



Doomed to Drown?  
Infrastructure Governance and Environmental  
Justice in Bangladesh

Image: Villagers standing atop embankment with sluice gate in coastal Bangladesh; photo by K.G. Rogers

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**Topic:** Delta Dynamics

**Place:** The Ganges-Brahmaputra Delta, Bangladesh

**Time:** Now (living case study)

**Course length:** Case study itself is 24 contact hours + field trip if available, during a 10-week summer course. Modules designed to build upon each other but can be used independently. Case study designed to be flexibly adapted to any global delta system, per instructor's expertise

Focus areas: Economics (agriculture, trade), Class (rural farmers), Geosciences (Geomorphological changes), Demography (Populations movements), Institutions, Socio-ecological Systems, Policy, Socio-Technical Systems

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## Case Study Summary

Like other deltas worldwide, human living space is a valuable commodity in Bangladesh, particularly along river channels where flooding redistributes land that forms the foundation of villages and farms. Rapid sea-level rise is salinizing low-lying cropland, while dam building and irrigation in river basins imprint downstream delta communities by reducing freshwater flows and threatening water and food security. Intertwined with these environmental issues are a deeply embedded cultural identity, a wide chasm in living standards, and other socio-economic pressures associated with development. Bangladesh is a place beyond others where social and environmental concerns converge, thus providing a dynamic, complex and globally significant case study for a transdisciplinary-focused curriculum.

This case study includes progressive learning modules designed to introduce students to systems thinking using infrastructure governance in the Bengal Delta, Bangladesh. The case study would fit well within a curriculum for upper-division Environmental Engineering or Environmental Studies undergraduates and is aimed at training students in a transdisciplinary approach of complex problem identification and analysis. Each module is designed to be flexible, so that it may be applied to other densely populated delta landscapes where physical dynamics and climate change are rapidly shifting land-water boundaries, creating new socio-environmental risks and impacts.

The independent modules we have created are integrative and designed to build upon each other, enabling students to understand how components of a Social-Environmental System (SES) are interdependent. Through the modules students will explore feedbacks and emergent properties arising from agricultural land transformation related to large-scale infrastructure development in coastal Bangladesh, and the associated hydrological, geomorphological, social, and economic impacts. Each module will equip students to integrate the social and environmental dynamics within the Bengal Delta SES and explore questions using different lenses of analysis. The students will first learn the basic principles of systems thinking and socio-ecological systems by identifying the relationships, dependencies, and feedbacks between the various elements of delta SES. They will then apply their training to system-thinking based exercises such as causal loop diagramming (CLD) and role-playing exercises based on the Bangladesh case study. The larger course curriculum includes a 10-day field trip to coastal Bangladesh where the students will visit rural villages to gain a contextual understanding of the system. They will use their training of participatory CLD with community members and other stakeholders to conduct a comparative assessment of what they, as young researchers, 'perceived' as the dynamics within the deltaic system vs the perception and experiential knowledge of actors living within the system.

## Goals and Objectives

### SES Learning Goals:

1. Students gain a systems understanding from studying a delta SES
2. Develop transdisciplinary research questions
3. Consider the importance of scale and context in addressing socio-environmental problems
4. Understand the role and impacts of key drivers and leverage points in an SES
5. Understand tradeoffs in socio-environmental governance and management
6. Co-develop systems maps in teams
7. Synthesize existing socio-environmental data and ideas

### Student Learning Objectives (SLO): (case study driven)

1. List biophysical and socio-economic-political aspects of the delta system
2. Apply systems thinking concepts to map relationships and feedbacks within a socio-environmental system
3. Understand the connections between knowledge users and environmental dynamics
4. Apply critical thinking skills to solve complex socio-environmental problems
5. Develop an understanding of tradeoffs and benefits in policy making and governance
6. Synthesize data from various formats and sources

### Prerequisites:

Students should be juniors or seniors in Environmental Studies, or have taken the following prerequisites in an equivalent program:

- **Introductory Natural Science** (2 courses from Biology, Earth Science, Atmospheric and Ocean Sciences, Geography, or Biology)
- **Introductory Physics or Chemistry**
- **Intermediate Natural Science course**
- **Intermediate Policy course**
- **Intermediate Social Science course**
- **Economics**
- **Ethics**
- **Statistics or Calculus I**
- **Advanced Writing course (or equivalent)**

### Course Design

**Audience:** Upper-level undergraduate or graduate level

**Course design:** Blended summer course with both in-class and field component. Approximately 8-10 weeks with 3 weeks on campus, 2-3 weeks in the field, and 2 weeks of a final project.

This course structure is designed to consist of progressive modules that can be used to augment a longer semester course.

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## Case Study: Summary

The fertile soils, vibrant ecosystems and abundant waterways of river deltas have attracted humans and supported social, cultural, and economic development for millennia. Occupying just 5% of global land area, deltas house over 7% of the world's population including rapidly developing, densely populated Asian megacities. Consequently, deltas are more than coastal landforms providing rich environmental resources to support their large populations. They also contain intricate social-environmental systems facing the challenge of balancing resource demands with conservation, political stability, food and freshwater security, social equality, and sustainable development. Understanding the complex human-environment tradeoffs taking place within the densely populated and dynamic spaces of river deltas embodies one of the greatest challenges to sustainability science. Based on these observations, the proposed case study will focus on what has been described by Syvitski and others (2009) as a delta in peril of catastrophic flooding: the Ganges-Brahmaputra-Meghna (Bengal) delta in Bangladesh.

The active delta that encompasses Bangladesh formed from 10,000 years of sediment delivery by two great trans-Himalayan Rivers: the Ganges and Brahmaputra. Bangladesh's agrarian economy depends on the sediment brought to the delta's surface during the annual flooding of its extensive channel network every summer monsoon, for both nutrient replenishment and to maintain the delta's surface elevation above rising sea level. Dependence on the rivers has deeply imprinted Bangladesh's cultural identity and economy, as only life on a fertile and constantly shifting riverine landscape can. However, most of the people in Bangladesh live on ecologically fragile river islands (chars) and cyclone-prone coastal belts and are therefore exposed to both river and coastal flooding. People of Bangladesh have traditionally responded to seasonal flooding by building houses on raised platforms and constructing temporary earthen embankments that could be broken and rebuilt to allow water drainage from the fields.

However, the increase in the frequency and intensity of cyclones in the region and subsequent flooding in the lowlands have rendered traditional methods of flood control inadequate. The Climate Change Vulnerability Index, which annually ranks 170 countries based on their vulnerability to impacts of climate change, ranks Bangladesh as one of the topmost countries at risk due to its high levels of exposure and sensitivity to climate impacts and lowest capacity to adapt to climate change trends and extreme events. High dependency of Bangladesh's economy on agricultural activities, high levels of poverty, high population density, and land constraints combined with geomorphological conditions of Bangladesh make it extremely vulnerable to climate change (Ali, 1999; Selvaraju, 2006). In addition, gradual and long-term climate variability such as shifts in temperature and rainfall patterns and sea level rise are exacerbating the pressure on agricultural land, crop production, and water resources. This is impacting the livelihoods of resource dependent communities in Bangladesh.

Various international development agencies have funded projects to help Bangladesh develop its capacity to cope with adverse effects of climate change. Beginning in the late 1960's, a widespread coastal embankment project began across the entire coastal region with funding from USAID. These 139 ring dykes, called by the Dutch word "polders", were emplaced around delta islands to protect cropland from saltwater intrusion by tides and storm surges. The polders have numerous sluice gates meant to allow for the draining of excess rainwater during the monsoon and were initially successful in boosting agricultural productivity. However, the polders and sluice gates were poorly maintained. Over time, polders have become increasingly vulnerable to overtopping by storm surges. Additionally, embankments have restricted the flow of sediment onto the land surface, reducing soil fertility and lowering land surface elevations. (Auerbach et al., 2015) This makes the delta

more susceptible to catastrophic flooding during recurring cyclones in the Bay of Bengal. Poorly functioning sluice gates now allow saline water to penetrate the interior of polders, and has contributed to the widespread emergence of shrimp farming—a profitable business for a few individuals, but also a controversial land use practice that has led to marginalization of the poorest farmers, social conflict, and environmental transformation of the delta.

The current government of Bangladesh has outlined a pro-poor Climate Strategy, which prioritizes adaptation and disaster risk reduction. As a part of this strategy, the World Bank has initiated a funding plan that would provide the Government of Bangladesh \$400 million to elevate the height of existing embankments. Extending the embankment heights would protect rural communities from more intense storm surges and sea-level rise predicted for this century, yet would not solve the immediate problems of waterlogging, sediment restriction, environmental transformation, and social conflicts that arise from these structures.

