IMPACT OF CLIMATIC VULNERABILITIES ON INDIAN MOUNTAIN RIVERS

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Overview

- *Introduction.*
- *Justification of measuring the impacts of climate change on the Tessta- Torsa River Basin.*
- *Hydrologic modeling and watershed management.*
- *Different aspects and tools of managing the watersheds.*
- *An overview of Teesta River system.*
- *Method involved in development of Tr-55 and HEC-HMS hydrologic models.*
- *Results and Discussion.*
- *Conclusion.*

Introduction.

- *The present research is an attempt to use distributed hydrological modeling to quantify the future water availability of Teesta river system. The river basin up to the outlet of the upper basin has been given the main emphasis for investigation because the water supply arrangement of the states like West Bengal, and Sikkim are considerably dependent up to that part of the respective river basin. Thus the regions up to the outlet of the systems are especially vulnerable to potential changes in regional temperature and precipitation pattern.*

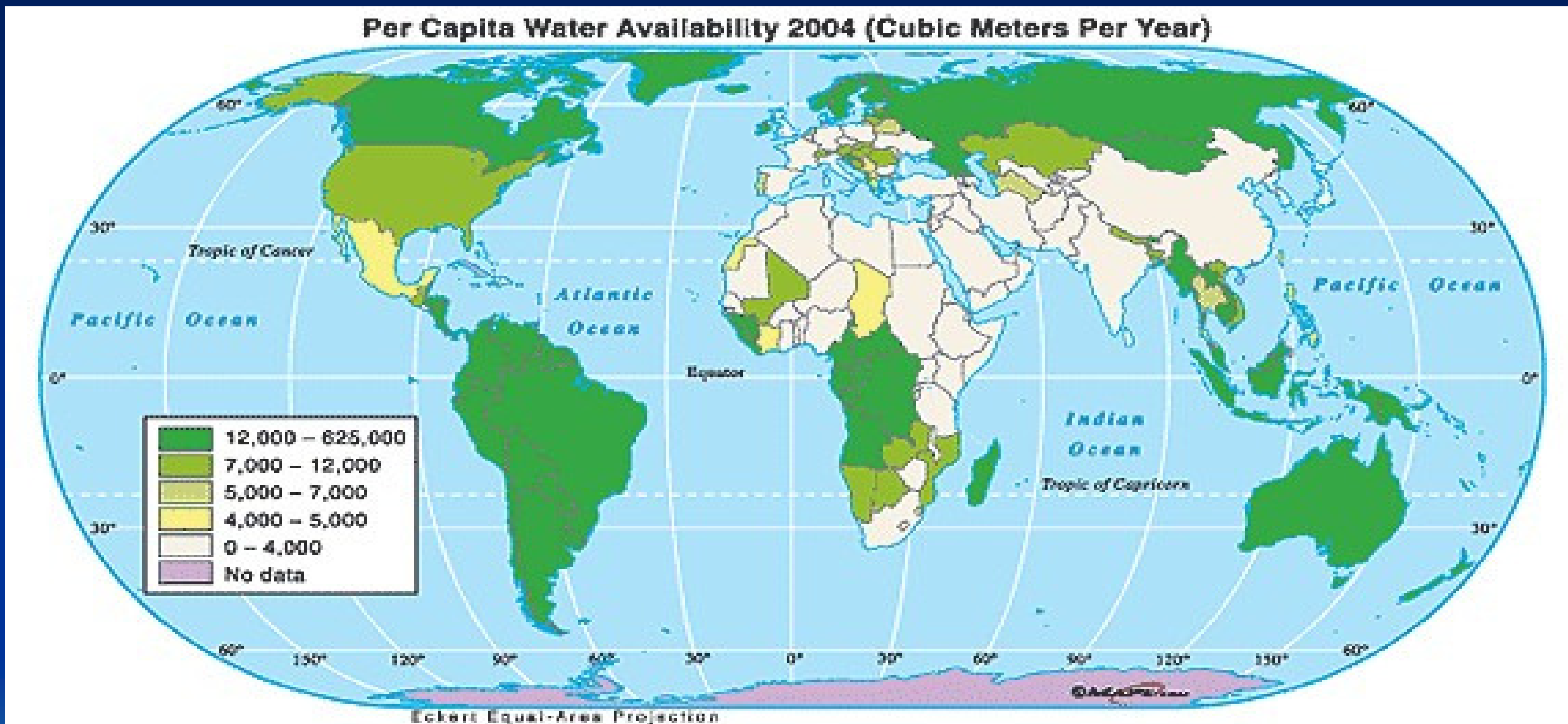
Justification of measuring the impacts of climate change on the Tessta- Torsa River Basin.

Major Causes of Watershed Degradation

- *Unequal Distribution of Water Resources*
- *Uncontrolled Extraction of Natural Resources*
- *Burgeoning Population*
- *Pollution*
- *Global Warming*

Unequal Distribution of Water Resources

Figure Showing Per Capita Water Availability within Continents :



According to UNESCO(2002),India has water availability equal to 1880 m^3/capita /year which is pre-ceeded by Mauritius and followed by Germany. The highest water availability is observed in USA 1,563,168 m^3/capita /year whereas lowest is observed in Kuwait(10 m^3/capita /year)

Uncontrolled Extraction of Natural Resources

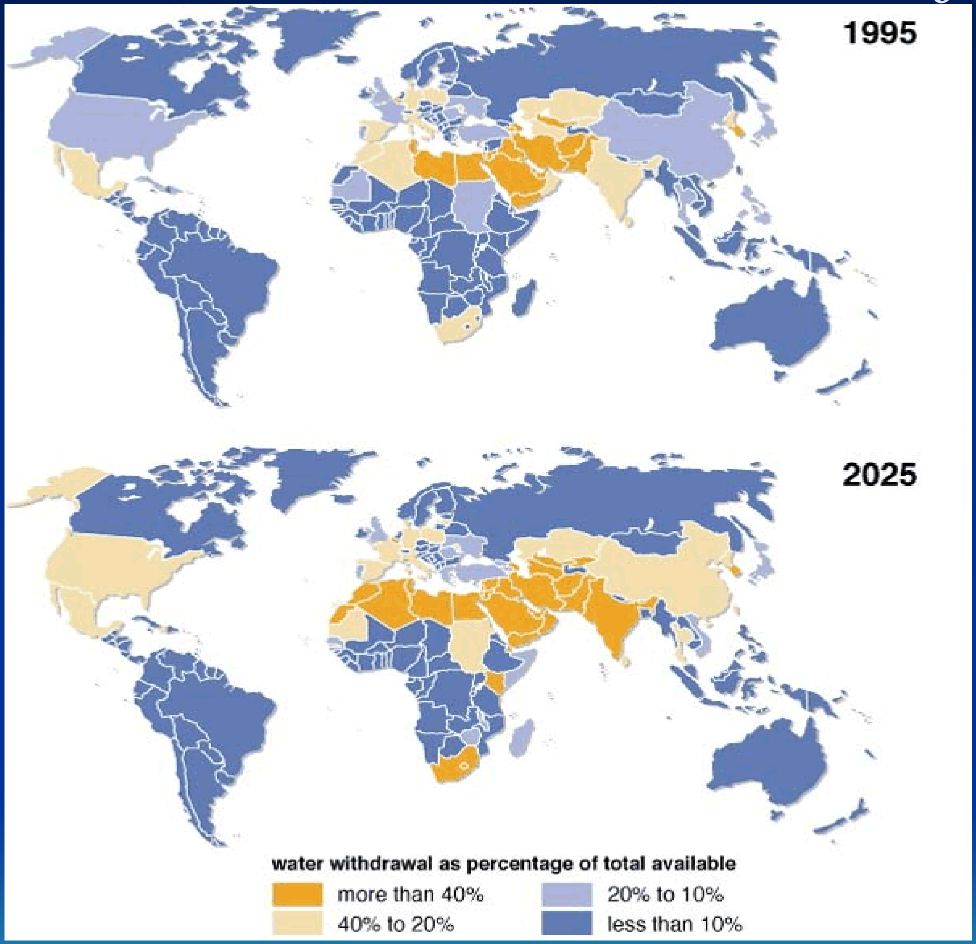


Figure Showing Water withdrawal as Percentage of Total Available(IPCC,2007) :

