipes' exist in the polder? It takes 3 values: 0, 0.5 and 1; 0 indicates no unplanned inlets; 0.5 indicates some unplanned inlets; 1 indicates many unplanned inlets	Surveys
	Drainage Congestion	This variable answers the question: How much land-area in the polder is characterized by drainage congestion? It takes the natural log of the area of land (in ha) under drainage congestion	Dasgupta et al. (2010), BWDB (2012a, b, 2013)
	Embankment Breach	This variable answers the question: What length of the embankment is breached? It measures the total breach of embankment in km.	Dasgupta et al. (2010); BWDB (2012a, b, 2013)
Portfolio of livelihood resource endowments	Natural Capital	This variable answers the question: How much natural capital do communities living in this polder have access to? This variable ranks polders according to the level of natural capital. It can take 19 values. Natural capital increases as the value of this variable increases	BBS (2010)
	Financial Capital	This variable answers the question: How much financial capital do communities living in this polder have access to? This variable ranks polders according to the level of financial capital. It can take 19 values. Financial capital increases as the value of this variable increases	BBS (2010)
	Social Capital	This variable answers the question: How much social capital do communities living in this polder have access to? This variable ranks polders according to the level of social capital. It can take 4 values. Social capital increases as the value of this variable increases	Surveys
	Community Rule	This variable answers the question: Do polder-residents have a say in the rule-making process? It can take 2 values: 0 = No; 1 = Yes	Surveys
Institutional variables	Seasonal Rule	This variable answers the question: Are seasonal rules used for operating the sluiceways in this polder? It can take 2 values: 0 = No; 1 = Yes	Surveys

Table 1 (continued)

Type of Variable	Variable Name	Definition	Source
Political variables	Conflict Cause	This variable answers the question: What is the primary cause of conflict within the polder? It can take 2 values: 1 = Conflict over operation of sluice gates; 0 = Other causes	Surveys
	Conflict Groups	This variable answers the question: What are the different groups of people involved in conflict with each other in this polder? This variable can take 11 different values depending on the type of groups involved in conflict. Higher values of this variable indicate that a large variety of groups (such as fisherman) are in conflict with local influential people; lower values of this variable represent conflict amongst a smaller variety of less powerful people	Surveys
	Conflict resolution	This variable answers the question: What kind of strategies have residents of this polder adapted, to resolve conflicts within this polder? This variable can take 14 different values depending on the strategy. Lower values of this variable represent simple conflict resolution strategies such as avoidance, collaboration etc. Higher values of this variable represent more complex conflict resolution strategies which combine strategies such as avoidance, accommodation, compromise, competition and collaboration.	Surveys
	Conflict mediation	This variable answers the question: Is third-party mediation required for conflict resolution? This variable can take 3 different values: 0, 0.5 and 1; 0 = conflict resolved locally; 0.5 = some conflicts resolved locally; some required third-party mediation; 1 = all conflicts required third-party mediation, conflicts could not be solved locally	Surveys
	Rehab cost	This variable answers the question: What is the cost of rehabilitating the polder? It takes the natural log of the rehabilitation cost in crores of Bangladeshi Taka (BDT). 1 crore = 10 million; 100 BDT = 1 Euro (approx.)	BBS (2010)

Table 1 (continued)

Type of Variable	Variable Name	Definition	Source
Contextual socio-economic variables	Population density	This variable answers the question: What is the population density in this polder? It takes the natural log of the population density (per sq. km of area) in the districts in which this polder is located	BBS (2014a, b, 2015)
	Toilet access	This variable answers the question: What percentage of households in this polder has access to sanitary toilet facilities? It takes the natural log of the percentage of households with access to sanitary toilet facility, in the districts in which the polders are located	BBS (2014a, b, 2015)
	Water access	This variable answers the question: What percentage of households in this polder has access to tubewells for drinking water? It takes the natural log of the percentage of households with access to tubewells for drinking water, in the districts in which the polders are located	BBS (2014a, b, 2015)
	Electricity access	This variable answers the question: What percentage of households in this polder has access to electricity? It takes the natural log of the percentage of households with access to electricity, in the districts in which the polders are located	BBS (2014a, b, 2015)

