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
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?

\[ TEB = DUV_1 + iDUV_2 + EV_3 + OUV_4 = \sum_{i=1}^{4} f(MV_i, d \theta) \forall i = 1,4 \]
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 conditions

Water use in agriculture

<table>
<thead>
<tr>
<th>Crops</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
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<td>Tobacco</td>
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</tbody>
</table>

△ Sowing/Transplanting  ▏ Vegetative growth  ▇ Harvesting
Measuring changes in Floods

Productivity changes mixed signal

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

<table>
<thead>
<tr>
<th>Agricultural Crops</th>
<th>Crop Choice</th>
<th>Land Use</th>
<th>Differences in holding area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Source Water Regime</td>
<td>Normal Water Regime</td>
<td>Scarce Water Regime</td>
</tr>
<tr>
<td>Rice (Amon and Boro)</td>
<td>37.1%</td>
<td>61.8%</td>
<td>65.4%</td>
</tr>
<tr>
<td>Potato</td>
<td>27.1%</td>
<td>37.9%</td>
<td>9.94%</td>
</tr>
<tr>
<td>Maize</td>
<td>41.2%</td>
<td>39.4%</td>
<td>15.3%</td>
</tr>
<tr>
<td>Tobacco</td>
<td>11.8%</td>
<td>31.8%</td>
<td>3.19%</td>
</tr>
<tr>
<td>Total</td>
<td>138.2%</td>
<td>200.0%</td>
<td>96.92%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Cost per acre (in BD Taka)</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Source Water Regime (SWR)</td>
<td>Normal Water Regime (NWR)</td>
</tr>
<tr>
<td>Rice</td>
<td>34632.50</td>
<td>23065.96</td>
</tr>
<tr>
<td>Potato</td>
<td>58851.04</td>
<td>25834.64</td>
</tr>
<tr>
<td>Maize</td>
<td>48927.28</td>
<td>25189.33</td>
</tr>
<tr>
<td>Tobacco</td>
<td>33643.25</td>
<td>26197.90</td>
</tr>
</tbody>
</table>

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

\[ C_i = \beta_0 + \beta_1 Q_i + \beta_2 Q_i^2 + \beta_3 Q_i^3 + \gamma_i SWR + \sum \delta_k U_k + \theta_i Q_i + \epsilon_i \]

Dependent Variable The Equation

Cost of Rice Production per acre

\[ C_{rice} = 8056.24 + 321.44 Q + 0.425 Q^2 - 0.00008 Q^3 + 1710.03 SWR + 680.55 JUTEQ \]

\[ R^2 = 0.926, n=217 \]

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

\[ C_{jute} = 24058.86 + 63.15296 Q^2 + 17181.41 SWR + 125.59 RICEQ \]

\[ R^2 = 0.977, n=42 \]

where, \( Q \) is production of jute per acre, and SWR is 1 for farms located in scarce water regime and 0 otherwise, RICEQ in rice yield per acre in the same plot.

Cost of Potato Production per acre

\[ C_{potato} = 8076.473 + 1.44128 Q^2 + 4603.86 SWR \]

\[ R^2 = 0.65, n=71 \]

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

\[ C_{maize} = 8.45 + 523.31 Q + 0.0060226 Q^3 + 4211.22 SWR \]

\[ R^2 = 0.793, n=94 \]

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

\[ C_{tobacco} = 23318.85 + 1757.37 Q + 25460.22 SWR \]

\[ R^2 = 0.563, n=41 \]

where, \( Q \) is production of tobacco per acre, and SWR is 1 for farms located in scarce water regime and 0 otherwise.

Two measurements!

<table>
<thead>
<tr>
<th>Crops</th>
<th>Estimate using survey data</th>
<th>Estimate using the cost functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>11,566.54</td>
<td>1,710.03</td>
</tr>
<tr>
<td>Potato</td>
<td>32,856.40*</td>
<td>4,603.86</td>
</tr>
<tr>
<td>Jute</td>
<td>24,333.45</td>
<td>17,181.41</td>
</tr>
<tr>
<td>Maize</td>
<td>4,661.37</td>
<td>4,211.22</td>
</tr>
<tr>
<td>Tobacco</td>
<td>5,445.35</td>
<td>25,460.22*</td>
</tr>
</tbody>
</table>