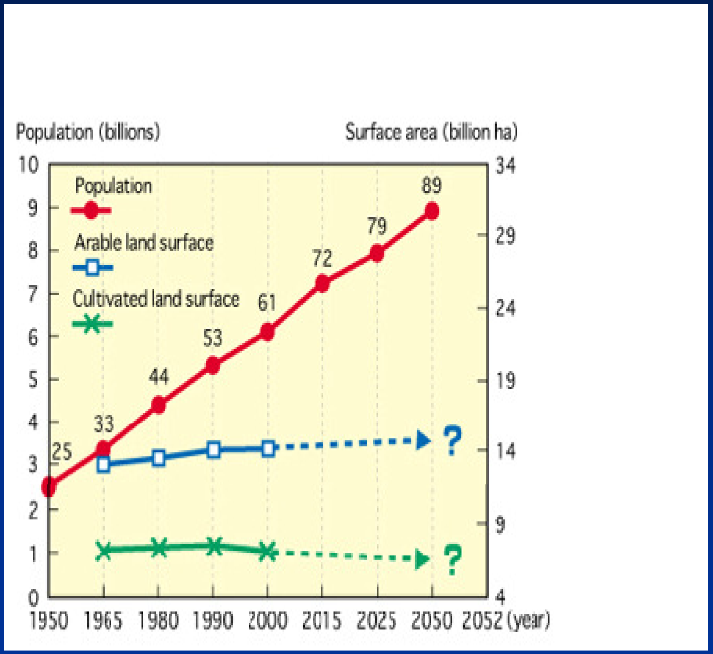


Figure Showing World Population and Arable and Cultivated Land Surface Area(RSBS 2009)

Water stress results from an imbalance between water use and water resources. The proportion of **water withdrawal** with respect to **total renewable resources** can indicate the degree of stress on available water.

Pollution

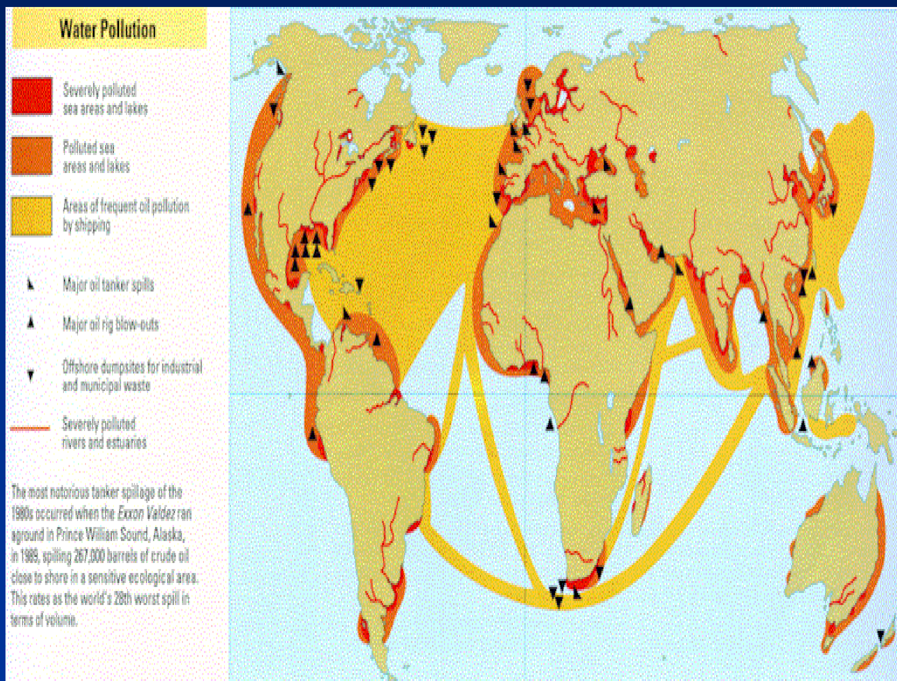


Figure Showing Situations in relation to water pollution(WHO/UNICEF,2004)

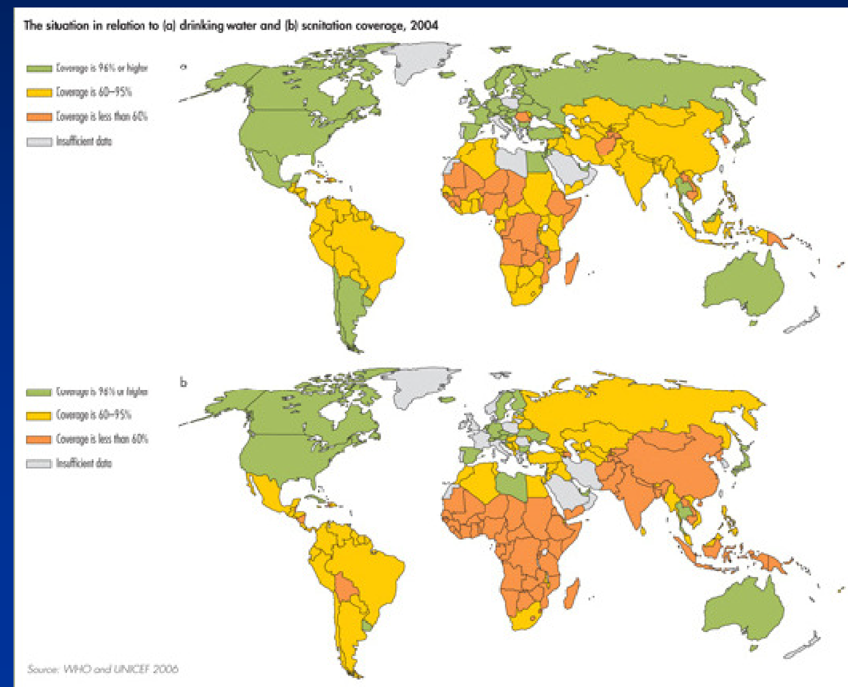


Figure Showing Situations in relation to drinking water and sanitation (WHO/UNICEF,2006)

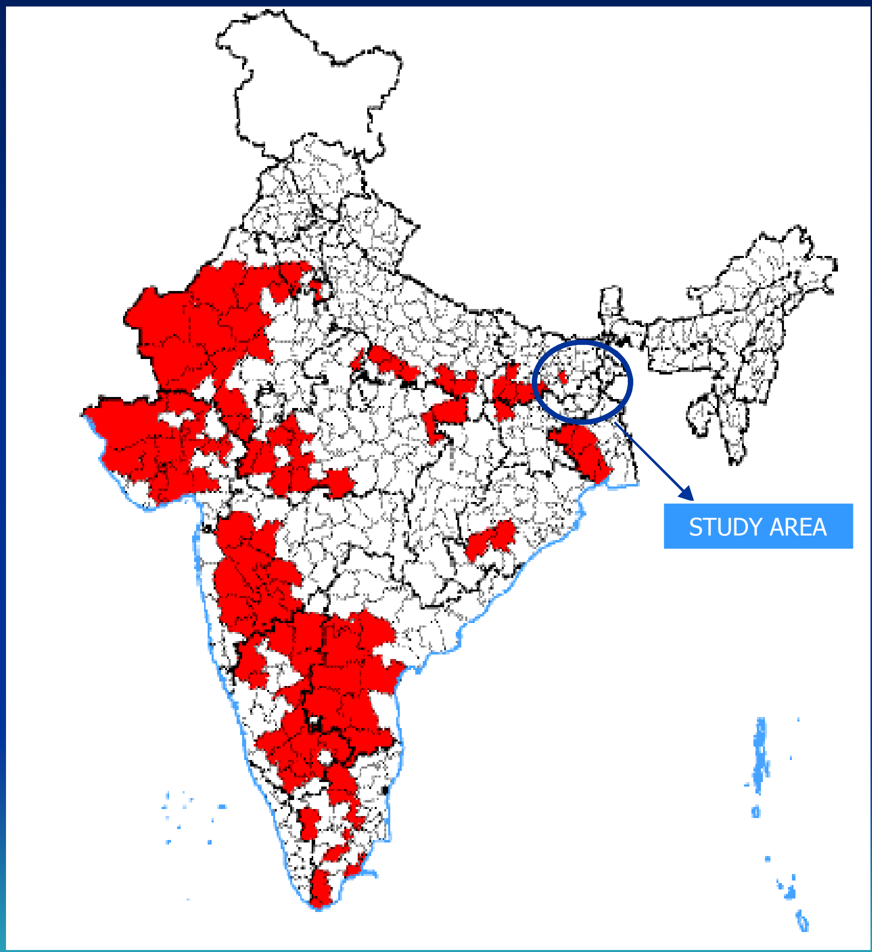
There is more waste water generated and dispersed today than at any other time in the history of our planet: more than one out of six people lack access to safe drinking water, namely 1.1 billion people, and more than two out of six lack adequate sanitation, namely 2.6 billion people (Estimation for 2002, by the WHO/UNICEF JMP, 2004).