geared towards developing a large-N, cross-sectional dataset with each row in the dataset representing one of the polders. Therefore, first, indicators were developed for each variable in the theoretical model. Second, extensive secondary research was conducted to determine whether open-source or proprietary databases exist for measuring each indicator. Third, open-source, secondary data (including maps) was collected, wherever it was possible; and, proprietary databases (including maps) were procured, wherever available. Fourth, a detailed survey questionnaire was developed for the primary collection of data. Fifth, primary data was collected. 76 BWDB officials responsible for administering the 137 polders were surveyed using the survey instrument over a 4 month period, between Sep-2018 and Dec-2018. The surveys were then triangulated to obtain aggregate scores for each polder. GIS (& spatial) analysis was conducted in parallel, to extract numerical information (for statistical analysis) from the maps. Sixth, the large-N, dataset was developed by combining the primary and secondary data. Seventh, statistical analysis was conducted on this dataset.

Appendix 2 of the Supplementary File contains the following additional details on the data collection process used for this research:

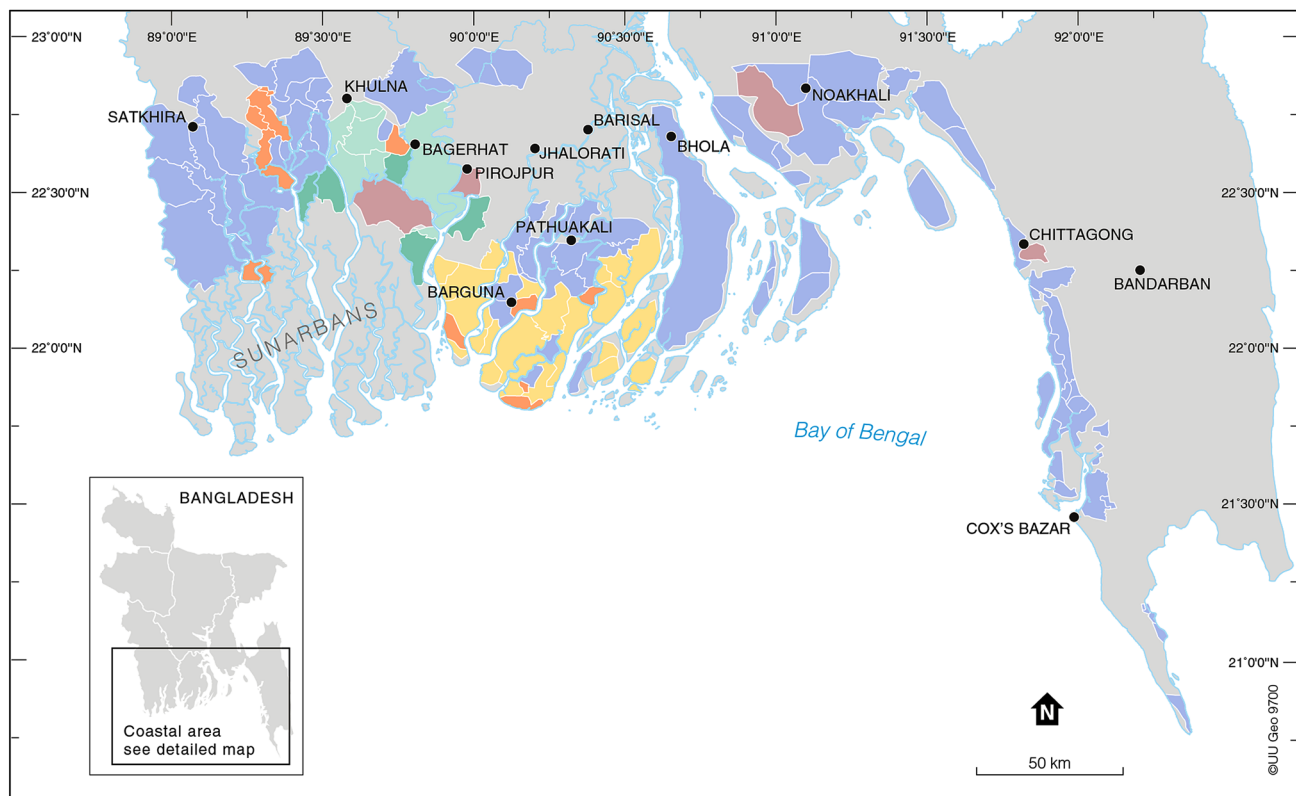
- List of secondary data (including maps) used for preparing the large-N dataset.
- Process followed for developing and testing the questionnaire.
- Questionnaire used for the surveys.
- Process followed for conducting the surveys.
- Profile of survey respondents.
- Triangulation.