This case study introduces students to the interface between science and development policy by examining coupled social-environmental delta dynamics and governance of large-scale infrastructure projects that are being increasingly emplaced to protect delta populations globally from the impacts of 21st-century climate change. Through causal loop mapping exercises and a role-playing game, the case study encourages students to use systems thinking to confront the social, environmental, and institutional tradeoffs often embedded in environmental decision-making and the implications of these decisions.

#### **References:**

- Ali, A., 1999. Climate change impacts and adaptation assessment in Bangladesh. *Climate research*, 12(2-3), pp.109-116.
- Auerbach, L.W., Goodbred Jr, S.L., Mondal, D.R., Wilson, C.A., Ahmed, K.R., Roy, K., Steckler, M.S., Small, C., Gilligan, J.M. and Ackerly, B.A., 2015. Flood risk of natural and embanked landscapes on the Ganges–Brahmaputra tidal delta plain. *Nature Climate Change*, 5(2), p.153.
- Selvaraju, R., Subbiah, A.R., Baas, S. and Juergens, I., 2006. Livelihood adaptation to climate variability and change in drought-prone areas of Bangladesh: Developing institutions and options.
- Syvitski, J.P., Kettner, A.J., Overeem, I., Hutton, E.W., Hannon, M.T., Brakenridge, G.R., Day, J., Vörösmarty, C., Saito, Y., Giosan, L. and Nicholls, R.J., 2009. Sinking deltas due to human activities. *Nature Geoscience*, 2(10), p.681.

#### **Background information for the instructor:**

<http://documents.worldbank.org/curated/en/346221488836115251/Bangladesh-Coastal-Embankment-Improvement-Project-Phase-I-CEIP-I-P128276-Implementation-Status-Results-Report-Sequence-07>

<http://www.worldbank.org/en/news/press-release/2013/10/01/bangladesh-receives-400-million-to-rehabilitate-600km-embankments-in-coastal-districts>

World Bank, 3-part series with videos

<https://blogs.worldbank.org/endpovertyinsouthasia/bangladesh-building-resilience-eye-storm>

## Module 0: Case Overview and Introduction to Systems

### *Topic*

This module focuses on familiarizing students with the salient historical, social, and environmental context of the case study, introduces the concepts of systems thinking, socio-environmental systems, and other critical terminology for successful completion of the course.

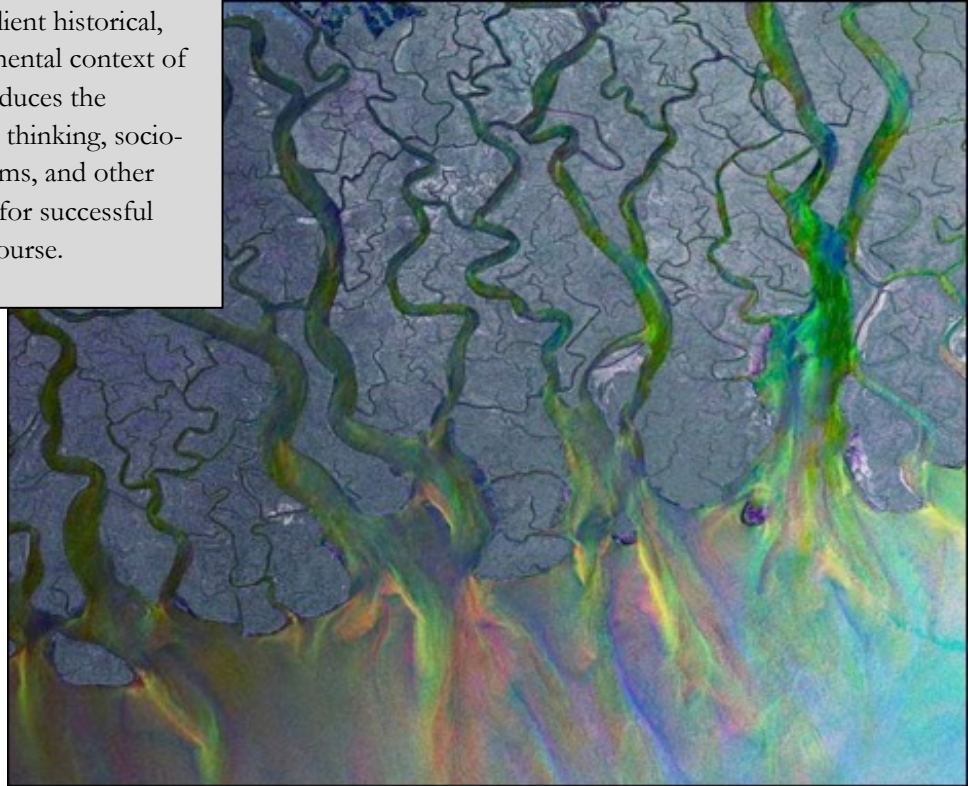


Image: Envisat image of Ganges Delta, European Space Agency

### 0.1 Learning Objectives

1. Describe the study site and details of place (brief history, key social and bio-physical processes, environmental policies and infrastructure)
2. Experience systems thinking through an introductory exercise
3. Develop understanding of key concepts of Systems Thinking and socio-environmental systems

#### Module 0: Teaching Notes Overview

**Goal: Gain historical, social, and environmental context of the case study site; introduction to concepts of systems thinking, socio-environmental systems, and other critical terminology**

	Learning Objectives	Exercises	Assessment
1. Case Overview	1. Describe the study site and details of place (brief history of Bangladesh, key	1. Individual pre-reading: Narrative of initial story	

<p>2. Introduction to Systems Thinking and Socio-Ecological systems</p>	<p>social and environmental processes in the Bengal Delta</p> <p>2. Experience and demonstrate understanding of key concepts of systems thinking following an introductory concept mapping exercise</p> <p>3. Define socio-environmental system and associated concepts</p>	<p>of Bangladesh as a country and as a delta</p> <p>2. Class lecture: Overview of systems thinking in SES</p> <ul style="list-style-type: none"> <li>- What is systems thinking?</li> <li>- Key concepts in systems thinking</li> <li>- Interpreting and understanding feedbacks, behavior, and leverage points</li> <li>- What is a socio-environmental system?</li> <li>- Elements of socio-environmental systems</li> <li>- Accounting for scale in SES</li> <li>- Setting the boundaries of an SES</li> <li>- Identifying key functions in the SES</li> </ul> <p>3. Individual and class experiential activities: Think/write-pair-share; class concept mapping</p>	<p>Students turn in note cards with individual “think/write” answers at end of class; instructor returns cards at end of course for self-assessments and assessment of system thinking skills</p> <p>Systems map of a socio-environmental system along with a narrative of key elements and interconnected relationships</p>
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## 0.2 Teaching Notes and Activities

Module 0 provides a brief background introduction to the case and the Bengal Delta system through pre-reading and introduces students to the foundational concepts of systems thinking and socio-environmental systems. The module is designed to enable students to understand and experience systems thinking through numerous examples and experiential classroom activities such as think-pair-write and systems mapping exercises. To sum, the two foci of this module are: 1. introduction to systems thinking and socio-environmental systems and 2. understanding how the Bengal Delta system is a socio-environmental system.

1. Suggested pre-reading: Introduction to river deltas as landforms, and Bangladesh as both a nation and a delta (Suggested for course on Bangladesh and the Bengal Delta, modify background reading accordingly if case study focuses on a different delta)
  - Overview of deltas: <https://www.nationalgeographic.org/encyclopedia/delta/>
  - Bangladesh Country studies, beginning with “The Society and its environment”: <http://countrystudies.us/bangladesh/>
  - Van Schendel, W. (2009). *A history of Bangladesh*. Cambridge University Press (Timeline; Part I: The Long View)



- Akter, J., Sarker, M. H., Popescu, I., & Roelvink, D. (2015). Evolution of the Bengal Delta and its prevailing processes. *Journal of Coastal Research*, 32(5), 1212-1226.

2. Lectures: PowerPoint format that includes an overview of key concepts and definitions in systems thinking and socio-environmental systems

2.1 Overview of systems thinking

- What is systems thinking?
- Foundations of systems thinking: non-linearity, feedbacks, problem boundaries, interdependence, emergent properties, system behavior delays and leverage points, tradeoffs. Demonstrate through examples such as bathtub or thermostat models
- Systems thinking and its applications in the real world

2.2. Overview of socio-environmental systems

- Elements of socio-environmental systems (SES)
- Boundaries of an SES -Interpreting and understanding feedbacks in an SES-Accounting for scale in an SES
- Why are deltas a good example of a socio-environmental system and how can we apply systems thinking to understand a delta system? Overview of general structures of deltas and livelihoods influenced by deltas

Follow up with a brief introduction on river deltas and Bangladesh that builds on the pre-class reading.