Problems of Indian Rivers

- *In India, owing to the **exponential increase in population**, **large-scale land cover degradation** (due to increase in urban boundaries), **soil erosion** (owing to uncontrolled ploughing and deforestation for agricultural activity) and **uncontrolled demand** where demand exceeds supply are causing the watersheds to degrade.*
  - *Already many small tributaries of the River Ganges have disappeared.*
  - *The flood area has increased from 25 million hectares to 60 million hectares.*
  - *Climate variations have also decreased the groundwater table in the southern part of India. The reduction in water table has reduced the agricultural yield of Bangalore and other major cities of south India (Shivasankar 2008).*
  - *The per capita water availability in India was **3450 cu m in 1952**. It now stands at **1800 cu m** and by 2025 it is expected to fall to **1200 to 1500 cu m per person**.*

Indian Scenario of Water Resources

- Mumbai's demand for water is expected to rise to **7970** MLD (million litres daily) by 2011, and the current supply is **3100** MLD which already constitutes a substantial shortfall as the city receives only **2500** MLD, the balance lost on account of leakages and pilfering.
- In **Delhi** the supply of water is around **650** million gallons of water per day against the demand for **750** million.
- According to a World Bank study, of the **27 Asian cities** with populations of over 1,000,000, **Chennai** and **Delhi** are ranked as the worst performing metropolitan cities in terms of hours of water availability per day, while **Mumbai** is ranked as second worst performer and **Calcutta (**demand : 290 mgd, supply : 300mgd**)** fourth worst.(Dutta,2006)
- As early as **1982** it was reported that **70%** of all available water in India was polluted. It may have also resulted in problems of excessive fluoride, iron, arsenic and salinity in water affecting about **44 million people in India (**Deorah,2006).



*Drought Prone Areas
(Source : Environment Atlas,2010)

Problem Indication and Identification

- Drought occurs in over 80% of the country's land area even if there is a shortfall in rains of only 25% from the national annual average of 554mm (for the monsoon period from June to July).

- Even though the per capita availability of water in India is among the best in the world, the utilisable quantity is much less.

- On the one hand, most of the rainwater flows into the sea without being harnessed and, on the other hand, groundwater is being depleted owing to its over-extraction.

- Some States like Bihar are experiencing the double phenomenon of floods in one part and drought in another.

- “Despite bountiful natural resources, the country has not succeeded in harnessing them adequately” (MoIB 2003).

Hydrologic modeling and watershed management.

Need of the Hour : Optimal Watershed Management

- Identification of the problems faced by the watershed
- Response of the watershed in different uncertain conditions and climate change
- Decision Support Mechanism and Policy Adoption based on present status and the response of the watershed to future uncertainty

Objective and Scope of the Present Study

- Development of Indicators of Watershed Status : *WATER,* to identify the present status
- Selection of a proper mathematical and/or conceptual model for estimation of the watershed response to future uncertainty due to climate change.
- Comparison of Watershed Status Represented by the Indicators between Observed and the Estimated response.
- Decision Making and Preparation of Policies and Practices to check the degradation, reverse the trend and go for the optimality.

Different aspects and tools of managing the watersheds

Some Popular Hydrologic Modeling Systems

- ***Hydrologic Engineering Centre – Hydrologic Modeling System (HECHMS).***
- ***Trend Research Manual 55(Tr-55).***

***Watershed Rank** (WATER)*

Indicators Included :

- Surface Runoff
- Water Availability
- Virtual Water
- Water Footprint
- Green Water
- Water Sequestration
- Water Quality
- Presence of Industrial Pollutant
- Presence of Organic Pollutant

Water Availability(WA)

This variable measures the available renewable water after deduction (average annual surface runoff and groundwater recharge generated from endogenous precipitation). The Water Availability per capita per year is calculated as per the water budget equation which is (Subramaniya, 1994) ,

$$= \left(\frac{P-(Q+E+G+T)}{p} \right)$$

Where, P is precipitation, Q is basin runoff, E is Evaporation,G is groundwater outflow,T is transpiration and p is population of a region

Virtual Water (VW)

- Virtual water is defined as the volume of water used in the production of a commodity, good or service.
- 1000 liters of water are needed to produce 1 kilogram of wheat but for beef about 15 times as much is required.
- The majority of the water is consumed as food and different products which are commonly used in day to day life.

(Chapagain and Hoekstra 2004; Chapagain et.al. 2006)

Water Footprint (WF)

- Water Footprint is defined as an indicator of water consumption that looks at both direct and indirect water use of a consumer or producer (Aldaya et.al. 2009).
- The global average Water Footprint is 1240 m^3 water/person/year.
- The Chinese average is 700 m^3 water/person/year one of the smallest in the world and the United States's 2480 m^3 water/person/year is the largest in the world.
- The Finnish average Water Footprint is 1730 m^3 water/person/year.
- The water footprint of the UK is 1695 m^3 water/person/year (Chapagain and Orr 2009)
- A moderate WF will indicate optimal management of water whereas too large or too low will show the opposite

Determination of Water Footprint

If, f = percentage of annual supply of fresh water of a location,
f_i = percentage of annual supply of fresh water to the manufacturing as well as service industries or producers of the location for maintaining their service and development of the products.
and p_c = numbers of consumers for the produce of the same location,

Then, Availability of Fresh Water = $\mathbf{WA \times f}$ (1)
Again, By using Equation.1,Fresh Water supplied to manufacturing and service industries for maintaining the development and servicing of their products can be calculated as,

$$= (WA \times f) \times f_i \qquad (2)$$

and from Equation.2, Water Footprint (WF) in m3/capita/year can be calculated as,

$$WF = [(WA \times f)+\{ (WA \times f) \times f_i]/ p_c$$

$$= (WA \times f) [\{(1 + f_i)\}/ p_c] \qquad (3)$$

Green Water (GW)

- Green Water is actually the water used by plants (Falkenmar 2003)
- Green water is ignored by engineers because they can't pipe or pump it, by economists because they can't price it, and by governments because they can't tax it. (ISIRC 2009).
- Worldwide per capita grain production reached a peak in 1985 at 377kg, falling to 329kg by 2003.
- The difference in grain producing regions is also evident when looking at Africa, which peaked as early as 1967 at 189kg per person and fell to 150kg by 2003.
- Moderate amount of green water use is desired where as higher or lower green water will represent misuse.