Data analysis

The level of analysis is a geo-political region (coastal belt of Bangladesh). The unit of analysis is a polder. The dependent variables and the independent variables used in regression analysis are derived from the equations outlined in Fig. 2 and are defined below in Table 1.

The dependent variable for Eq. 1 is ordered and ranked. It takes 12 values. Since the number of values that the dependent variable takes is greater than 5, ordinary multiple regression using OLS assumptions were used for analysis in Stata. The model was tested for model specification error, linearity errors, multi-collinearity, homoscedasticity of residuals, and normality of residuals. The model demonstrated no such error, after correcting for unusual and influential data.

The dependent variables for Eqs. 2a and 2b are also ordered and ranked. These dependent variables take 5 values. Therefore, proportional odds ordered logistic regression techniques were used for testing these equations in Stata



Map 1 Geographical spread of the polders of Bangladesh. Adapted from Google Maps (2019) and BWDB (2012c)

(Burnham and Ma 2017). 4 different models were tested for Eq. 2a. 2 different models were tested for Eq. 2b. This is because different groups of independent variables affect the two dependent variables under different circumstances. The models were tested for model specification error, multicollinearity and whether the models met the proportional odds assumption. These errors were not detected in the tested models. 7 different models were developed and tested because different combinations of independent variables affect the dependent variables in different ways. These results are summarized and discussed in the next section.

Findings

Table 2 summarizes the findings of regression analysis. Summary statistics on all the variables and the results of the regression analysis (according to model) are detailed in Appendix 3 of the Supplementary File. In general, these findings highlight 6 major points.

It appears that the type of livelihood strategies (self-employment vs. migration or agriculture vs. non-agriculture) adopted by polder-residents affects both the resilience of

polder-infrastructure and the vulnerability of polder-residents (Models 2 and 3 in Table 2). Agriculture has historically been the dominant source of livelihood in most polders. In polders where agriculture is sufficient to meet the day-to-day requirements of residents and migration levels are low, residents are less vulnerable to the effects of extreme events and other shocks. Social capital is high. When faced with sudden shocks and disturbances, residents self-organize and perform stop-gap infrastructural maintenance-activities on their own, in the absence of immediate action by public officials. On the long term, they can also effectively pressurize public officials to invest in more intensive, large-scale infrastructure-maintenance activities. In other words, the infrastructure is more resilient in such polders. However, if agriculture becomes less viable because of various demographic, socio-economic and climatic reasons, outward migration increases. Residents are forced to seek other forms of livelihood (shrimp-farming, brick-making, etc.). However, these forms of livelihood are viable only in those areas which are more difficult to live as they are characterized by higher levels of salinity and are more prone to natural disasters. Residents come under the influence of unscrupulous, rent-seeking employers. Social capital gets reduced. Vulnerability

Table 2 Summary of findings

		Dependent variables							
		Equation 1	Equation 2						
Independent variables			Equation 2a				Equation 2b		
Type of Variable	Variable Name	Livelihood Strategies Model 1	Infrastructure-Resilience				Livelihood-Vulnerability		
			Model 2	Model 4	Model 5	Model 6	Model 3	Model 7	
Portfolio of Livelihood Resource Endowments	Natural Capital	-0.3646*** (0.0890)							
	Financial Capital	0.2190** (0.0819)							
	Social Capital	-0.1919* (0.0855)							
Physiographic	Physiographic Region	-0.2251* (0.0897)	-3.9111*** (0.7452)	-2.8543*** (0.6551)	-4.0060*** (0.7227)	-3.1348*** (0.7375)		-2.2966** (0.8732)	
Hydrological	Type of Dyke		1.6375** (0.5066)	0.9937* (0.483)	1.6096*** (0.4884)	1.2612* (0.5568)	2.4978*** (0.549)	2.0097*** (0.5587)	
	Embankment Breach		2.3820** (0.7888)		1.6372* (0.7634)	1.7266* (0.8685)			
	Unplanned Inlets	-0.3451*** (0.0721)							
Institutional Variables	Community Rule			-1.2540*** (0.3642)				-1.5526*** (0.3980)	
	Seasonal Rule				-1.7265*** (0.3657)	-1.5892*** (0.387)			
Political Variables	Conflict Cause			-0.7292* (0.3511)	-0.7333* (0.3621)				
	Conflict Groups		1.4315* (0.596)				1.3847* (0.6950)		
	Conflict resolution		-2.2894** (0.7068)				-1.3158 (0.7990)	-1.4299 (0.7685)	
	Conflict Mediation					1.4996** (0.5567)			

