ASIAN CENTER FOR DEVELOPMENT

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Tale of a Tamed River

The Value of Ecosystem Services of Teesta River – an estimate of value of provisional services in agriculture and fisheries

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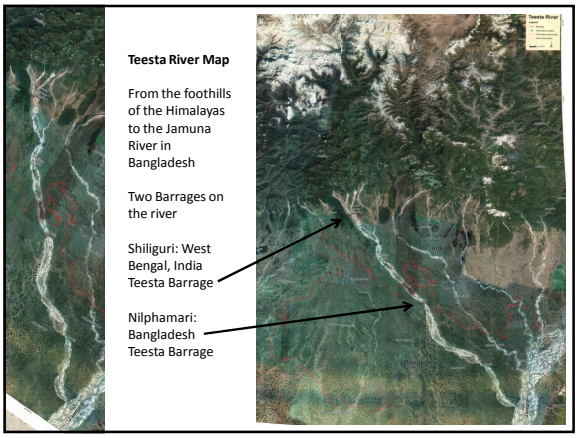
Introduction

- Teesta is a trans-boundary river flowing from India into Bangladesh
- The river is being controlled by Sikkim, West Bengal and also Bangladesh to use water for irrigation and for hydro-electricity
- About 414 km Teesta travels in Sikkim for 151km, in West-Bengal-Sikkim border for 19km, inside West Bengal for 123km and in Bangladesh for 121km



Teesta River Map

From the foothills of the Himalayas to the Jamuna River in Bangladesh

Two Barrages on the river

Shiliguri: West Bengal, India Teesta Barrage

Nilphamari: Bangladesh Teesta Barrage

Research Objectives

- To estimate the value of water in terms of agricultural losses for lower riparian population.
- To estimate the value of water in terms of fisheries losses in lower riparian population.
- To document changes in flooding pattern, if any, due to taming of the river

Effect to Impact of water regime changes

- Effect of water diversion
  - One region receives normal flow of water during dry season
  - Another region remains under water stress condition
- Impacts
  - Human being changes their behavior of
    - Production
    - Affects livelihood
  - River bed rises up in un-controlled region
  - Incidence of flood increases

Impact paths

- Water regime divides into two
  - Water stress or water scarce regime – where less water is available
  - Normal water regime – where water is diverted to ensure production of agriculture or electricity
- Impacts on water scarce area
  - River bed rises
  - Flood increases and spreads
  - Risk in agriculture increases
  - Soil is nourished through silt deposits
  - Soil could be adversely affected through sand deposits

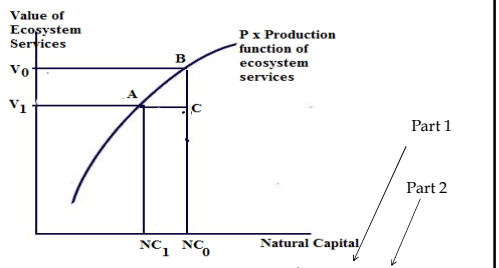
Who are affected?

- Water is diverted to benefit one region of a country against another.
- Against each barrage there is an upper and a lower region within a country
- Millions of people on both sides are dependent on water
- Changes in the flow of river affects these people as the flow of ecosystem services from the river changes
- Values also changes for others who care for non-use services of the river ecosystems
  - Biodiversity
  - Hydrological regime moderation
  - Culture and heritage

Why valuation?

- Challenge the water 'engineers' who often ignores the off-site costs and keeps a blind eye on the losses of ecosystem services
- Challenges the cost-benefit analysis of projects constructed primarily to benefit a region/location
- Pushes people to think through in terms of co-benefits from a project and share the nature for the benefit of mankind
- Promotes sustainable resource management.

Which value?



$$TEV = DUV_1 + IDUV_2 + EV_3 + OV_4 = \sum_{i=1}^{4} \int (MV_i \, d\theta) \;\; \forall \, i = 1,4$$

What type of services?

- Provisional services
  - Production / direct benefit to people
- Regulatory services
  - Indirect and non-tangible services of the river – like hydrological cycle, regulation of floods etc.
- Cultural services
  - Indirect use or non-consumptive use of river resources – tourism/religion/education etc.
- Habitat services
  - Services like nursery services for animals and plants, pollination services, etc.