Water Sequestration (WS)

Water Sequestration is the amount of green water per square km of vegetation area and can be calculated as :

Let, percentage of soil moisture in an area of A sqkm is s

Let, basin area of the same region be A sqkm and percentage of vegetated area of that region is a_v,

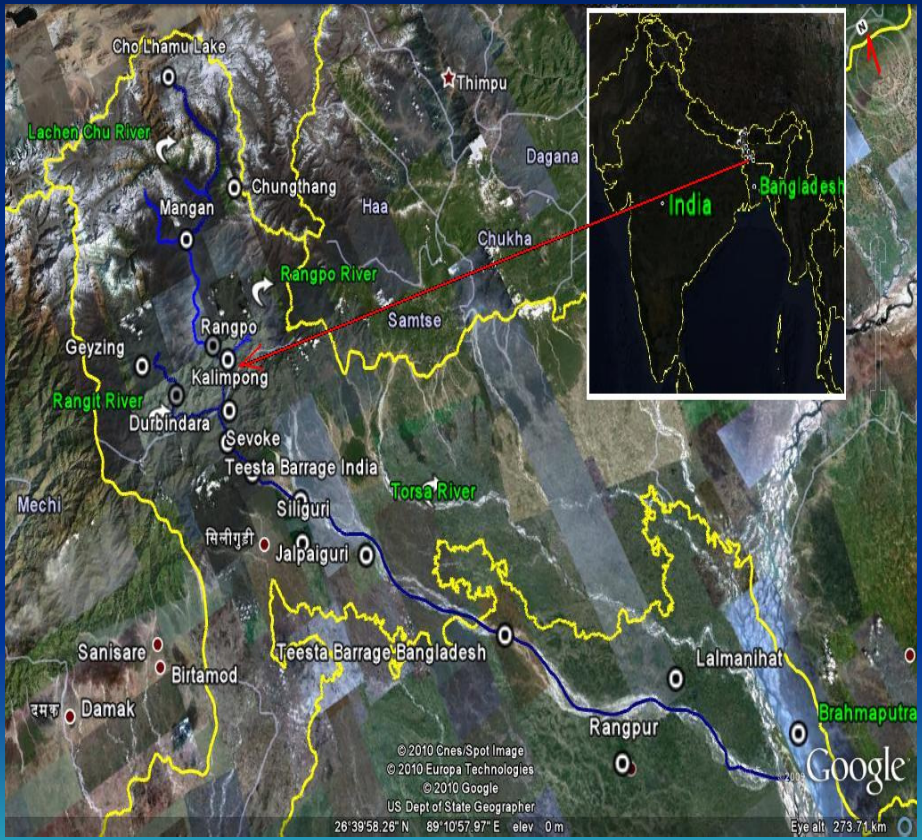
then, WSC in m^3/sqkm/year can be calculated as,

$$WSC = GW/(A \times a_v)\}$$

An overview of Teesta River system.

Study Area :
Teesta River System

Satellite Image



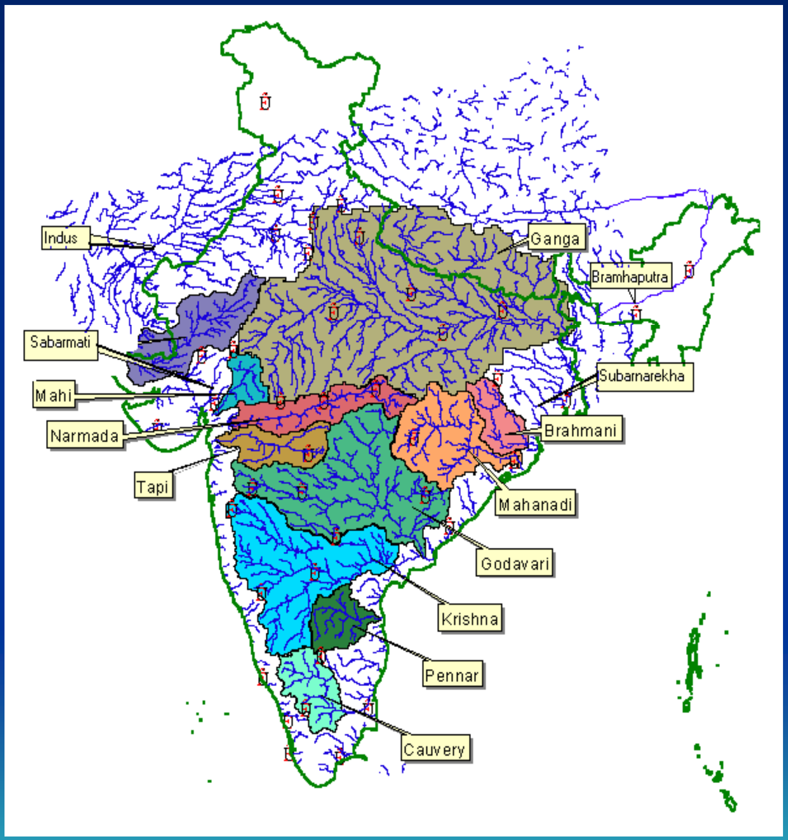


Figure Showing the satellite imagery of Teesta River System taken from 80km above MSL by SPOT satellite

Teesta River System

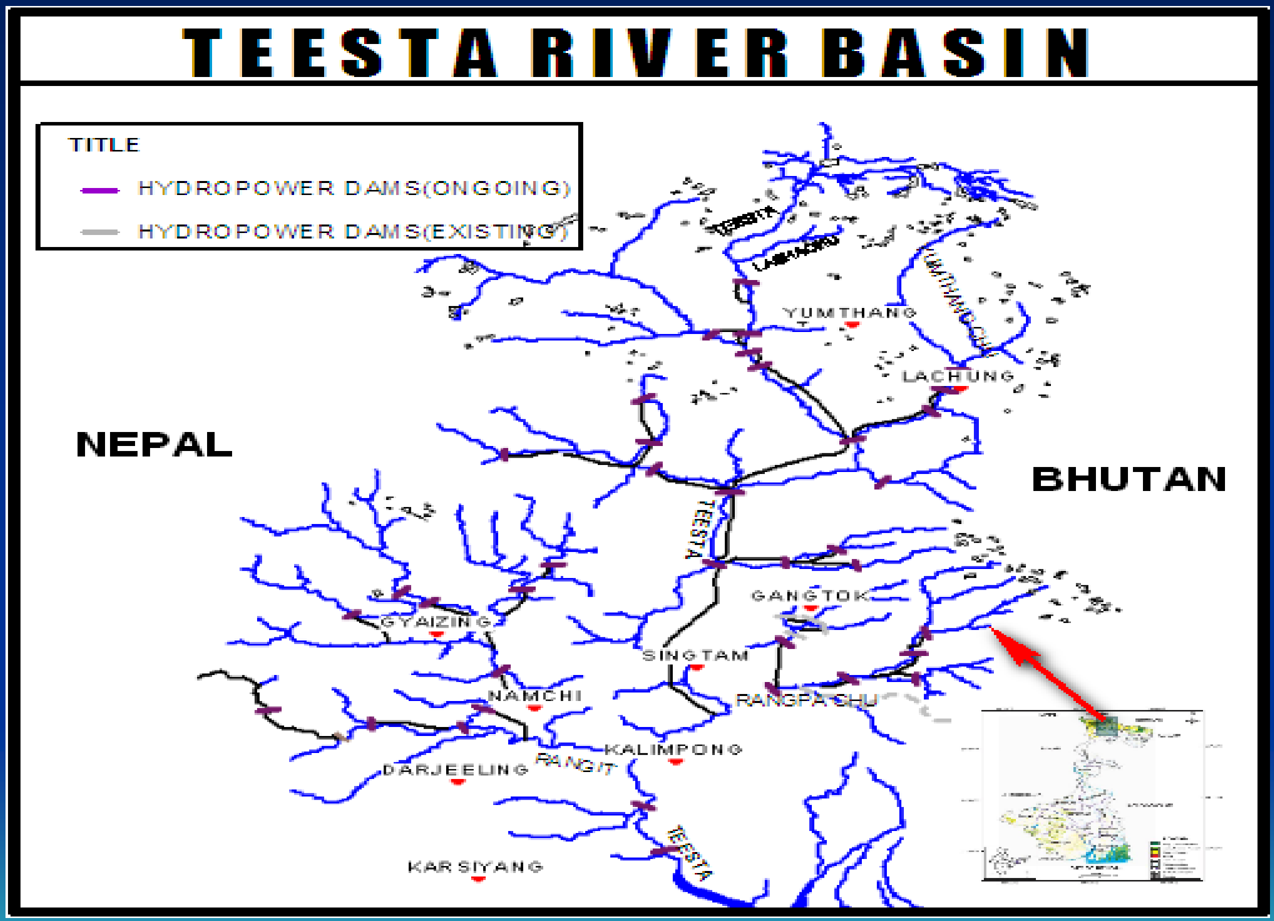


Table Showing Hydrological Information of the location of Teesta River System Consider in the Present Study