		Livelihood Strategies Model 1	Infrastructure-Resilience				Livelihood-Vulnerability	
Type of Variable	Variable Name		Model 2	Model 4	Model 5	Model 6	Model 3	Model 7
	Rehab Cost							4.4135*** (1.6369)
Interaction Terms	Livelihood Strategies * Seasonal Rule		-2.6083*** (0.5490)					
	Livelihood Strategies * Community Rule						-2.0585** (0.6647)	
	Physiographic Region * Drainage						3.4793** (1.2914)	
	Population Density	0.2072 (0.1396)						
Contextual socio-economic variables	Toilet Access						-1.9149 (1.1308)	
	Water Access						-1.2251 (0.7984)	
N		125	133	136	133	120	136	136
R ²		0.3975						
LR chi2			LR chi2(6) = 69.19	LR chi2(4) = 40.09	LR chi2(5) = 55.79	LR chi2(5) = 53.44	LR chi2(5) = 54.79	LR chi2(7) = 59.91

*p-values; * p < 0.05, ** p < 0.01, *** p < 0.001*
standard error in parentheses

The grey blocks in this table represent those relationships which were not tested. These relationships were not tested because of the manner in which the SLA argues about how these variables affect each other. For instance, the SLA argues that various forms of capital affect livelihood strategies. Livelihood strategies, in turn, affect vulnerability and resilience. See hypothesis (Section “Study site”) and Table 1

levels increase and residents become less capable to adapt to natural disasters. In such polders, there is a perverse incentive to weaken the embankments (so that saline water can be introduced into the lands to encourage shrimp-farming) or, to carry out sand-mining for brick factories. Infrastructure-resilience in such polders is thus low.

The portfolio of livelihood strategies adopted by polder residents appears to be affected by the portfolio of livelihood resource endowments that polder-residents have access to. Three kinds of livelihood resource endowments (natural capital, financial capital, and social capital) are considered in this article. All the three kinds of capital affect livelihood strategies. As proposed by the SLA, the resource-base that residents have access to, affects their livelihood strategies. Access to financial capital may enable residents to adopt

financially-intensive forms of livelihood options (such as purchasing motor-bikes for providing transportation services). Access to natural capital may enable residents to adopt forms of livelihood which are more dependent on land-based resources (such as agriculture). Access to social capital may enable residents to pursue livelihood strategies which require more coordinated action (Scoones 1998) or may enable residents to access other kinds of resources in times of emergencies (such as short-term loans for buying farm equipment.).

It seems that the rule-making process used for managing polder infrastructure affects outcomes within a polder (Frey 2017). This article analyzes the rule-making process in two ways: a) whether polder-residents have a say in the rule-making process; and, b) whether seasonal rules¹ are used for operating the sluiceways. Livelihood-vulnerability is lower and infrastructure-resilience is higher in polders when polder-residents have a say in the rule-making process. If residents have no say in the operation of the sluiceways, they have no control over how water flows in and out of the sluiceways. Increasing salinity levels in a polder often increase vulnerability levels and if residents have no control over the flow of saline-water into their lands, their vulnerability increases. In addition, if residents have no say in the rule-making process, in the face of shocks or disturbances, their ability to undertake quick, adaptive infrastructure-protection activities gets hampered. Therefore, livelihood-vulnerability is higher and infrastructure-resilience is lower in polders when polder-residents have no say in the rule-making process. Livelihood-vulnerability of residents is not affected by whether seasonal rules are used for operating the sluiceways in polders. This is probably because livelihood vulnerability is not seasonal but is more dependent on aggregate salinity levels in the polder. For instance, daily tidal surges bring saline-water into the polders, and if the operation of sluiceways is not timed with the tidal surges, saline-water continues to enter the polders, irrespective of whether seasonal rules control the operation of sluiceways. Infrastructure-resilience is, however, affected by the seasonal rules used for operating sluiceways. This is probably because the infrastructure in a polder, especially the embankments, is subject to erosion and damage every year due to floods during the monsoon season. Having seasonal rules controlling the flow of water during the flood season probably reduces damages to the infrastructure, thus increasing its resilience.