Steps for valuation

- Need to relate two changes and
  - Changes in the physical condition of river
  - Corresponding changes in the flow of services
- Step 1: Measure changes in physical flow of water
- Step 2: Quantify impacts of changes
- Step 3: Value the changes

Services of Teesta river

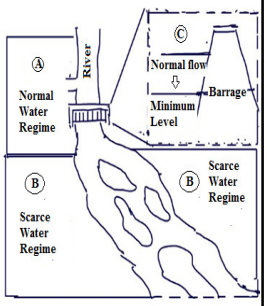
- Sikkim
  - Cultural services dominates
- West Bengal
  - Regulatory services
  - Habitat services
  - Provisional services
- Bangladesh
  - Provisional services dominates
  - Regulatory services

Our Study

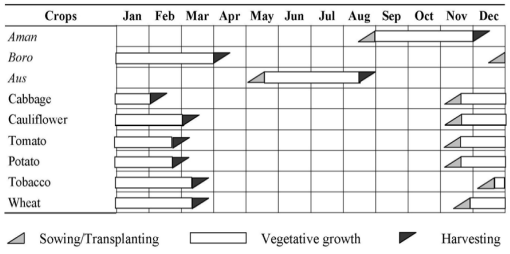
- Bangladesh
  - Provisional services dominates
    - Production of agricultural crops
    - Harvest of fishes from the river
  - Regulatory services
    - Flood control/chaos [not valued but measured]
    - Biodiversity [did not value]
    - Hydrological cycle [indirectly valued]

Analytical Framework: provisional services

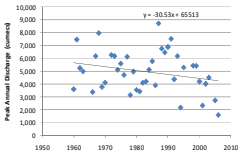
- Need appropriate counter-factual to understand impacts
  - Need to understand current human behavior like **'would have been'** scenario under normal water conditions
  - Need to analyze human behavior under **water stress** conditons

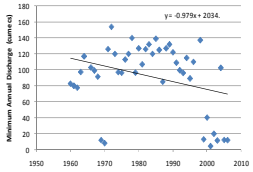


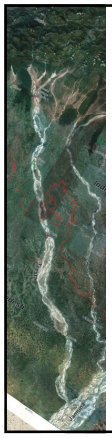
Water use in agriculture



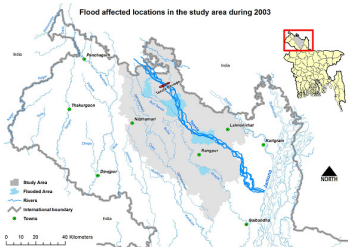
Peak and Lean period water flow

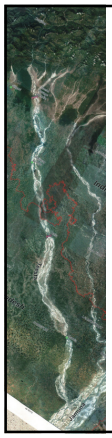






Floods by year





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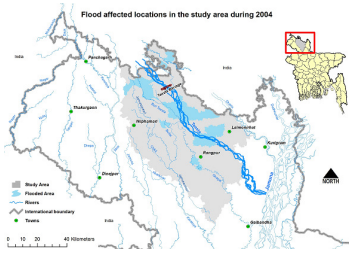
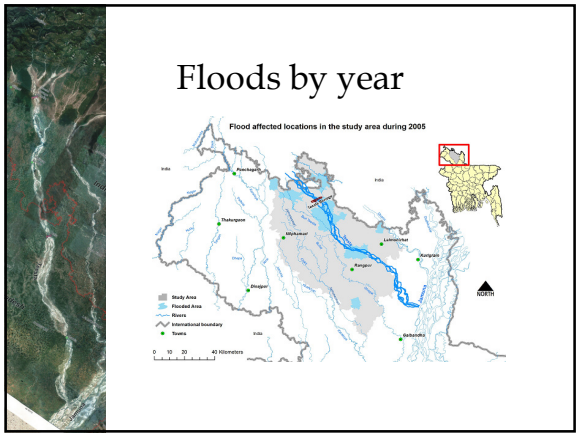
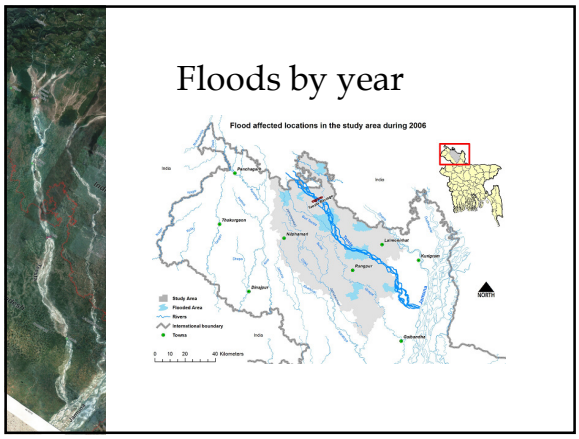