Table Showing Hydrological Information of the location of Teesta River System Consider in the Present Study									
Station(No.)	**District**	**State/ Country**	**Latitude**	**Longitude**	**Water Availability (m^3/ capita/year)**	**Green Water (m^3)**	**Virtual Water (m^3)**	**Water footprint (m^3/ capita/year)**	**Water sequestration**
Geyzing (30)	(W)		27.30	88.24	1629.55	206.24	103.12	488.86	0.17
Namchi(19)	(S)		27.19	88.30	989.44	89.61	44.8	296.83	0.07
Tendu East (5)	Tendu		27.18	88.9	2511.39	572.01	286	753.42	0.47
Jorethang (18)	(S)		27.16	88.35	992.95	38.73	19.36	297.88	0.03
Namchi (17)	(S)		27.15	88.33	985.12	-15.52	7.76	295.54	0.01
Kalimong (29)		W.B	27.12	88.41	176.91	52.54	23.88	53.07	0.04
Rangit (27)	(E)		27.05	88.35	251.29	33.17	16.58	75.38	0.03
TenduWest(6)	Tendu		27.03	88.93	2846.85	691.78	345.89	854.05	0.57
Durbindara(20)		W. B	26.96	88.46	27.76	1.83	0.56	5.55	0.001
East Samtse(45)	Samtse		26.96	89.10	2233.35	469	234.5	670	0.38
Mirik(37)		W.B	26.96	88.10	2250.09	1350.05	450.02	450.02	1.11
Darjeeling (1)		W.B	26.96	88.63	3463.4	987.07	329.02	692.68	0.81
North Darjeeling (23)		W.B	26.95	88.56	370.72	139.47	42.26	74.14	0.11
South Darjeeling (2)		W.B	26.94	88.62	494.81	59.38	29.69	148.44	0.048
Sevok (24)	Jalpaiguri	W.B	26.90	88.51	159.51	3.83	1.91	47.85	0.001
West Samtse (46)	Samtse		26.87	89.05	2175.72	744.1	248.03	435.14	0.61
Siliguri (39)	Jalpaiguri	W.B	26.79	88.47	3575.76	2580.66	860.22	715.15	2.12
Kranti Dam(38)	Jalpaiguri	W.B	26.71	88.70	4714.06	2836.5	945.5	942.81	2.33
North Jalpaiguri (11)	Jalpaiguri	W.B	26.71	88.76	777.47	985.89	328.63	155.49	0.81
South Jalpaiguri 12	Jalpaiguri	W.B	26.58	88.58	1350.19	648.09	216.03	270.04	0.53
Birgan (42)		W.B	26.28	89.06	1152.34	509.16	203.66	230.47	0.42
Cooch Behar (44)		W.B	26.13	89.54	450.87	184.82	73.93	90.17	0.15
Lalmonirhat (43)	Lalmonirhat		25.84	89.50	331.85	270.11	108.04	66.37	0.22

METHODOLOGY

Selection of Simulation Model

- Conceptual Hydrologic Model
  - Hydrologic Engineering Center-Hydrologic Modeling System (HECHMS)
  - Modified Rational (MODRAT) Model
  - Trend Research Manual 55(Tr55)

HEC-HMS

Directly-connected impervious surface or Pervious surface. Directly-connected impervious surface in a watershed is that portion of the watershed for which all contributing precipitation runs off, with no infiltration, evaporation, or other volume losses. Precipitation on the pervious surfaces is subject to losses.

$$pe_t = \begin{Bmatrix} p_t - f_c & if\ p_t > f_c \\ 0 & otherwise \end{Bmatrix}$$

$$pe_t = \begin{Bmatrix} 0 & if \sum p_i < I_a \\ p_t - f_c & if \sum p_i > I_a\ and\ p_t > f_c \\ 0 & if \sum p_i > I_a\ and\ p_t < f_c \end{Bmatrix}$$

Where,
f_c, potential rate of precipitation loss,
p_t is the MAP depth
pe_t is the excess precipitation

LIMITATION

1. Infiltration and precipitation rate constant throughout the surface.
2. Catchment divided into pervious and impervious where as impervious with depression is also available but not considered while modeling

Tr55

$$Q_p = Q_u A \, Q F_p \qquad Q = \frac{(P - I_a)^2}{P - I_a + s} \qquad I_a = 0.2\,s \qquad s = \frac{1000}{CN} - 10$$

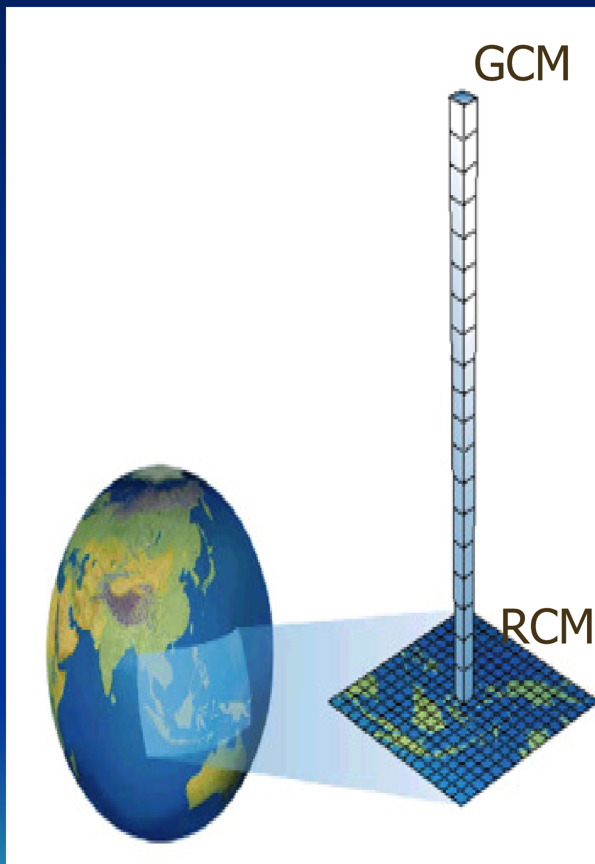
$$Q_u = f\left(T_c\,,\ \frac{I_a}{P},\ \text{Rainfall Distribution Type}\right) \qquad F_p = f(\%\ \text{Ponds and Swamps})$$

Where: **A** = total watershed area (Km^2).
CN = overall curve number for the watershed.
Fp = pond and swamp adjustment factor
Ia = initial abstraction (m).
P = precipitation (mm) for 24-hr duration storm of return period
Q = depth of runoff over entire watershed (mm).
Qp = peak discharge (cms).
Qu = unit peak discharge (cms/ Km^2)
s = potential maximum watershed water retention after runoff begins (mm).
Tc = time of concentration for the watershed (hr).