3. Experiential Activities: Think/write-pair-share; systems mapping

These activities are meant to introduce students to systems thinking and the use of system mapping to explore a complex social-environmental issue. This activity can be preceded by a simple Think/Write-Pair-Share activity where students individually or in pairs write down key elements or processes that they think make up a delta socio-environment system

3.1 Think/write-pair-share activity:

**Materials:** Notecards; each student will receive two notecards (cards can be different colors to help organize individual vs. group answers). The class is presented with a broad question such as “What are the key elements / processes within Bangladesh’s delta system?”, and then given time (2-3 minutes) to independently come up with answers, which they write on a notecard. Then students work in self-selected groups of two to three to discuss and compile their respective answers (5 minutes), which they will write on a separate notecard. Groups then share their answers with the rest of the class and discussion follows on how these factors influence the delta as an SES. Individual and group notecards will be turned in at the end of the class period as a way of assessing students’ initial understanding of the system. The cards may be held and re-distributed to students at the end of the semester for self-assessment of learning progress and improvement of student’s systems thinking skills during the course.

3.2 System Mapping\*:

\* This introductory activity is adapted from *InTeGrate*; (<http://archive.wceruw.org/cl1/flag/cat/conmap/conmap7.htm>)

**Materials:** White board/chalk board and colored markers/chalk

Following on the think/write-pair-share exercise, the instructor and students develop a systems map as a class, based on the pre-readings and introductory lecture. This first map will be drawn from the students' collective knowledge of factors that they learned about through their pre-reading, notecards, and discussion.

A comprehensive list of elements/processes identified by the students in notecards in the Think/Write-pair-share activity is compiled on the board separately. Students are asked to identify the central or most important elements within the system. These central elements are first mapped on the board along with their relationships and feedbacks (if any). For example, if the students identified floods, river discharge and sedimentation as the central elements and have listed secondary elements such as rainfall, and land building as factors that interact with the central elements, the systems map would show: monsoon rains fall over the river basin, which increases river discharge, which causes flooding – but can also increase the amount of sediment transported by rivers to the delta, which increases soil fertility, land surface building, etc. Interactions and feedbacks between components of the map should be explicitly considered and highlighted (e.g. if there is less rain, there river discharge and flooding will decrease...but it may increase the risk of drought).

Steps:

- A. Provide students with a broad question that will be the topic for the system mapping (e.g. what social and environmental factors influence a delta system?)
- B. Either in small groups or as a whole class have the students identify general elements/variables/factors that they associate with the question. Make a list of each element, process or issue on the board so that all students can see them.
- C. Ask a student to choose the central/ most important elements on the board (e.g. river flooding, sedimentation, migration), and start the mapping exercise by drawing the relationship between the elements and highlighting feedbacks and interdependence. For example: coastal flooding is connected to soil salinity, soil salinity is connected to crop productivity and so on.
- D. Have the students identify how an interaction between two variables changes the overall state of each variable (e.g. an increase in sediment deposition *increases* land surface elevation; higher land surface *decreases* the risk of coastal flooding; lower occurrence of coastal flooding *decreases* salinization; lowered salinization *increases* crop productivity; etc.). Use different colored markers to indicate if the new issues are positively (green) or negatively (red) related to the general topic (e.g. 'an *increase* in river flooding *increases* soil salinity' is a positive relationship). Continue in this fashion and be responsive to where the student interest leads the process; the actual output of the map is much less important than the process. As interest in any particular line of topics wanes, start a new line of topics (e.g. population growth increases food demand, increased food demand leads to increase in agricultural land pressure, increase in land pressure leads to decrease in soil quality etc.) - this is where the list of topics from the beginning of the activity comes in handy.

- E. As the system map develops, make sure to draw lines connecting the variables/elements along with their relationships and highlight feedback loops. It is desirable for the map to be messy and complex. If there are disagreements among members of the class, for example, it is good to highlight that on the map (e.g. there might be debate on whether increased river discharge and flooding increases or decreases sediment deposition, or erosion) - or there might be areas where more research is needed (or it is just unknown to the class).
- F. Following the completion of the systems mapping exercise, the students pick one element identified in the systems map, and trace how that one element can have non-linear or surprising / emergent effects on the system.

**Homework Assignment.** Students work in pairs to select a general example of a socio-environmental system and construct a systems map, with the option of hand-drawing the map or using a software tool (e.g. Visual Understanding Environment (VUE), <http://vue.tufts.edu>).

### 0.3 Rubrics for Module 0

Module 0: Rubric summary, Case Overview and Introduction to Systems				
Category	Very good (4)	Good (3)	Poor (2)	Very Poor (1)
Pre-reading and think/write-pair-share exercise	There is mention of at least 5 relevant elements/variables /factors within the socio-environmental system on group notecards (individual cards will not be assessed) There is a logical identification of relationship and feedback between the elements of the system			Very few selected by the group has any relevance to the socio-environmental system There is no logical connection between elements of the river-delta system
Homework Assignment: Systems mapping	Map is clear, easy to read and follow; feedback relationships are logical and related; at least 10 nodes are identified and connected; positive and negative feedbacks are correctly labeled			Map is hard to read or illegible; no clear relationship between connected nodes; positive and negative relationships are not labeled. Map contains 3 or less nodes.
	The narrative of the system map is clear and logical. Central elements are identified; Relationships and feedbacks are clearly stated			Writeup is not clear and lucid. Central elements are not identified, and relationships are either not stated or ignored.

## Module 1A: System Mapping of Biophysical Processes Shaping the Bengal Delta

### *Topic*

The purpose of module 1A is to explore the biophysical processes and associated feedbacks that create and sustain river deltas globally, using the Bengal delta of Bangladesh as an example. Scale is introduced by considering how modifications in a river basin upstream of a delta may impact biophysical processes on the delta's surface. By deconstructing the environmental and social processes separately, student understanding of how each contribute to delta sustainability may be assessed before diving into



Image: Muddy water draining from a rice paddy field into a coastal river channel in Bangladesh; photo by K.G. Rogers

### 1.A.1 Learning Objectives

1. Define the geomorphic elements that govern delta formation and maintenance, including rivers, sediment transport, waves and tides, subsidence, erosion and deposition
2. Understand constructive and destructive biophysical processes and the feedback relationship between them that impact delta morphology
3. Identify the impact of infrastructure building at multiple scales on biophysical processes within a delta

<b>Module 1A: System Mapping of Biophysical Processes</b>			
<b>Teaching Notes Overview</b>			
<b>Goal: Understand feedbacks between biophysical and technical processes that influence the shape and stability of deltas</b>			
	<b>Learning Objectives</b>	<b>Exercises</b>	<b>Assessment</b>
Part 1A: Biophysical Processes	1. List and define important biophysical processes within a delta system  2. Describe upstream and downstream geomorphological processes responsible for delta formation and change  3. Identify how infrastructure may impact a delta's shape and stability	1. Lecture on overview of delta systems, highlighting elements and processes that relate to delta formation and maintenance in general  2. Brainstorm biophysical aspects of a delta system with partner  3. Build a system map of the biophysical aspect of deltas and write an associated narrative	1. System map homework on VUE or Cmap  2. Written narrative on the system map. The narrative for the system map should highlight the relationship between the elements of the map. Specifically, students should be able to identify the central biophysical processes operating within a delta system.

### 1.A.2 Teaching Notes and Activities

Module 1A provides a general introduction to the biophysical and engineering processes that influence delta systems as morphological entities. This module will be information dense, although students should be familiar with many of the concepts from previous earth science courses. The two foci of this module are 1) a review of vocabulary, concepts and processes, and 2) understanding the connections between river basin and delta processes.