Conflict is an essential component of decision-making processes (van Laerhoven and Andersson 2013; Frey 2017). Therefore, it is not surprising that in our study a range of conflict-related variables (each capturing a different sub-dimension of conflict) appear to affect outcomes in polders: (a) types of groups involved in conflict; (b) types of strategies adopted to resolve conflict; and (c) whether third-party mediation is required for the conflict resolution. As the number of groups involved in conflict increases, livelihood-vulnerability increases and infrastructure-resilience decreases. This is probably because the intensity of conflict increases as the number of groups increases. When the intensity of

conflict is low, polder-residents use a wide range of strategies (collaboration, competition, compromise, accommodation, and avoidance) to resolve the conflict (Thomas 1992). Polder-residents seek to resolve the conflict locally, without third-party mediation (van Laerhoven and Andersson 2013). As the intensity of conflict increases, residents gradually seek to accommodate the demands of their opponents; when this strategy fails, they seek compromise. However, as the intensity of conflict continues to increase, residents finally run of strategies to resolve conflict and seek third-party mediation.

Hydrological variables (type of embankment and unplanned inlets) also seem to have an effect on polder outcomes. Sea-facing embankments are less resilient and are associated with higher levels of livelihood-vulnerability as compared to embankments located farther away from the sea. This is because the effects of man-made climate change, tidal surges, increase in salinity, flooding and erosion are greater in polders located nearer the sea (BWDB 2012c). The number of unplanned inlets in a polder has a statistically significant relationship with the type of livelihood strategies practiced in polders (see Model 1 in Table 2). Typically, a higher number of unplanned inlets are observed in polders in which a significant chunk of resources is dedicated to shrimp-farming. This is because unplanned inlets are created to increase the flow of saline water into polders. Increasing salinity benefits shrimp farming. Therefore, polders in which residents are more dependent on services-oriented livelihood strategies have a lower number of unplanned inlets as compared to polders associated with aquaculture. Other hydrological variables are mainly used as controls. The effect of these variables on outcome variables is either minimal or statistically insignificant. The cost of rehabilitating polders is another variable used as a control variable. Similarly, a number of contextual socio-economic variables are also used as controls. The effect of these contextual variables on outcome variables is statistically insignificant, in most of the tested models.

The polders under consideration are heterogeneous in nature. They are spread across a wide landscape and vary in terms of geological, geomorphological, climatic and hydrological conditions. To account for such heterogeneity, Brammer (2012) mapped the coastal belt of Bangladesh into a wide range of physiographic regions. In this article, these physiographic regions are used for controlling heterogeneity in polders during regression analysis. Nonetheless, the physiographic regions in which the polders are located bear a statistically significant relationship with the livelihood-vulnerability and infrastructure-resilience of polders.

¹ Such as: in certain polders, all sluiceways are closed during the monsoon period, so that sea-water does not enter the polders; in other polders, fresh-water is not allowed to leave the polder during the months of December and January.

Discussion and conclusion

These results have two kinds of implications: (a) theoretical implications for the SLA; and, (b) empirical implications for livelihood-vulnerability and infrastructure-resilience in polders. In terms of theoretical implications, two broad conclusions can be drawn. Scoones (2015) had called for more quantitative studies using the SLA to statistically evaluate whether the relationships proposed by the approach hold across larger data-sets. This research upholds such theoretical relationships. The relationships proposed by the SLA are statistically significant and are generalizable across a large number of heterogeneous sites. While Scoones (1998, 2015) has argued that institutional and political variables affect livelihood and sustainability outcomes, other scholars (Allison and Horemans 2006; Moser 2008; de Haan and Zoomers 2005) have argued that the political dimensions of human interactions (conflict, rule-making, etc.) have not been adequately captured in the SLA. This research demonstrates that various kinds of conflict-related and rule-making variables do affect sustainability outcomes. Empirically, this research throws light on the various factors which affect the resilience of polder-infrastructure and the vulnerability of polder-residents.