LIMITATION

1.Methods based on open and unconfined flow over land and in channels.
2.Graphical peak method is limited to a single, homogenous watershed area.
3.For multiple homogenous sub-watersheds use the tabular hydrograph method
4.Storage-Routing Curves should not be used if the adjustment for ponding is used.

CLIMATE MODELS



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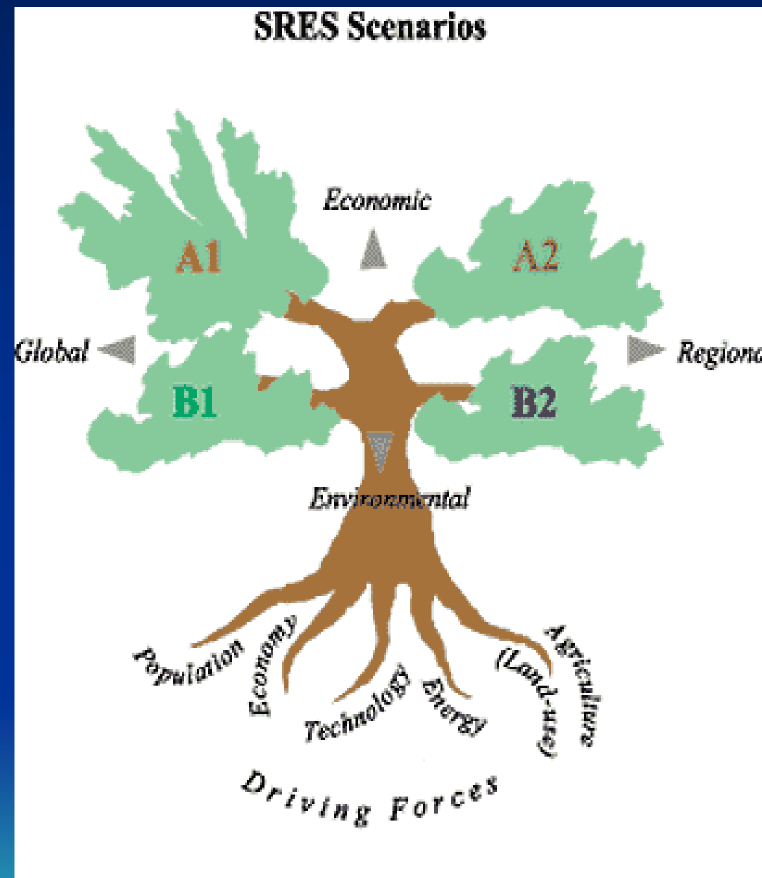
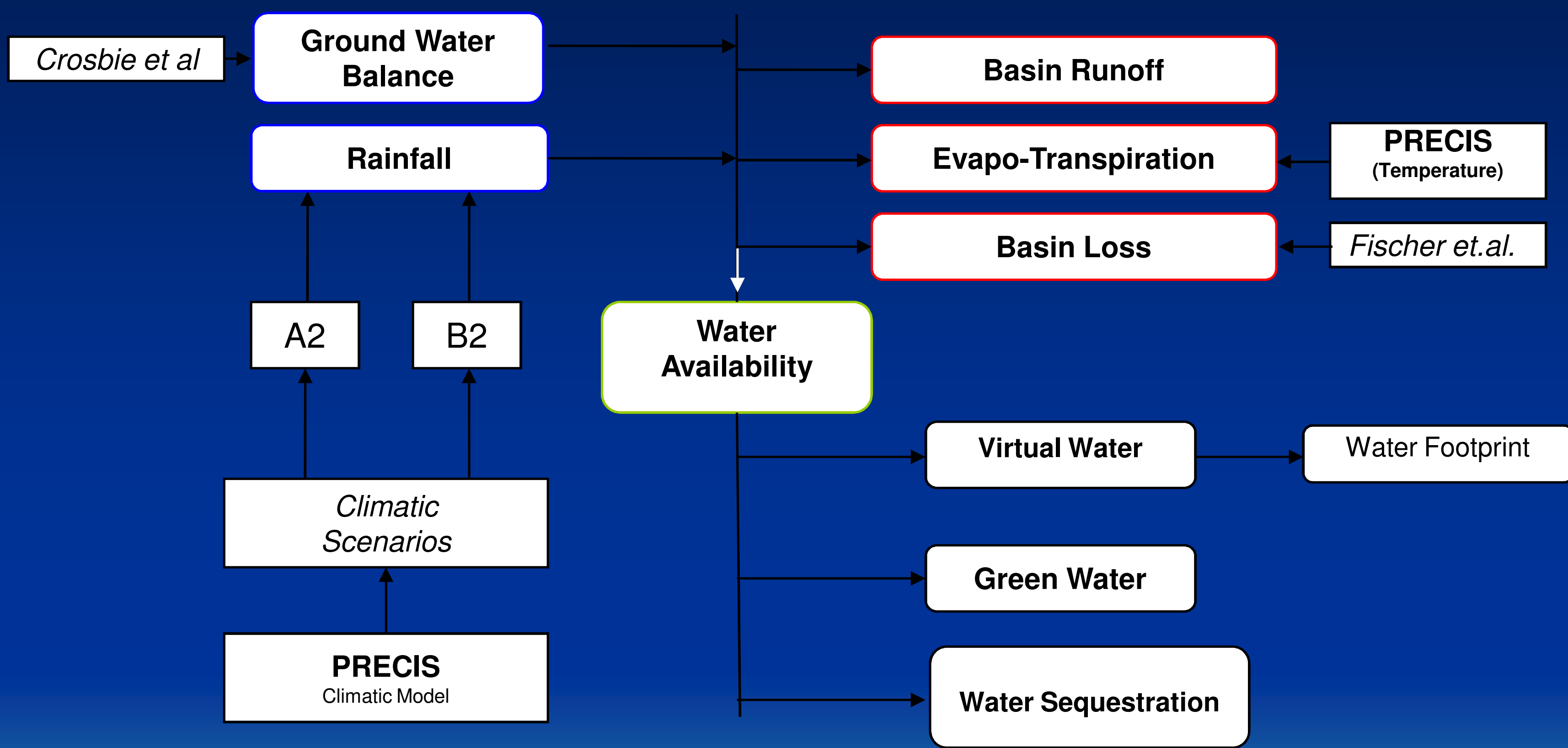


Overview of the Study Methodology



RESULTS AND DISCUSSION

Different Study Locations of Teesta River System according to the A2 and B2 Scenario of Climate Change

Table Showing Peak Flow(m^3/s) from Different Study Locations of Teesta River System according to the A2 and B2 Scenario of Climate Change

Locations				A2			B2		
State	District	Station	Observed (1972-2002)	2011-40	2041-70	2071-2100	2011-40	2041-70	2071-2100
Sikkim	(W)	Geyzing	24.96	548.65	575.23	601.81	543.33	548.65	601.81
	(S)	Namchi	35.65	1086.18	1138.80	1191.4	1075.6	1086.2	1191.40
W.B		Mirik	4616.05	561.90	589.07	616.23	556.47	561.90	616.23
W.B		Kalimpong	4624.52	3749.25	3930.67	4112.1	3712.9	3749.2	4112.09
W.B			382.75	561.90	589.07	616.23	556.47	561.90	616.23
W. B	Jalpaiguri	Sevok	5349.19	5329.69	5587.54	5845.4	5278.1	5329.7	5845.39
W.B	Jalpaiguri	Siliguri	9999.54	6862.95	7194.90	7526.9	6796.6	6862.9	7526.85
W.B	Jalpaiguri	Jalpaiguri	1562.74	608.89	638.34	667.80	603.00	608.89	667.79
W.B	CoochBehar	CoochBehar	1233.19	3600.84	3774.81	3948.8	3566.1	3600.8	3948.79
Banagladesh	Lalmonir hat	Lalmonir hat	13405.80	2841.57	2980.15	3118.4	2813.4	2841.2	3116.57

Table Showing Water Availability of Teesta River System according to the A2 and B2 Scenario of Climate Change