1. Introduction: Define the geomorphic elements that govern delta formation and maintenance as a landform.

Lectures: PowerPoint format that includes overview of delta systems, highlighting elements, concepts and processes that relate to delta formation and maintenance in general. Review concepts relevant to shaping of deltas generally, such as: tides, waves, sediment transport, erosion, deposition, wetlands/mangroves, rivers, flooding, groundwater, soil fertility, cyclones, subsidence, etc. Follow general overview by “zooming in” to specific geographical areas and their processes. For example, first review the terrestrial/riverine processes then review marine processes, then introduce students to the complexity of interacting river and marine processes in the coastal zone. This section could include an optional introductory video (e.g. <https://www.youtube.com/watch?v=A47ythEcz74>)

2. System Mapping: Understand the constructive and destructive biophysical processes and feedbacks that impact delta morphology

A. **Partners:** Have students partner with each other to complete and think through the relationship of one delta process with other variables. Make a table of biophysical processes/elements, and how

they influence each other (refer back to system mapping exercises in Module 0; e.g. an increase in sediment deposition *increases* land surface elevation; higher land surface *decreases* the risk of coastal flooding; lower occurrence of coastal flooding *decreases* salinization, etc.).

**B. Group Work:** In groups of 3-4 create a system map that incorporates the already discussed biophysical processes/ elements. Within the system map, draw relationships between elements/variables/factors and write a brief description of the type of relationship between the variables (positive/negative). This system map and written description forms the assignment for assessment of understanding of biophysical processes within the Bangladesh delta system (See Rubric A for Module 1A)

3. Short Narrative Writing Exercise: Understand how upstream and in-situ infrastructure can trigger feedbacks in biophysical dynamics

**A. Group Reflection exercise:** In groups, encourage students to think about how each variable and process could impact or be impacted by the building of infrastructure, both upstream in the river basin, and upon the delta's surface. For example, how would a dam upstream of a delta influence river flooding on floodplains within the basin and within the delta? How about a flood control dike that prevents river and tides from inundating the landscape?

**B. Homework:** Students will work in groups to create a narrative that tells the story of how biophysical processes interact and specifically how those process interactions influence infrastructure development and vice versa. The goal is to evaluate the students' grasp of the elements within the system and creation of linkages between elements as they relate to the additional of infrastructure. These narrative forms the assignment for assessment of relationships between upstream river and in-situ infrastructure within the Bengal Delta system (See Rubric B for Module 1A)

**C. Class Discussion:** Once narratives and system maps are collected and reviewed by the instructor, a group discussion is conducted to demonstrate what each group developed and to evaluate the similarities and differences between groups. This will require preparation from the instructor in order to guide students' contribution to discussion. This discussion will lead to the development of a collective class concept map that is used in subsequent activities.

**D. Muddiest Point exercise:** Before leaving class, students will hand in a notecard with a few sentences explaining one concept that they had trouble understanding. This will be used to assess the students' level of understanding, and so the instructor can revisit difficult concepts and/or review important points. This helps to ensure that students have integrated the necessary background material to prepare them for the causal loop diagramming and role-playing exercises that occur in subsequent modules.

### 1.A.3 Rubrics for Module 1A

Students should be directed toward answering this question for the system map:

**What biophysical factors in the geologic past and present influence the shape of the Bengal Delta?**

<b>Rubric A for Module 1A: Biophysical Processes system map assessment</b>
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System Map Element	Very good (4)	Good (3)	Poor (2)	Very Poor (1)
Breadth of Net & Centrality	Map includes <b>8-12</b> important biophysical element (e.g., sediment transports, precipitation, river discharge) and describes domain on multiple levels			Map includes few elements and processes with many important concepts missing
Embeddedness	Most elements are interlinked with several other concepts			Few elements are linked to other concepts
Use of descriptive links	Links succinctly and accurately describe all relationships (positive/negative, verbiage)			Links are vague and show inconsistent relationships
Efficient links	Each link type is distinct from all others, clearly describes all relationships, used consistently			Most links are synonymous or vaguely describe relationships and aren't distinct from other links.
Accuracy	Relationships between the elements are characterized accurately; no inaccuracies			Relationships between the elements are characterized inaccurately, many inaccuracies
Critical Thinking	Evidence of high levels of critical thinking showing high level of understanding of the system			Evidence of limited critical thinking showing low level of understanding of the system
Layout	Student prominently displays the purpose somewhere on the map (i.e., in title, or central theme" of the map. Map is contained in single page and is well laid out with clear labeling and linkages between elements/processes/variables			Map is not contained in single page, is confusing to read, with unclear or no labeling of relationships or linkages between elements/processes/variables

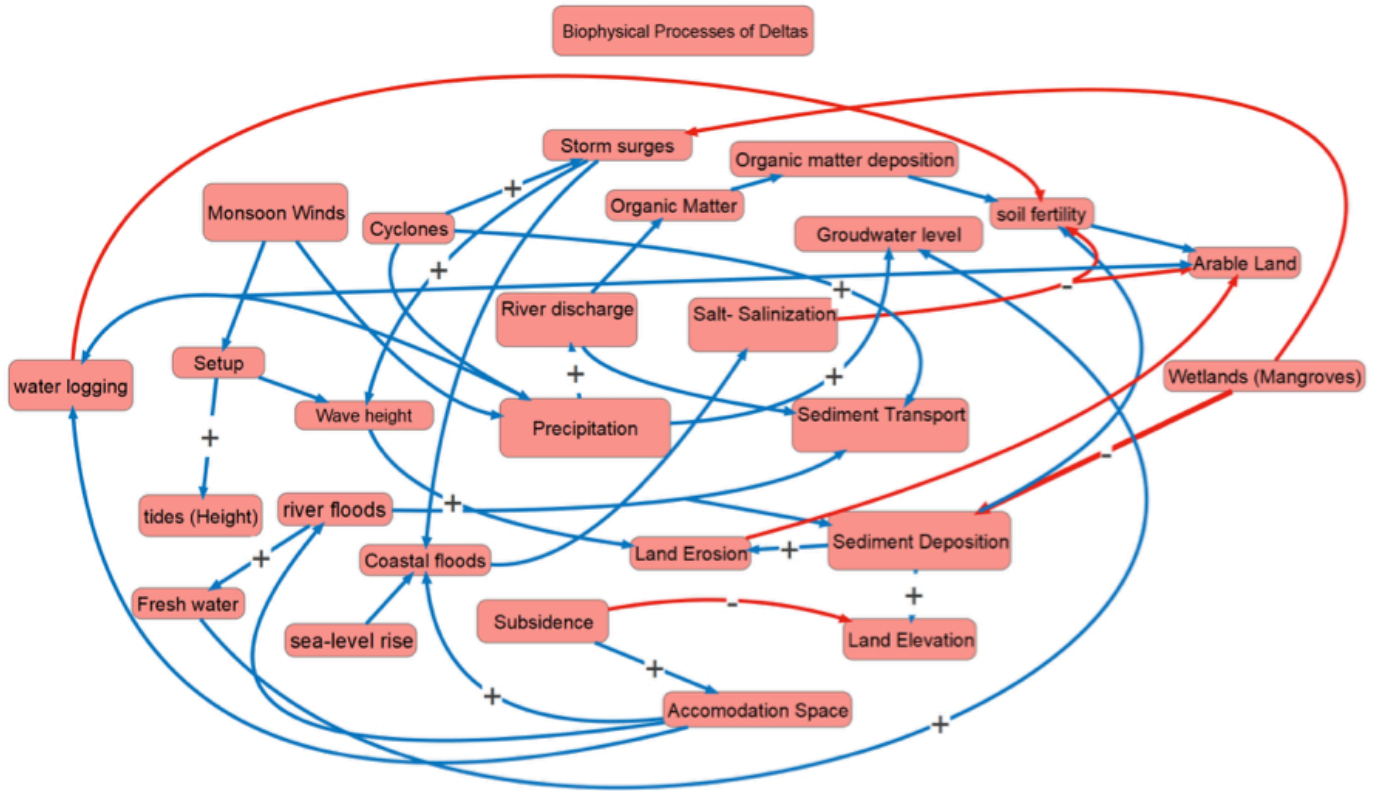
**Rubric B for Module 1A:**

**Written Narrative Assessment**

Paragraph element	Very good (4)	Good (3)	Poor (2)	Very Poor (1)
Addresses main narrative	Student addresses the main biophysical narrative of the system map			Student does not address main narrative of the system map
Easy to follow; well written	Narrative is logical, grammatically correct			Narrative is not logical, many grammatical errors
Consistent with the system map	Narrative addresses the main biophysical components in the system map and discusses the main relationships between the various biophysical components of the map			Narrative does not cover all the elements in the biophysical system map
Communication	Information presented clearly and succinctly, suggesting a high level of understanding of the system			Information is not clearly presented, very difficult to understand

# 1.A.4 Guide for instructors

## Module 1A: Prototype of a Physical Processes Concept Map





## Module 1B: System Mapping of Social Processes in Bangladesh

### *Topic*

Module 1B explores in detail the social contexts and processes of life on a river delta, using Bangladesh as an example. By deconstructing the environmental and social processes separately, student understanding of how each contribute to delta sustainability may be assessed before diving into synthesis activities.