As discussed in the Introduction, Bangladesh is not the only country which has polders along its coastal belt. Polder-like structures have been constructed across the world. However, no comprehensive, large-scale study has yet been conducted on the effect such structures have on livelihood and sustainability outcomes. Drawing on a data-set of polders from Bangladesh, this article has analyzed how various institutional, political, socio-economic and physiographic factors affect outcomes in polders. The theoretical propositions tested in this article are drawn from the Sustainable Livelihood Approach (SLA). These propositions have been qualitatively derived from studies conducted across the world. Therefore, the findings of this article should also be generalizable for polder-like structures across the world—with a few caveats: socio-economic and political conditions vary dramatically at the macro-level, from country to country. A global study of polders needs to control for such variation. Feedback effects need to be considered. The SLA suggests that outcome variables also effect contextual and independent variables, via feedback loops. However, for the sake of simplicity, such feedback effects have been ignored in this article. Due to the paucity of data, the effect of factors like drainage congestion could not be considered. Analyzing the effect of such factors will throw additional light on the pros and cons of polderization. Additional research also needs to be conducted for identifying those variables which differentially affect livelihood vulnerability but not infrastructure resilience (and vice versa) and for identifying

and explaining interrelationships between such variables. In addition, future research needs to identify contextual socio-economic variables which affect livelihood strategies, infrastructure resilience and livelihood vulnerability in polders.

A few practical lessons can be drawn from this study. The resource-base (natural, social and financial) affects livelihood strategies of polder residents. However, the construction of unplanned inlets often changes the resource-base. This can alter the livelihood choices available to residents with negative repercussions for livelihood vulnerability. In addition, the unplanned inlets often affect the resilience of polder-infrastructure negatively. The construction of these unplanned inlets often take place with the active cognizance of public officials. Therefore, the role of public officials in the construction of the unplanned inlets needs to be looked into. The polders of Bangladesh are highly contentious. A wide range of interest groups are active. The goals and motivations of these groups vary widely. Wide power imbalances exist. Therefore, when conflicts take place, the most-vulnerable residents often are not able to use appropriate conflict resolution strategies to ensure that the conflict ends in their favor. Third-party mediation often becomes necessary to ensure that conflict resolution results in equitable solution.

Therefore, to conclude this article, in addition to socio-economic and political conditions prevalent in polders (as hypothesized by the SLA), geological, geomorphological, climatic and hydrological conditions also affect the livelihood decisions of polder-residents and also affect the condition of the polder-infrastructure. In other words, context matters (Frey 2017). Panaceas do not always succeed (Ostrom et al. 2007).