Table Showing Water Availability(m^3/capita/year) from Different Study Locations of Teesta River System according to the A2 and B2 Scenario of Climate Change

Locations				A2			B2		
State/ Country	District	Station	Observed (1972-2002)	2011-40	2041-70	2071-2100	2011-40	2041-70	2071-2100
	(W)	Geyzing	1629.55	552.37	293.18	162.78	820.79	560.12	310.23
	(S)	Namchi(N)	989.44	293.86	155.84	86.41	436.66	297.89	164.76
	Tendu	Tendu (E)	2511.39	869.44	461.35	255.85	1291.9	881.36	488.08
	(S)	Jorethang	992.95	284.48	150.76	83.49	422.71	288.30	159.25
	(S)	Namch(S)	985.12	-259.91	-139.07	-78.29	-385.84	-264.12	-148.36
W.B		Kalimpong	176.91	79.96	39.20	18.61	117.62	77.97	36.84
	(E)	Rangit	251.29	218.07	115.67	64.10	324.05	221.04	122.32
	Tendu	TenduWest	2846.85	986.27	523.92	291.97	1465.4	1000.9	554.81
W. B		Durbindara	27.76	54.63	22.37	6.06	78.31	48.75	14.03
	Samtse	Samtse (E)	2233.35	772.31	409.93	227.62	1147.6	783.14	433.79
W.B		Mirik	2250.09	822.04	436.03	241.73	1221.3	833.19	461.01
W.B			3463.40	1207.2	640.21	354.77	1793.6	1223.4	676.65
W.B		(N)	370.72	127.80	67.39	36.98	189.68	129.12	70.66
W.B		(S)	494.81	136.54	71.18	38.25	202.28	137.10	73.44
W.B	Jalpaiguri	Sevok	159.51	1700.16	894.72	488.71	2523.88	1716.21	936.25
	Samtse		2175.72	757.46	402.03	223.21	1125.55	768.08	425.42
W.B	Jalpaiguri	Siliguri	3575.76	1276.41	675.69	372.97	1896.03	1292.21	712.58
W.B	Jalpaiguri	Kranti Dam	4714.06	1699.28	900.15	497.96	2524.27	1721.25	949.98
W.B	Jalpaiguri	Jalpaiguri(N)	777.47	275.76	145.47	79.81	409.39	278.67	152.67
W.B	Jalpaiguri	Jalpaiguri(S)	1350.19	476.98	250.87	136.91	707.81	481.27	262.18
W.B		Birgan	1152.34	506.60	266.76	145.93	751.98	511.55	279.26
W.B			450.87	134.61	69.25	36.28	199.13	134.31	70.11
	Lalmonirhat	Lalmonirhat	331.85	167.63	87.85	47.65	248.64	168.85	91.36

Table Showing Water Availability(m^3/capita/year) of Teesta River System according to the A2 and B2 Scenario of Climate Change

Table Showing Water Availability(m^3/capita/year) from Different Study Locations of Teesta River System according to the A2 and B2 Scenario of Climate Change

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	Samtse		2175.72	757.46	402.03	223.21	1125.55	768.08	425.42
W.B	Jalpaiguri	Siliguri	3575.76	1276.41	675.69	372.97	1896.03	1292.21	712.58
W.B	Jalpaiguri	Kranti Dam	4714.06	1699.28	900.15	497.96	2524.27	1721.25	949.98
W.B	Jalpaiguri	Jalpaiguri(N)	777.47	275.76	145.47	79.81	409.39	278.67	152.67
W.B	Jalpaiguri	Jalpaiguri(S)	1350.19	476.98	250.87	136.91	707.81	481.27	262.18
W.B		Birgan	1152.34	506.60	266.76	145.93	751.98	511.55	279.26
W.B			450.87	134.61	69.25	36.28	199.13	134.31	70.11
	Lalmonirhat	Lalmonirhat	331.85	167.63	87.85	47.65	248.64	168.85	91.36

Table Showing Water Footprint(m^3/capita/year) from Different Study Locations of Teesta River System according to the A2 and B2 Scenario of Climate Change

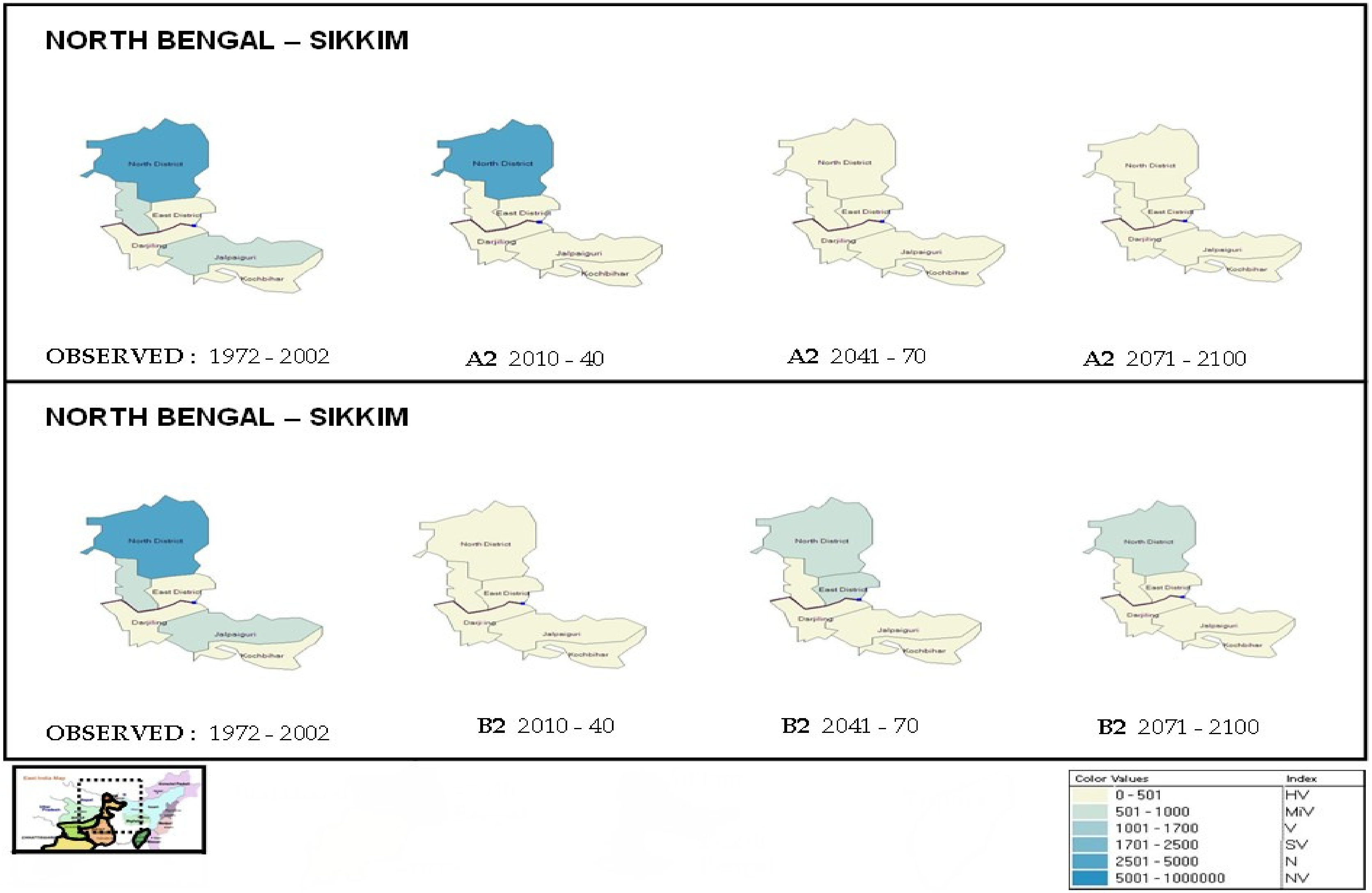
Table Showing Water Footprint(m^3/capita/year) from Different Study Locations of Teesta River System according to the A2 and B2 Scenario of Climate Change									
Locations				A2			B2		
State/ Country	District	Station	Observed (1972-2002)	2011-40	2041-70	2071-2100	2011-40	2041-70	2071-2100
	(W)	Geyzing	488.86	165.71	87.95	48.83	246.24	168.03	93.07
	(S)	Namchi (N)	296.83	88.15	46.75	25.92	131.00	89.36	49.43
	Tendu	TenduEast	753.42	260.83	138.40	76.75	387.57	264.41	146.42
	(S)	Jorethang	297.88	85.34	45.23	25.05	126.81	86.48	47.77
	(S)	Namchi (S)	295.54	-77.97	-41.72	-23.46	-115.75	-79.23	-44.51
W.B		Kalimpong	53.07	23.98	11.76	5.58	35.28	23.39	11.05
	EastSikkim	Rangit	75.38	65.42	34.70	19.23	97.22	66.31	36.69
	Tendu	TenduWest	854.05	295.88	157.17	87.59	439.64	300.28	166.44
W. B		Durbindara	5.55	10.92	4.47	1.21	15.66	9.75	2.80
	Samtse		670.00	231.69	122.97	68.28	344.27	234.94	130.14
W.B		Mirik	450.02	164.41	87.20	48.34	244.27	166.64	92.20
W.B			692.68	241.45	128.04	70.95	358.73	244.69	135.33
W.B		(N)	74.14	25.56	13.48	7.39	37.94	25.82	14.13
W.B		(S)	148.44	40.96	21.35	11.47	60.68	41.13	22.03
W.B	Jalpaiguri	Sevok	47.85	510.05	268.41	146.61	757.16	514.86	280.87
	Samtse		435.14	151.49	80.40	44.64	225.11	153.61	85.08
W.B	Jalpaiguri	Siliguri	715.15	255.28	135.14	74.59	379.20	258.44	142.51
W.B	Jalpaiguri	Kranti Dam	942.81	339.85	180.03	99.59	504.85	344.25	189.99
W.B	Jalpaiguri	Jalpaiguri (N)	155.49	55.15	29.09	15.96	81.87	55.73	30.53
W.B	Jalpaiguri	Jalpaiguri (S)	270.04	95.39	50.17	27.38	141.56	96.25	52.44
W.B		Birgan	230.47	101.32	53.35	29.18	150.39	102.31	55.85
W.B			90.17	26.92	13.85	7.25	39.83	26.86	14.02
	Lalmonirhat	Lalmonirhat	66.37	33.52	17.57	9.53	49.73	33.77	18.27