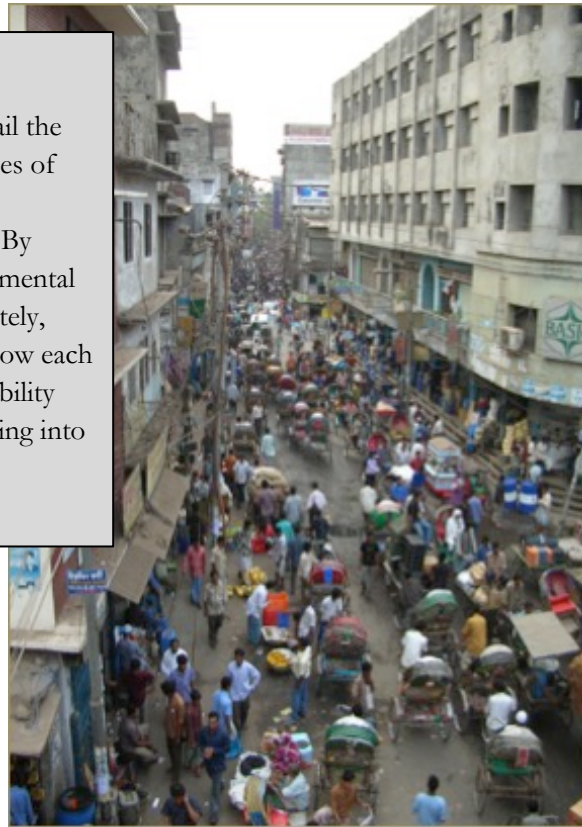


Image: Old Dhaka Marketplace, Bangladesh; photo by K.G. Rogers

### 1.B.1 Learning Objectives

1. Identify the broad social, political, and economic processes that have supported human development in delta systems in historic and modern contexts.
2. Understand elements of the historical, demographic, economic, and political systems that provide the context for environmental governance and decision-making in Bangladesh
3. Map how these concepts are related to one another within the context of Bangladesh:
  - Government (local, country-level, international policies, other institutions)
  - Demographic (age, race, religion, gender, migration)
  - Economic (jobs, livelihoods, poverty)
4. Describe how these elements can influence micro-level decision-making of individuals living on river deltas

<b>Module 1B: System Mapping of Social Processes</b>			
<b>Teaching Notes Overview</b>			
<b>Goal: Understand the social, political, and economic processes and feedbacks that influence environmental governance and decision-making in delta systems</b>			
	<b>Learning Objectives</b>	<b>Exercises</b>	<b>Assessment</b>
Social Processes	1. Understand the social, political, and economic processes that have supported human development in delta systems in historic and modern contexts  2. Understand the elements of the history, demography, economy, and political system of Bangladesh  3. Map how these concepts are related to one another within the context of a delta system in Bangladesh.	1. Sticky note exercise to explore the challenge and benefits of living in a delta  2. Lectures on the social, economic, political and institutional aspects of living in a delta  3. Think-pair-share exercise where students learn about key social, demographic, and economic indicators in Bangladesh  4. Build system map of social processes in Bangladesh	1. System map homework on VCUE or Cmap  2. Written narrative on the concept map. The narrative for the concept map should tell the story about the map. Specifically, students should provide an answer to the main question the map is designed to address.

### 1.B.2 Teaching Notes and Activities

Module 1B provides a general introduction to the social processes that function within delta. The three foci of this module are to enable students to 1) understand the social, political, and economic processes that have supported human development in delta systems in historic and modern contexts, 2) understand the elements of the history, demography, economy, and political system of Bangladesh, and 3) map how these concepts are related to one another within the context of the Bengal Delta. This module uses a combination of lectures, classroom discussions, sticky note exercises, jigsaw activity, and conceptual mapping exercises as teaching tools.

1. Understand the social, political, and economic processes and feedbacks that influence human development in delta systems across the world in historic and modern contexts.

A. **Sticky note exercise:** Begin class by passing out a couple of sticky notes to each student. Draw a large Venn diagram on the board. Keeping the context broad (so that it could apply to deltas outside of Bangladesh), ask students to imagine the challenges and benefits to living and working in a delta system. Students will write either one benefit or one challenge on each sticky note. Ask students to place their sticky notes on the challenge side, the benefits side, or in the middle (if it could be a challenge and benefit depending on the context). As students add notes, continue to pass out sticky notes and prompt for specific ideas such as “What are some examples of economic challenges for those living/working in a delta?”. Continue this prompting for social, institutional, and political ideas.

After these have been added, talk through the examples on the board and their placement as challenge or benefits. Note feedbacks, contradictions, and context/perspective-specific placements as they come up.

**B. Lecture:** Use a lecture to introduce students to basic concepts of the social, political, and economic benefits and challenges to delta living, from both a historical and modern viewpoint.

2. Understand the key elements of the history, demography, economy, institutional, and political system of Bangladesh:

- Government (local, country-level, international policies, other institutions)
- Demographic (age, race, religion, gender, migration)
- Economic (jobs/livelihoods, poverty)

**A. Think-pair-share:** Before class, students complete a homework assignment to learn about social, demographic, and economic indicators in Bangladesh. Students use publicly available data through the World Bank, and a population pyramid to find these indicators:

<http://data.worldbank.org/indicator>

<https://www.populationpyramid.net/bangladesh/2017/>

Students fill out a table with the information that they find and are asked to describe the information using their contextual knowledge. Prompts can be used such as: “Please describe the data you have found, and any interesting patterns or observations that emerge.” “Using the information from the population pyramid, please describe the changes to the population distribution over time. How might these changes impact current social life? How could these changes influence people’s relationship with their environment?”

Students share their homework findings in pairs and compare their explanations and descriptions.

**B. Small jigsaw activity:** Divide students into three groups (representing social, political, and economic themes) and have them discuss in more detail the examples that may fall into their category and the relationship between those examples and deltas. Ask students to consider difference between modern benefits/challenges and historic benefits/challenges to living in a delta. Students prepare a short presentation to convey the main findings/points from their discussions to the class. Groups are re-divided to have members from social, political, and economic representatives, and each representative shares their presentation.

3. Map how these concepts are related to one another within the context of a dynamic coastal or delta setting

**A. Concept mapping:** After reviewing the social/demographic, economic, and political concepts and contexts of Bangladesh, divide students into small groups (2-4 students) and guide them to create a conceptual diagram documenting social/demographic, economic, and political concepts and context, and mapping the relationships between these ideas. For homework, students write a narrative to 1) describe the interactions between social/demographic, economic, and political processes in Bangladesh, and 2) conceptualize how these social processes are influenced by a constantly shifting, biophysically dynamic delta landscape.

**B. Gallery walk:** Groups members share their narratives with one another. Then groups share their diagrams and narratives with one another through a “gallery walk” format. One group member remains with

the diagram to share with classmates as they walk by, and then this person switches out (informally) with other group members so all get the chance to see and discuss all diagrams. As a full class, similarities and differences among diagrams are discussed. Following this, a collective class concept map of social processes is then developed

#### 4. Describe how these elements can influence the lives and decisions of individuals living in dynamic landscapes

**A. Lecture:** Use a lecture to discuss the importance of context and elements of the sociological imagination and individuals’ roles and statuses (such as age, gender, livelihoods, socio-economic status etc.) in the lives of individuals living in the deltas.

**B. Storytelling Scenarios:** Have students divide into small groups (3-4). Prepare example storytelling scenarios on cards and pass the card to a volunteer for each group. The volunteer reads their scenario to the group, which tells a story of an individual living in Bangladesh and who needs to make a “decision” regarding a particular problem associated with living in a dynamic delta system. For example: *“Ranya has lost another portion of her field to flooding. She will not be able to feed her 3 children, and she is the sole provider for the household. Some from her town have chosen to move to the city, but her extended family have all chosen to remain and rebuild, or to pursue fishing. What does Ranya do?”*. Group members write all the contextual factors that may influence the person’s decision. After completing the final round, post the completed total conceptual diagram from the previous activity. Ask students to add to their influential contexts/concepts for their scenario using more ideas from the conceptual diagram. Then, ask students to imagine and write a short backstory for their scenario by drawing on ideas from the conceptual diagram. (For example: Did government policies influence the building of infrastructure for the protection from flooding? What economic opportunities might draw Ranya from her home?)