Floods by year
Flood affected locations in the study area during 2005
India
Panchagarh
Thakurgaon
Nilphamari
Lalmonirhat
Kurigram
Rangpur
Gaibandha
Bhutan
Study Area
Flooded Area
Rivers
International boundary
Towns
0 10 20 40 Kilometers
NORTH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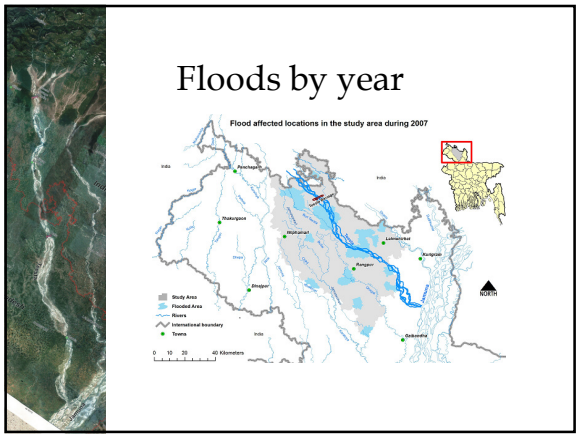
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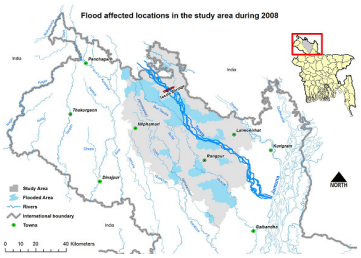

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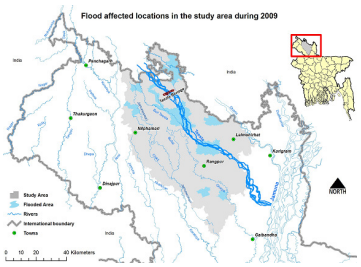

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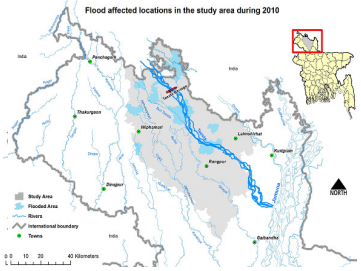
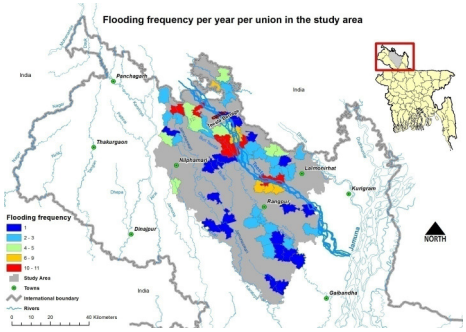


Measuring changes in Floods



Productivity changes mixed signal

Table 1: Crop choice and land use pattern by water regimes

	Crop Choice		Land Use		
Agricultural Crops	Scarce Water Regime	Normal Water Regime	Scarce Water Regime	Normal Water Regime	Difference in holding area
Rice (Amon and Boro)	37.1%	81.8%	65.40%	55.49%	n.s.
Potato	27.1%	37.9%	9.94%	11.52%	n.s.
Jute	21.2%	9.1%	0.37%	0.00%	n.s.
Maize	41.2%	39.4%	15.53%	17.75%	n.s.
Tobacco	11.8%	31.8%	3.19%	12.16%	+ ve ***
Total	138.2%♦	200.0%♦	94.43%♦♦	96.92%♦♦	

Source: Field Survey in Rangpur, Lalmonirhat and Nilphamari districts – 2013

Note: * means difference is statistically significant at 1%, + ve means (Teesta Project Area – Downstream Area) is positive. ♦ shows number of crops per farmer, and ♦♦ indicates % of agricultural land under these five crops.**

Changes in costs

	Cost per acre (in BD Taka)		Comparison		
	Scarce Water Regime (SWR)	Normal Water Regime (NWR)	Difference in costs per acre (in Taka)	Cost ratio between scarce and normal water regimes (SWR/NWR)	Yield ratio between scarce and normal water regimes (SWR/NWR)
	1	2	3	4	5
Rice	34632.50	23065.96	11566.54	1.50	1.95
Potato	58691.04	25834.64	32856.40*	2.27*	1.72**
Jute	49472.78	25139.33	24333.45	1.97	0.72
Maize	38912.17	34250.80	4661.37	1.14	1.08
Tobacco	31643.25	26197.90	5445.35	1.21	0.97

Source: Field Survey (2013) by Asian Center for Development, SWR is scarce water regime, NWR is normal water regime. Note: * means 10% level of significance

Cost function approach

$$C_i = \beta_{i0} + \beta_{i1}Q_i + \beta_{i2}Q_i^2 + \beta_{i3}Q_i^3 + \gamma_i SWR + \sum \delta_{ik}U_k + \theta_j Q_j + \varepsilon_i$$