Note: * means significant at 10%. 
### Value of loss in agricultural services

<table>
<thead>
<tr>
<th>Major Crops</th>
<th>In the floodplains of Teesta River</th>
<th>Inside Teesta Barrage area</th>
<th>Using Mean-Difference in cost per acre</th>
<th>Using estimated coefficients from the cost functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>405,633</td>
<td>619,98</td>
<td>4,691.77</td>
<td>693.64</td>
</tr>
<tr>
<td>Potato</td>
<td>61,627</td>
<td>12871</td>
<td>2,024.85</td>
<td>283.72</td>
</tr>
<tr>
<td>Jute</td>
<td>2,295</td>
<td>0</td>
<td>55.84</td>
<td>39.43</td>
</tr>
<tr>
<td>Maize</td>
<td>96,344</td>
<td>10936</td>
<td>449.10</td>
<td>405.73</td>
</tr>
<tr>
<td>Tobacco</td>
<td>19,812</td>
<td>13585</td>
<td>107.88</td>
<td>504.42</td>
</tr>
<tr>
<td>Total</td>
<td>620,248</td>
<td>111,732</td>
<td>7,329.43</td>
<td>1,926.94</td>
</tr>
</tbody>
</table>

### Fisheries

<table>
<thead>
<tr>
<th>Description</th>
<th>Teesta River</th>
<th>Others</th>
<th>Statistical Differences</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of catch per team per day</td>
<td>11.082</td>
<td>2.107</td>
<td>-8.975</td>
<td>**</td>
</tr>
<tr>
<td>Quantity of catch per person per day</td>
<td>1.816</td>
<td>0.736</td>
<td>-1.081</td>
<td>***</td>
</tr>
<tr>
<td>No of days spent per fishing trip</td>
<td>2.986</td>
<td>1.857</td>
<td>-1.129</td>
<td>***</td>
</tr>
<tr>
<td>Hours of fishing per day</td>
<td>5.936</td>
<td>2.214</td>
<td>-3.722</td>
<td>***</td>
</tr>
<tr>
<td>Number of persons per team</td>
<td>5.171</td>
<td>1.571</td>
<td>-3.600</td>
<td>**</td>
</tr>
<tr>
<td>Fishers living in Teesta Barrage Area</td>
<td>0.129</td>
<td>0.286</td>
<td>0.157</td>
<td></td>
</tr>
</tbody>
</table>

### Production Function Approach

Dependent variable: Log of Daily Fish Catch

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Coefficient</th>
<th>L of Sign</th>
<th>SE</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln (labor)</td>
<td>1.137</td>
<td>***</td>
<td>0.094</td>
<td>12.04</td>
</tr>
<tr>
<td>Ln (hour per day)</td>
<td>0.252</td>
<td>**</td>
<td>0.132</td>
<td>1.91</td>
</tr>
<tr>
<td>Ln (Length per trip)</td>
<td>0.168</td>
<td>**</td>
<td>0.092</td>
<td>1.84</td>
</tr>
<tr>
<td>Teesta (=1 if fishing from Teesta River)</td>
<td>0.575</td>
<td>**</td>
<td>0.249</td>
<td>2.31</td>
</tr>
<tr>
<td>SWR (=1 if in scarce water regime)</td>
<td>0.027</td>
<td>***</td>
<td>0.191</td>
<td>-0.14</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.844</td>
<td>***</td>
<td>0.238</td>
<td>-3.55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>2013</th>
<th>1993</th>
</tr>
</thead>
<tbody>
<tr>
<td>in kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catch per person per day from other rivers</td>
<td>0.74</td>
<td>1.84</td>
</tr>
<tr>
<td>Catch per person per day from Teesta river</td>
<td>1.82</td>
<td>4.54</td>
</tr>
<tr>
<td>Percent of Teesta catch of Total Catch</td>
<td>0.71</td>
<td>0.71</td>
</tr>
<tr>
<td>Average catch per person per day</td>
<td>1.28</td>
<td>3.19</td>
</tr>
</tbody>
</table>
values

• In terms of 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

<table>
<thead>
<tr>
<th>Ecosystem Services</th>
<th>Unit of analysis and value</th>
<th>Value lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provisional services in agricultural through water supply to agricultural land</td>
<td>Acres of land: 620,248 acres of agricultural land</td>
<td>1926.9 million taka per year</td>
</tr>
<tr>
<td>Provisional services in fisheries production due to water shortages</td>
<td>production loss per day: 490,000 fisher folks</td>
<td>26.97 million taka per year</td>
</tr>
<tr>
<td>Flood affects due to river-bad rise.</td>
<td>Unions: not valued</td>
<td>Many Unions in Nilphamari, Lalmonirhat and Ranpur now get additional flooding. Several unions are now inundated every year.</td>
</tr>
</tbody>
</table>