**C. Muddiest Point exercise:** Before leaving class, students will hand in a notecard with a few sentences explaining one concept that they had trouble understanding. This will be used to assess the students’ level of understanding, such that the instructor can revisit difficult concepts and/or review important points to ensure that all students have integrated the necessary background material to prepare them for the causal loop diagramming and role-playing exercises presented in subsequent module

### 1.B.3 Rubrics for Module 1B Exercise: Social System Maps

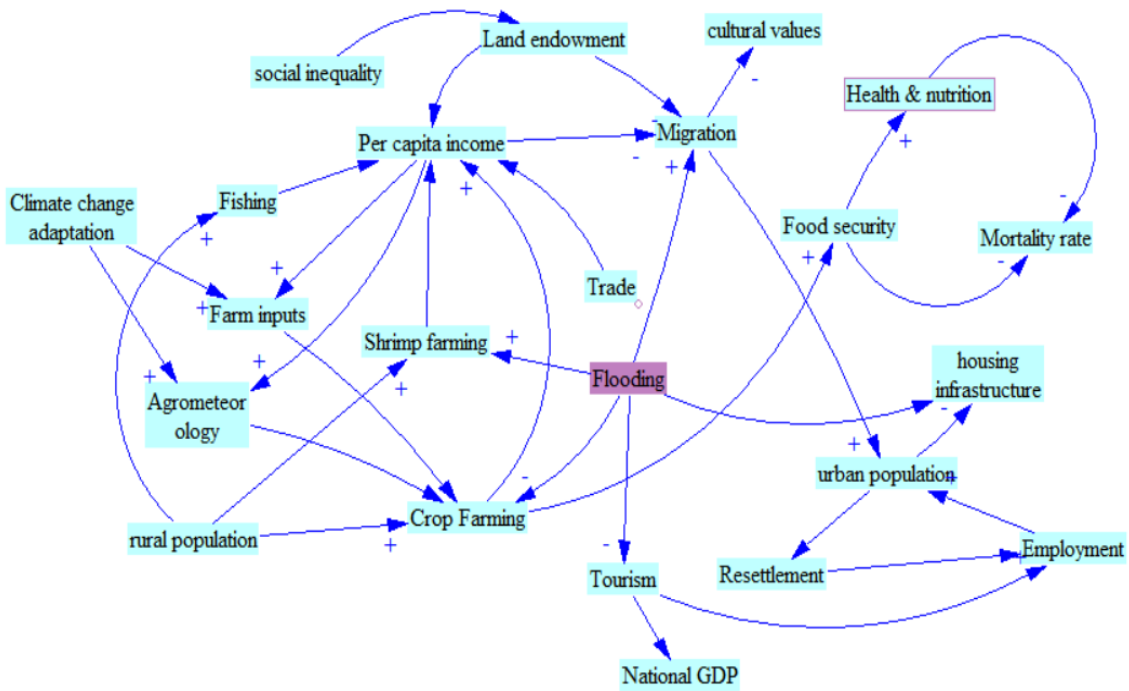
<b>Rubric A for Module 1B: Social processes system map assessment</b>				
System Map Element	Very good (4)	Good (3)	Poor (2)	Very Poor (1)
Breadth of Net	Map includes <b>8-12</b> important socio-political-economic elements (e.g. Migration, food security, income, livelihoods, subsidies etc.) and describes the relationship between the elements on multiple levels			Map includes a minimum of elements/concepts/processes with many important elements missing
Embeddedness	All elements are interlinked with several other elements			Few elements are linked to other elements
Use of descriptive	Links succinctly and			Links are vague and show

links	accurately describes all relationships (positive/negative, verbiage)			inconsistent relationships
Efficient links	Each link type is distinct from all others, clearly describes all relationships, used consistently			Most links are synonymous or vaguely describe relationships and aren't distinct from other links.
Accuracy	Relationships between the elements are characterized accurately; no inaccuracies			Relationships between the elements are characterized inaccurately; many inaccuracies
Critical Thinking	Evidence of high levels of critical thinking showing high level of understanding of the system			Evidence of limited critical thinking showing low level of understanding of the system
Layout	Student prominently displays the purpose somewhere on the map (i.e., in title, or central "theme" of the map. Map is contained in single page and is well laid out with clear labeling and linkages between elements/processes/variables			Map is not contained in single page, is confusing to read, with unclear or no labeling of relationships or linkages between elements/processes/variables

<b>Rubric B for Module 1B:</b>				
<b>Written Narrative Assessment</b> (The narrative for the concept map should tell the story about the map. Specifically, it should descriptively respond to the question the map is designed to address)				
Paragraph element	Very good (4)	Good (3)	Poor (2)	Very Poor (1)
Addresses main question	Student addresses the main socio-political-economic narrative of the concept map			Student does not address main socio-political narrative of the concept map
Easy to follow; well written	Narrative is logical, grammatically correct			Narrative is not logical, many grammatical errors
Consistent with the concept map	Narrative addresses the main social components in the concept map and discusses the main relationships between them			Narrative does not cover all the concepts in the social concept map
Communication	Information is presented clearly and succinctly, suggesting a high level of understanding of the system			Information is not clearly presented, very difficult to understand

## 1.B.4 Guide for Instructors

### Module 1B: Prototype of a social process systems map



## Module 2: Social-environmental synthesis: Identifying key drivers and leverage points

### *Topic*

The purpose of Module 2 is to synthesize the interacting social and environmental processes in the Bengal delta that are the focus of Module 1. Students will explore the different temporal and spatial scales at which social and environmental processes occur within the Bengal Delta in Bangladesh. Students will identify a specific problem that occurs within the Bengal delta system due to interactions of biophysical and social processes and examine socio-environmental dynamics through an integrated causal loop mapping exercise.



Image: Rice paddy farmers in coastal Bangladesh; photo by K.G. Rogers

### 2.1 Learning Objectives

1. Integrate key elements of biophysical and social components into one concept map
2. Identify the main feedback loops (positive/negative) in the integrated system and identify patterns in system behavior
3. Discuss role of temporal and spatial scales in the integrated biophysical and social delta system behavior
4. Evaluate the challenges of incorporating scale and integrating the elements faced when drawing the integrated concept map
5. Identify the drivers and leverage points in the integrated biophysical and social system that contributes to the key problems in the deltaic system

<b>Module 2: Social-environmental synthesis: Identification of key drivers and leverage points</b>			
<b>Teaching Notes Overview</b>			
<b>Goal: Identify a research problem arising from interaction of social and biophysical processes and explore the dynamics of an integrated system through a causal loop mapping exercise</b>			
	<b>Learning Objectives</b>	<b>Exercises</b>	<b>Assessment</b>
Part A: Combining social and biophysical components of a delta into an integrated socio-environmental system	1. Understand the integrated dynamics of the socio-environmental processes and explore system behavior based on those dynamics	1.1. Students construct an integrated causal loop diagram identifying the causalities and feedback loops that exist within the system  1.2 Students generate hypotheses on how the system will behave given the dynamics of the system (e.g., <i>A</i> increases <i>B</i> ; <i>B</i> decreases <i>A</i> ; thus, over time if <i>A</i> is occurring at a slower rate than <i>B</i> , then <i>B</i> will dominate the system)	1.1.1. Causal loop diagram that specifically addresses the elements the research problem identified  1.1.2. Narratives on the causal loop diagram  1.2.1. Hypotheses on how the system is expected to behave at different scales
Part B: Identification of key drivers and leverage points arising from integrated biophysical and social components of a delta system	2. Identify the key drivers and leverage points in the deltaic system which will enable a better management/governance of integrated social-biophysical systems	2.1. Student groups outline specific elements and processes in the integrated social and biophysical processes that act of drivers and leverage points  2.2. Students identify solutions pertaining to the drivers and leverage points that may be a solution to the key challenges in the integrated socio-environmental deltaic system.	2.1.1. Correct identification of drivers and leverage points in the integrated socio-environmental system

## 2.2 Teaching Notes & Activities

This module is designed to integrate the biophysical and social elements of a delta system and enable students to see the delta as an integrated Social-Environmental system. The module also exposes students to decision-making and governance aspects of the integrated social-environmental delta system through identification of possible drivers and leverage points of system behavior. The main activities included in this module are systems mapping and ‘problem identification’ activities.