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References

- Adger WN (2006) Vulnerability. *Glob Environ Change* 16(3):268–281
- Adnan MSG, Haque A, Hall JW (2019) Have coastal embankments reduced flooding in Bangladesh? *Sci Total Environ* 682:405–416
- Akber MA, Khan MWR, Islam MA, Rahman MM, Rahman MR (2018) Impact of land use change on ecosystem services of southwest coastal Bangladesh. *J Land Use Sci* 13(3):238–250
- Alam MS, Sasaki N, Datta A (2017) Waterlogging, crop damage and adaptation interventions in the coastal region of Bangladesh. A perception analysis of local people. *Environ Dev* 23:22–32
- Allison EH, Horemans B (2006) Putting the principles of the Sustainable Livelihoods Approach into fisheries development policy and practice. *Mar Policy* 30(6):757–766
- BBS (2010) Census of Agriculture 2008. Structure of Agricultural Holdings and Livestock Population. Bangladesh Bureau of Statistics (BBS), Government of the People's Republic of Bangladesh
- BBS (2014a) Bangladesh Population and Housing Census 2011. Bangladesh Bureau of Statistics (BBS), Government of the People's Republic of Bangladesh
- BBS (2014b) Bangladesh Population and Housing Census 2011. Zila Reports. Bangladesh Bureau of Statistics (BBS), Government of the People's Republic of Bangladesh (ISBN-978-984-519-068-8)
- BBS (2015) Bangladesh Population and Housing Census 2011. Community Reports: Zila Series. Bangladesh Bureau of Statistics (BBS), Government of the People's Republic of Bangladesh
- BBS (2014) Bangladesh Population and Housing Census 2011. Zila Reports. Bangladesh Bureau of Statistics (BBS), Government of the People's Republic of Bangladesh
- Brammer H (2012) The physical geography of Bangladesh. The University Press Limited, Dhaka
- Brand FS, Jax K (2007) Focusing the meaning(s) of resilience: resilience as a descriptive concept and a boundary object. *Ecol Soc* 12(1):23
- Burnham M, Ma Z (2017) Climate change adaptation: factors influencing Chinese smallholder farmers' perceived self-efficacy and adaptation intent. *Reg Environ Change* 17(1):171–186
- BWDB (2012a) Social Management Plan (SMP), Polder 39/2A. Bangladesh Water Development Board, Ministry of Water Resources, Government of the People's Republic of Bangladesh
- BWDB (2012b) Social Management Plan (SMP), Polder 41/7B. Bangladesh Water Development Board, Ministry of Water Resources, Government of the People's Republic of Bangladesh
- BWDB (2012c) Final Report, Volume VIII: Social & Environmental Reports, Coastal Embankment Improvement Project, Phase-I (CEIP-I), Consultancy Services for "Technical Feasibility Studies and Detailed Design for Coastal Embankment Improvement Programme (CEIP)" Contract Package No. BWDB/D2.2/S-3
- BWDB (2013) Coastal Embankment Improvement Project, Phase-I, (CEIP-I). Detailed Design Of Five Polders; Volume III: Environmental Impact Assessment; Part D: Polder No 35/3. Bangladesh Water Development Board, Ministry of Water Resources, Government of the People's Republic of Bangladesh
- Chambers R, Conway G (1992) Sustainable rural livelihoods: practical concepts for the 21st century. IDS discussion paper 296. Institute of Development Studies, Brighton, England
- Chang SE (2014) Infrastructure resilience to disasters. *The Bridge* 44(3):36–41
- Cheung WWL, Lam VWY, Sarmiento JL, Kearney K, Watson R, Pauly D (2009) Projecting global marine biodiversity impacts under climate change scenarios. *Fish Fish* 10(3):235–251
- Cutter SL, Barnes L, Berry M, Burton C, Evans E, Tate E, Webb J (2008) A place-based model for understanding community resilience to natural disasters. *Glob Environ Change* 18(4):598–606
- Dasgupta S, Huq M, Khan, Malik F, Pandey K, Ahmed MMZ, Khan, Zahurul H, Mukherjee N (2010) Vulnerability of Bangladesh to cyclones in a changing climate. potential damages and adaptation cost. World Bank, Development Research Group. Policy Research Working Paper, 5280
- de Haan L, Zoomers A (2005) Exploring the Frontier of Livelihoods Research. *Dev Change* 36(1):27–47
- Di Baldassarre G, Viglione A, Carr G, Kuil L, Salinas JL, Blöschl G (2013) Socio-hydrology: conceptualising human-flood interactions. *Hydrol Earth Syst Sci* 17(8):3295–3303
- Frey UJ (2017) A synthesis of key factors for sustainability in social-ecological systems. *Sustain Sci* 12(4):507–519
- Gallopín GC (2006) Linkages between vulnerability, resilience, and adaptive capacity. *Glob Environ Change* 16(3):293–303
- GED (2017) Bangladesh Delta Plan 2100: Draft. Government of the People's Republic of Bangladesh, Bangladesh Planning Commission, General Economics Division, Dhaka, Bangladesh
- Google Maps (2019) Google Maps, <https://www.google.nl/maps/place/Bangladesh/@23.4521774,81.3634705,5z/data=!4m5!3m4!1s0x30adaaed80e18ba7:0xf2d28e0c4e1fc6b18m2!3d23.684994!4d90.356331?hl=en>. Accessed 9 Apr 2020
- Hahn MB, Riederer AM, Foster (2009) The Livelihood Vulnerability Index: a pragmatic approach to assessing risks from climate variability and change—q case study in Mozambique. *Glob Environ Change* 19(1):74–88
- Inniss L, Simcock A (2016) The First Global Integrated Marine Assessment. World Ocean Assessment I. Cambridge University Press, Cambridge
- Ishtiaque A, Sangwan N, Yu DJ (2017) Robust-yet-fragile nature of partly engineered social-ecological systems: a case study of coastal Bangladesh. *Ecol Soc* 22(3):5
- Jr Auerbach LWSLG, Mondal DR, Wilson CA, Ahmed KR, Roy K, Steckler MS, Small C, Gilligan JM, Ackerly BA (2015) Flood risk of natural and embanked landscapes on the Ganges-Brahmaputra tidal delta plain. *Nclimate* 5(2):153–157
- Kreft S, Eckstein D, Melchior I (2016) Global Climate Risk Index 2017. Who Suffers Most From Extreme Weather Events? Weather-related Loss Events in 2015 and 1996 to 2015. German-Watch, Bonn
- McDaniels T, Chang S, Cole D, Mikawoz J, Longstaff H (2008) Fostering resilience to extreme events within infrastructure systems: characterizing decision contexts for mitigation and adaptation. *Glob Environ Change* 18(2):310–318
- McLennan B, Garvin T (2012) Intra-regional variation in land use and livelihood change during a forest transition in Costa Rica's dry North West. *Land Use Policy* 29(1):119–130
- Mersha AA, van Laerhoven F (2016) A gender approach to understanding the differentiated impact of barriers to adaptation: responses to climate change in rural Ethiopia. *Reg Environ Change* 16(6):1701–1713
- Miller F, Osbahr H, Boyd E, Thomalla F, Bharwani S, Ziervogel G, Walker B, Birkmann J, van der Leeuw S, Rockström J, Hinkel J,