Dependent Variable	The Equation	
Cost of Rice Production per acre	C_{rice} = 8056.24 + 321.44*** × Q + 0.425*** × Q^2 - 0.00008*** × Q^3 +1710.03 × SWR … + 680.55*** × JUTEQ	R^2=.926, n=217
	where, Q is production of rice (in paddy) per acre, and SWR is 1 for farms located in scarce water regime and 0 otherwise, JUTEQ is the jute yield per acre in the same plot.	
Cost of Jute Production per acre	C_{Jute}=+24058.86 + 63.15296*** × Q^2 + 17181.41 × SWR … +125.59*** × RICEQ	R^2=.977, n=42
	where, Q is production of jute per acre, and SWR is 1 for farms located in scarce water regime and 0 otherwise, RICEQ is rice yield per acre in the same plot	

Cost function …

Cost of Potato Production per acre	C_{potato} = 8076.473+1.44128*** × Q^2 + 4603.861 × SWR …	R^2=.65, n=71
	where, Q is production of potato per acre, and SWR is 1 for farms located in scarce water regime and 0 otherwise	
Cost of Maize Production per acre	C_{maize} = 8.45 + 523.31*** × Q + 0.0060226*** × Q^3 + 4211.22 × SWR …	R^2 = .793, n=94
	where, Q is production of maize per acre, and SWR is 1 for farms located in scarce water regime and 0 otherwise	
Cost of Tobacco Production per acre	$C_{tobacco}$=+23318.85 + 1757.37*** × Q + 25460.22* × SWR …	R^2=.563, n=41

Two measurements!

Crops	Estimate using survey data	Estimate using the cost functions
1	2	3
Rice	11,566.54	1,710.03
Potato	32,856.40*	4,603.86
Jute	24,333.45	17,181.41
Maize	4,661.37	4,211.22
Tobacco	5,445.35	25,460.22*

Note: * means significant at 10%.

Value of loss in agricultural services

	Acreage by crops		Value of loss of provisional services (million Taka)	
Major Crops	In the floodplains of Teesta River	Inside Teesta Barrage area	using Mean-Difference in cost per acre	using estimated coefficients from the cost functions
	1	2	3	4
Rice	405,633	61998	4,691.77	693.64
Potato	61,627	12871	2,024.85	283.72
Jute	2,295	0	55.84	39.43
Maize	96,344	19836	449.10	405.73
Tobacco	19,812	13585	107.88	504.42
Total	620,248	111,732	**7,329.43**	**1,926.94**

Fisheries

	Fishers fishing in			Statistical
Description	**Teesta River**	**Others tributaries**	**differences**	**Significance**
Quantity of catch per team per day	11.082	2.107	-8.975	**
Quantity of catch per person per day	1.816	0.736	-1.081	***
No of days spent per fishing trip	2.986	1.857	-1.129	
Hours of fishing per day	5.936	2.214	-3.721	***
Number of persons per team	5.171	1.571	-3.600	**
Fishers living in Teesta Barrage Area	0.129	0.286	0.157	

Production Function Approach

Dependent variable: Log of Daily Fish Catch				
Independent Variables	Coefficient	L of Sign	SE	t -value
Ln (labor)	1.137	***	0.094	12.04
Ln (hour per day)	0.252	**	0.132	1.91
Ln (Length per trip)	0.168	**	0.092	1.84
Teesta (=1 if fishing from Teesta River)	**0.575**	**	0.249	2.31
SWR (=1 if in scarce water regime)	0.027		0.191	-0.14
Constant	-0.844	***	0.238	-3.55

	2013	**1993**
Description	1	2
	in kg	
Catch per person per day from other rivers	0.74	1.84
Catch per person per day from Teesta river	1.82	4.54
Percent of Teesta catch of Total Catch	0.71	0.71
Average catch per person per day	1.28	3.19

values

- In terms loss in agricultural production (crops and fisheries) the value per acre per annum is 3106 taka or 39 US dollars. This is equivalent of 3.22 taka per year per acre per cumec of water.
- In terms of loss in fisheries, it is 599 taka per fisher per year or 7.68$. This is equivalent of 0.62 taka per year per cumec of water.

TEV due to water regime change

- The impact of which when translated into monetary terms is equivalent of 1,953.91 million taka or 25 million US$ per year. This is equivalent of nearly 2.03 million taka (or 25,970 US$) per cumec of water per year.

Summary of values

Ecosystem Services	Unit of analysis and value	Value lost
Provisional services in agricultural through water supply to agricultural land	Acres of land; 620,248 acres of agricultural land	1926.9 million taka per year
Provisional services in fisheries production due to water shortages	production loss per day; 450,000 fisher folks	26.97 million taka per year
Flood affects due to river-bed rise.	Unions: not valued	Many Unions in Nilphamari, Lalmonirhat and Rangpur now gets additional flooding, Several unions are now inundated every year.