### 1. Integrated system mapping



This activity requires a review of the two biophysical and social system maps constructed in the previous modules. First, re-draw the biophysical system map on the board and review the key processes and feedbacks within the system, then ask students to incorporate the elements and processes from the social system map into the biophysical map to develop an integrated socio-biophysical map. Students identify and discuss the linkages between social and biophysical components in the integrated system map.

## 2. Identification of problems, drivers and leverage points

This activity demonstrates the “wicked” aspect of many sustainability issues by showing students that there aren’t simple, linear solutions to complex problems and their evaluation requires consideration of the integrated system as a whole.

Steps:

- A. Ask students to identify an issue or problem in the integrated system map that they think is undesirable (e.g. increased climate vulnerability). The class should vote on one issue to be collectively assessed.
- B. Ask the students to identify the drivers of this problem (for example; sea level rise, flood inundation) and leverage points or key access points in the system through which this issue could be remedied. Encourage students to draw on what they already know from pre-readings, or to think broadly and use their imagination to come up with realistic, but “out of the box” solutions they may have learned about in other classes, e.g. policy solutions, infrastructure construction, relocation of vulnerable populations, restoring wetlands to trap sediment, etc. Students must collectively vote on a singular remedy. Add the remedy to the map, asking students where and how the remedy should be incorporated the system (e.g. dam removal can only occur at the site of a dam upstream of the delta, etc.). Use a new colored marker to identify the remedy and its effects.
- C. As a class, go through the map and propagate the effects of the selected remedy to all other aspects of the map. New, unintended, or surprising effects can be added to the map if they arise. Ideally, the chosen remedy will result in both desirable and undesirable outcomes in the system. Encourage students to think about how long it might take for the effects of their chosen remedy to propagate to certain nodes in the system, i.e. lag times and non-linear change. If the chosen remedy has few rippling impacts to the system, ask students to choose another remedy and move it through the system.
- D. Wrap up the integrated systems mapping exercise and re-iterate the objectives of the exercise: to experience systems thinking while appreciating the complexity and interdependencies within a social-environmental system.

## 2.3 Rubrics for Module 2

Students should be directed toward answering this question for the integrated system map and narrative:

**What are the primary social and environmental factors operating in Bangladesh? What are the feedbacks between social-environmental processes and infrastructure in dynamic settings such as the Bengal Delta?**

<b>Rubric A for Module 2: Integrated System Map Assessment</b>
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System Map Element	Very good (4)	Good (3)	Poor (2)	Very Poor (1)
Breadth of Net	Map includes at least <b>8-15</b> important biophysical and social elements which are interlinked with each other directly or indirectly			Map includes a minimum of elements/concepts/ processes with many missing interlinks between the bio-physical and social elements.
Embeddedness	All elements are interlinked with several other elements			Few elements are linked to other elements
Use of descriptive links	Links succinctly and accurately describe all relationships (positive/negative, verbiage)			Links are vague and show inconsistent relationships
Efficient links	Each link type is distinct from all others, clearly describes all relationships, used consistently			Most links are synonymous or vaguely describe relationships and aren't distinct from other links.
Accuracy	Relationships between the elements are characterized accurately; no inaccuracies			Relationships between the elements are characterized inaccurately; many inaccuracies
Critical Thinking	Evidence of high levels of critical thinking showing high level of understanding of the system			Evidence of limited critical thinking showing low level of understanding of the system
Layout	Student prominently displays the purpose somewhere on the map (i.e., in title, or central "theme" of the map). Map is contained in single page and is well laid out with clear labeling and linkages between elements/processes /variables			Map is not contained in single page, is confusing to read, with unclear or no labeling of relationships or linkages between elements/processes/variables

**Rubric B for Module 2:**

**Identification of problems, drivers and leverage points**

Research problem	Very good (4)	Good (3)	Poor (2)	Very Poor (1)
Validity of system problem	The system problem clearly arises from an interaction of both social and biophysical processes.			The system problem does not arise from an interaction of both social and biophysical processes.
Validity of system drivers	System drivers influence the identified system problem in a clear and logical manner.			System drivers do not influence the identified problem in a clear and logical manner.
Validity of system leverage points	Small change in identified system leverage points creates a large ripple effect on the system			Small change in identified system leverage points do not create a large ripple effect on the system

## Module 3: Role-playing exercise: incorporating policy implications; winners and losers, tradeoffs

### *Topic*

Module 3 incorporates the learning from previous modules in assessment of a real social-environmental problem and policy-making dilemma in the Bengal Delta. The purpose of this module is to understand how a development-centered policy decision could affect multiple elements of the social-environmental system. Students will gain an understanding of how environmental policy applications can create both ‘winners’ and ‘losers’ through a role-playing exercise



Image: Villagers negotiating the best way to repair a mud embankment in coastal Bangladesh; photo by K.G. Rogers

### 3.1. Learning Objectives

1. Use the social-environmental master systems map to identify, understand, and address how development strategies and policy decisions affect multiple concepts and their relationship to each other
2. Imagine the placements of multiple stakeholders and their interests on the master map, and how their interests impact map dynamics
3. Understand how policy interacts with various social and biophysical processes
4. Assume the role of various stakeholders through a role-playing exercise and understand how the same policy can have different impacts on different stakeholders
5. Understand the role of diverse interests, power, and tradeoffs on policy making
6. Synthesize the perspectives of stakeholders and the social-environmental system to develop policy suggestions

**Module 3: Role-playing exercise Teaching Notes Overview**

**Goal: Develop insights to how formal environmental policy may impact various systems processes and stakeholders in delta systems.**

	Learning Objectives	Exercises	Assessment
Application of social-environmental synthesis to solutions	<p>1. Use applications of social-environmental master systems map to identify, understand, and address how existing development and policy decisions affect multiple elements/processes on the map, or the relationships between concepts.</p> <p>2. Imagine the placements of multiple stakeholders and their interests on the master map, and how their interests impact map dynamics.</p> <p>3. Debate the interests, power, and scale of policy suggestions from the perspective of different stakeholders within the contexts of social-environmental systems.</p> <p>4. Synthesize the perspectives of stakeholders and the social-environmental system to develop policy suggestions.</p>	<p>1. Different groups/individuals develop talking points based on their roles to support specific viewpoints, based on information learned in previous modules.</p> <p>2. Role Play different actors at a World Bank council meeting debating solution for a complex problem regarding flood control infrastructure.</p>	<p>1. Groups with different roles synthesize and define their stance at the World Bank, considering the interactions between biophysical and social processes. Groups submit report summary.</p> <p>2. A World Bank roundtable debate between different actors discussing if/how/where/when/why funds meant for repairing infrastructure should be distributed.</p>

**3.2 Student handouts**

1. Role-playing exercise on policy decision-making. All information and handouts will be included in the student handouts folder; text reprinted here for review and editing

Distribute a handout with the following information:

*‘Global warming is resulting in rising sea levels, causing vulnerable low-lying delta regions to disappear each year’* – this is a common narrative regarding the impacts of climate change and global warming in Bangladesh. However, a recent (2015) study conducted by researchers at Vanderbilt University suggests that the construction of embankments in the 1960s, which have led to lower land elevations in the Ganga-Brahmaputra (Bengal) Delta in Bangladesh, creates a greater flood risk for people living near embankments than sea-level rise. The scenario we will work through today is far from trite. Several noted scholars have claimed that a critical component of protecting global food security from the impacts of climate change includes enhancing flood protection in the world’s densely populated Asian deltas, which are considered the “rice bowls of the world”. Likewise, designing effective policies for protecting delta communities from the effects of sea level rise will reduce the numbers of global climate refugees, i.e. people forced to migrate due to climate-related environmental disruption, originating from delta regions every year.

Federal policy makers and international funding agencies such as the World Bank are considering solutions for protecting people from yearly floods and to improve the ability of deltaic populations to adapt to the effects of climate change. (They) are considering a proposal to raise the height of existing embankment structures in the region, which will protect people in the near future, but would increase the risk of flooding in the far future. Similarly, the proposal does not include a provision for repairing broken sluice gates on the wide-spread embankment system, which in their current state are enhancing water logging in fields and in-filling of irrigation canals and channels with silt.

The World Bank has called a round table meeting of various stakeholders and stakeholder representatives to present their perspectives regarding the funding of a project to rehabilitate the embankment system. The bank has \$500 million available to fund repairs, which can be spent wholly on raising the height of the existing dikes across the entire delta, or distributed to raise the height of dikes in some areas, and repair sluice gates in others, or the money can be divided further to provide the most vulnerable communities with site-specific flood-control measures. Each of these proposed plans will result in tradeoffs that create ‘winners’ in some areas and ‘losers’ in others across the delta.