- Downing T, Folke C, Nelson D (2010) Resilience and vulnerability: complementary or conflicting concepts? *Ecol Soc* 15(3):11
- Morse S, McNamara N (eds) (2013a) Sustainable livelihood approach. Springer Netherlands, Dordrecht
- Morse S, McNamara N (2013b) The theory behind the sustainable livelihood approach. In: Morse S, McNamara N (eds) Sustainable livelihood approach. Springer Netherlands, Dordrecht, pp 15–60
- Moser C (2008) Assets and livelihoods: a framework for asset-based social policy. In: Moser C, Dani AA (eds) Assets, livelihoods and social policy. The World Bank. Washington DC, pp 43–82
- Mukhopadhyay A, Hornby DD, Hutton CW, Lázár AN, Johnson FA, Ghosh T (2018) Land cover and land use analysis in coastal Bangladesh. Ecosystem services for well-being in deltas. Palgrave Macmillan, Cham, pp 367–381
- 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. In: Conference: revitalizing the Ganges Coastal Zone: Turning Science into Policy and Practices
- Nelson DR, Adger WN, Brown K (2007) Adaptation to environmental change: contributions of a resilience framework. *Annu Rev Environ Resour* 32(1):395–419
- Ostrom E, Janssen MA, Anderies JM (2007) Going beyond panaceas. *PNAS* 104(39):15176–15178
- Pande S, Sivapalan M (2017) Progress in socio-hydrology: a meta-analysis of challenges and opportunities. *WIREs Water* 4(4):e1193
- Renaud FG, Syvitski JPM, Sebesvari Z, Werners SE, Kremer H, Kuenzer C, Ramesh R, Jeuken A, Friedrich J (2013) Tipping from the holocene to the anthropocene how threatened are major world deltas? *Curr Opin Environ Sustain* 5(6):644–654
- Scoones I (1998) Sustainable rural livelihoods: a framework for analysis. IDS working paper No 72. Institute of Development Studies, Brighton, England
- Scoones I (2015) Sustainable livelihoods and rural development. Agrarian change and peasant studies. Practical Action Publishing, Rugby. <https://doi.org/10.3362/9781780448749>
- Segeren WA (ed) (1982) Keynotes: Polders of the world. In: International symposium, Lelystad, The Netherlands. <https://edepot.wur.nl/380818>. Accessed 15 May 2020
- Thomas KW (1992) Conflict and negotiation processes in organizations. In: Dunnette MD, Hough LM (eds) Handbook of industrial and organizational psychology. Consulting Psychologists Press. Palo Alto, CA, pp 651–717
- Turner BL II (2010) Vulnerability and resilience: coalescing or parallel approaches for sustainability science? *Glob Environ Change* 20(4):570–576
- van Laerhoven F, Andersson KP (2013) The virtue of conflict: an institutional approach to the study of conflict in community forest governance. *Int For Rev* 15(1):122–135
- WB (2015) Bangladesh-Country snapshot (English). Washington, D.C. : World Bank Group. <http://documents.worldbank.org/curated/en/190391468190764030/Bangladesh-Country-snapshot>. Accessed 9 Apr 2020

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