Table Showing Water Sequestration(m^3/km^2) from Different Study Locations of Teesta River System according to the A2 and B2 Scenario of Climate Change

Table 7.4.Table Showing Water Sequestration(m^3/km^2) from Different Study Locations of Teesta River System according to the A2 and B2 Scenario of Climate Change

Locations				A2			B2		
State/ Country	District	Station	Observed (1972-2002)	2011-40	2041-70	2071-2100	2011-40	2041-70	2071-2100
		Geyzing	0.17	0.17	0.18	0.20	0.17	0.17	0.19
		Namchi (N)	0.07	0.06	0.07	0.07	0.06	0.06	0.07
	Tendu	Tendu East	0.47	0.48	0.52	0.57	0.48	0.49	0.55
		Jorethang	0.03	0.03	0.03	0.03	0.02	0.02	0.03
		Namchi (S)	0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
W.B		Kalimpong	0.04	0.06	0.05	0.05	0.05	0.05	0.05
	EastSikkim	Rangit	0.03	0.07	0.07	0.08	0.07	0.07	0.08
	Tendu	TenduWest	0.57	0.59	0.63	0.70	0.58	0.60	0.66
W. B		Durbindara	0.001	0.01	0.01	0.001	0.01	0.01	0.001
	Samtse		0.38	0.40	0.42	0.47	0.39	0.40	0.45
W.B		Mirik	1.11	1.22	1.29	1.43	1.20	1.23	1.36
W.B			0.81	0.85	0.90	0.99	0.84	0.86	0.95
W.B		(N)	0.11	0.12	0.12	0.13	0.11	0.12	0.13
W.B		(S)	0.048	0.04	0.04	0.04	0.03	0.04	0.04
W.B	Jalpaiguri	Sevok	0.001	0.10	0.11	0.11	0.09	0.10	0.11
	Samtse		0.61	0.64	0.67	0.75	0.63	0.65	0.72
W.B	Jalpaiguri	Siliguri	2.12	2.27	2.41	2.65	2.25	2.30	2.54
W.B	Jalpaiguri	Kranti Dam	2.33	2.52	2.67	2.96	2.50	2.55	2.82
W.B	Jalpaiguri	Jalpaiguri (N)	0.81	0.86	0.91	0.99	0.85	0.87	0.95
W.B	Jalpaiguri	Jalpaiguri (S)	0.53	0.56	0.59	0.65	0.56	0.57	0.62
W.B		Birgan	0.42	0.55	0.58	0.63	0.54	0.56	0.61
W.B			0.15	0.13	0.14	0.14	0.13	0.13	0.14
	Lalmonirhat	Lalmonirhat	0.22	0.33	0.35	0.38	0.33	0.34	0.36

Figure showing the District wise Vulnerable Regions along the Teesta River System



Conclusion

- The present study tried to estimate the impacts of climate change on water availability of Teesta River System with the help of Tr-55 conceptual hydrologic model. The results were compared with the HEC-HMS conceptual hydrologic model. The future scenarios of climate change were generated from PRECIS climate model. The A2 and B2 scenario of climate change for 2011-2100 was considered. The surface runoff was predicted for the generated climatic scenario with the help of the Tr-55 model. The results were applied to the Water Budget Equation to find the water availability.

Contd.

- According to the vulnerability analysis, the districts of the river system becomes highly vulnerable from semi and non-vulnerable in case of A2 scenario of climate change and for B2 scenario of climate change, the regions were highly vulnerable in 2011-2040 but the situation improves to only vulnerable from 2041 to 2100.
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Contd

- The land use, soil type along with the amount of vegetation was found to have a major influence on the runoff predictions .The low amount of vegetation, porous soil and highly industrial land use had enforced the increase in runoff for industrially active A2 scenario but for the environmentally stable B2 scenario, the decrease in runoff showed the upgraded status of the watershed.

- The increased amount of virtual water for A2 scenario shows the increasing demand for water from industry which was causing stress on total water availability of the two basins. The amount of water availability was found to be inversely related with amount of virtual water where when virtual water gets increased, amount of water available get decrease but change in water availability was found to be proportional to virtual water. Accordingly, for the environmentally stable B2 scenario, a slower but increasing trend in virtual water was observed whereas the change in water availability was also found to be slower.

- The degradation of water quality was found to be more in A2 scenario due to higher concentration of industries which would increase the amount of effluents in the river water. The organic pollution was found to be increased for both A2 and B2 scenario. Due to strict waste management controls, the intensity of change in A2 is found to be greater than B2.

Limitation

- Deficit of Neuro-genetic models,
  - Number of weights(verified by weight formula(Baum and Haussler(1989))
  - Out of range data(data scaled to unit-less fraction)
  - Discovering network architecture (appn of GA)
- Accuracy of Climatic Models,
  - Assumed 21st century climate would be like 20th century climate;
  - Assembled and processed results from simulations using global climate models; and
  - Introduction of thresholds and breakpoints.
- Limitation in Data Collection
  - Reliability of Data Quantity and Quality (moving average)
  - Missing Data(Appn of GIS and remote sensing (Bjerklie et.al.,2003)
  - Ungauged basin(Appn of GIS and remote sensing (Bjerklie et.al.,2003)

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Thank you