Raising embankment heights provides a short-term protection of crops and homesteads from regular flooding but may not be built high enough to withstand sea level rise predictions for the next 50 years. They also don’t prevent storm surges associated with frequent cyclones from cresting embankment walls. Dedicating all the funds to raising embankment heights would preclude repair of malfunctioning sluice gates. Broken sluice gates currently restrict sediment from being delivered to the delta’s surface, which impedes its ability to fertilize croplands and naturally sustain a surface elevation above that of rising coastal water levels. As a result, farmers are unable to ensure that monsoon rainwater can be drained off fields each summer and need to invest in chemical fertilizers to maintain soil fertility in their croplands.

**A. Role Play Meeting/debate of stakeholders: stakeholder group representatives will present their perspectives regarding the funding of a project to rehabilitate embankments throughout the coastal zone**

Stakeholders (descriptions of each in student handout folder, one each to be distributed to student groups):

**World Bank Official:** The World Bank wants to fund the project, though they are concerned that the proposed “new” embankment heights initially designed by their engineers may not be high enough to withstand the level of sea level rise that has been projected by numerical models for the next 50 years. They have invited experts on sea level rise and local stakeholders to the World Bank offices in Dhaka to debate the merits of the model predictions to help them determine if it is worth spending the money to heighten embankment walls. The models also contain a high level of uncertainty, therefore the Bank must decide whether to trust the model outputs and fund the raising of embankment walls, or reallocate the money to repair broken sluice gates, design a sustainable mechanism for allowing sediment to pass onto polder interiors, or run more studies--which would take several years, within which another large cyclone may strike Bangladesh.

**Rice Farmer Association Representative:** Paddy farmers are concerned that their land is not receiving new sediment every year during the monsoon floods, due to the presence of the embankments. They are also contending with waterlogging because the poorly maintained sluice gates do not allow for proper field drainage. Because of the decrease in soil fertility due to sediment restriction, they have resorted to using large quantities of costly fertilizer to increase their yields. However, they are often not instructed on how much fertilizer to apply, and therefore overuse their fertilizer, resulting in a decrease of productivity and an increase in pests. They also feel vulnerable to flooding by sea level rise, as well as storm surges, that can breach or overtop embankment walls if they are not high enough. They would benefit from an improved embankment system that will allow sediment to be deposited on their farmland, allow for drainage of monsoon water after the floods, yet is high enough to protect them from increased coastal water levels. (Suggested modification: include two Rice Farmers: one who lives near to embankment perimeter--most vulnerable to immediate flooding if polder is breached; one who lives in embankment interior, at higher risk of water logging)

**Shrimp Farmer Association Representative:** Shrimp cultivators are not as troubled about the embankment heights as rice farmers. Shrimp farmers can still cultivate shrimp and continue to sell them for a high price at the local market, despite the failing embankment system. They are, however, concerned about the need to flush their shrimp pens with saline water from tidal channels in order to prevent the spread of viral diseases within their stock. Some shrimp farmers have remedied their need for saline water by illegally punching holes in current embankment walls and allowing salty tidal water to flow freely into the polders. This creates problems for rice farmers, because many rice farmers do not have access to saline-tolerant rice seedlings, or the salinity is above the threshold of salt tolerant rice varieties. As a result, many rice farmers are forced to convert their paddy fields to shrimp farms. Additionally, punching holes in polder walls renders them more susceptible to catastrophic failure under high tides or strong storm surges. Nonetheless, many community leaders turn a blind eye on these practices, because of the high economic return of shrimp compared to rice.

**Local community leaders (one male, one female):** Community leaders have observed the impacts of the failing infrastructure on their environment and communities. They are concerned about protecting their area's resources and people's livelihoods and will be allocated funds to repair embankments within their jurisdictions.

One community leader at the stakeholder meeting intends to use the funds as specified by the World Bank and will hire local workers to manually repair the embankments and/or sluice gates according to the designs of the engineers hired by the World Bank. She realizes this is the most sustainable solution for the people in her community and creates jobs. She also wants the World Bank to partition some of the funds for drilling local tube wells that will provide her community with safe drinking water, and will improve the well-being of local women by alleviating the need for women to walk several kilometers to fetch clean water, as is the current situation.

A second community leader at the meeting recognizes that his community would benefit from a fully functioning embankment system but is financially swayed by shrimp farmers and landowners with whom he has economic and otherwise powerful ties to. He also claims that he wants funding to repair the polders within his jurisdiction, but in fact will not use all the money for embankment repairs, and instead will dole out some of the funds to his landowning pals and may pocket the rest. Both community leaders are at the meeting, though they do not reveal how they intend to use the World Bank's money, should the project be funded.

**Climate researchers studying flood risks and impacts in the area:** The climate scientists have come to the meeting to discuss the short term and long term results of various sea level rise scenarios they have modeled for the Bangladesh coast, which are based on ranges of emissions reductions as reported within the latest IPCC Report. They are there to provide objective feedback on the model results, which indicate that sea level rise may exceed the planned height of the updated embankment walls within 30-50 years.

**Task:** Decide how to allocate \$500 million donated by the World Bank to the Government of Bangladesh for improving the large-scale coastal embankment system and identify tradeoffs in making this decision. What could be alternative solutions to the problem?

### 3.3 Teaching notes and Activities

#### 1. Pre-class activity (in student handout folder):

Prior to the class period in which the game will be played, students will be given a take-home, pre-class activity. The handout describes the role of governments and development banks in facilitating global development-centered policy programs. Students are then asked to use news reports, Internet searches, etc. to find a current development initiative located anywhere in the world that impacts a social-environmental system. Students must provide a brief statement explaining the actors involved (the funding agency, name and objective of NGOs or governmental organizations, nation or geographical area where the initiative is focused, target population, etc.), and the specific goal or objectives of the initiative (e.g. increase food or water security, irrigation, forest conservation, build cyclone shelters, etc.). This is meant to introduce students to the multiple agents involved with various development initiatives, and to stimulate thinking about the relationship between development, policy, and the scales at which tradeoffs occur.

#### 2. Role playing exercise:

(Activity sheet in student handout folder): Students will form teams of two or three and will take on the role(s) of one of the stakeholder groups described in the student handout. Roles will be assigned by nearest neighbor/seating arrangement of the classroom. Students will be given in-class time (20 minutes) to discuss how the embankment improvement project would influence them as stakeholders and how their perspective and position in society could influence how funds are allocated. Students will need to consider the following aspects in making their decision of how/whether to fund the project: budget, costs, constraints and benefits of implementing the project, future impacts on the landscape and to communities, risks associated with the project, alternative options, etc. Students may develop other important considerations and apply creativity and knowledge of social-environmental systems to provide additional support for their decision.

At the mock stakeholder meeting, students will wear the hats of their assigned stakeholder, and debate their opinion/rationale and will close the debate with a collective vote on whether and how to fund the project. The instructor will act as the meeting facilitator and timekeeper.

Actionable outcome: At the end of the exercise, student teams will construct a summary report of the key tradeoffs in the embankment project proposed by the World Bank. The report should also include the impact of the project on the various stakeholders and insights in who would be a winner or who would be a loser in this project. The report should additionally propose any alternative solutions or improvements in the proposal along with a justification of proposed solutions.

### 3. Rubrics for Module 3

One rubric is used to grade each group, as follows:

<b>Module 3: Rubric summary of their position in regard to the World Bank proposal</b>				
<b>Category</b>	Very good (4)	Good (3)	Poor (2)	Very Poor (1)
Summary Content	The summary clearly states their stakeholders main view on the World Bank project using sound logic, and justifies their position using facts from their previous knowledge and readings provided in class			The summary does a poor job of stating their stakeholders main view on the World Bank; does not justify their position using facts or previous knowledge and readings provided in class
Tradeoffs	The summary clearly highlights the tradeoffs in the proposed solution for the various stakeholders in the delta system			The summary does not discuss the tradeoffs, or the perspective of the various stakeholders associated with the delta system
Synthesis	The team makes a strong connection between the biophysical and social processes that influenced their position on the World Bank project.			The team does not consider biophysical and social processes that influenced their position with the World Bank.
Style	The summary follows the style guidelines (i.e., is double-spaced, has appropriate headings, includes appropriate in-text citations and a Literature Cited section)			The summary does not follow the style guidelines

#### ***Student Handouts:***

1. Stakeholder descriptions (6 total)
2. Background/Scenario
3. Pre-class activity

**Supplemental:** Quiz/reflection exercise