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An analysis of upstream withdrawal scenarios using geo-spatial approach in the Surma-Kushiyara river basin

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Abstract

The upstream withdrawal is a worldwide incident but seen mostly in the developing countries. A downstream country like Bangladesh is facing this problem in all of its large rivers which in turn directly affect her socio-economic, environmental and geo-physical phenomena. It is an open proposal that India is preparing to construct a dam at Tipaimukh and a barrage at Fulertal in the upper reaches of the Barak. In the decisive point of view, it is very important to analyze its effects specifically with hydrodynamic views. The objectives of this research were therefore to investigate the probable impact on inundation pattern in terms of extent and depth due to upstream withdrawal in the Surama-Kushiyara basin by MIKE 11 GIS. Three scenarios of flow regulation chosen for analysis included as (i) average year flow without Tipaimukh dam, (ii) average year flow with Tipaimukh dam, and (iii) average year flow with Tipaimukh dam and Fulertal barrage. A study area in between the two rivers in the basin was selected to analyze the effect of inundation pattern due to upstream withdrawal and/or diversion. The effect of such external changes has been analyzed in terms of reduction in flooded area due to dam as well as dam and barrage operation, but also the change of inundation area in terms of larger depth to shallow depth was analyzed using F0, F1, F2, F3 and F4 type of land classification corresponding to the depth of inundation of 0-30 cm, 30-90 cm, 90-120 cm, 120-360 cm and greater than 360 cm. It appears that in the post-dam situation, the extent of inundation shows a decrease by about 60% in pre-monsoon, 22.5% in monsoon and 63% in post-monsoon season. For the barrage in addition to the dam, no further change in inundation extent was evident from the simulation result with some redistribution of F0, F1, F2, F3 and F4 land types.

Keywords: Upstream Withdrawal, Inundation Pattern, Scenarios, Land type

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A review of literature reveals that wetlands have declined or disappeared in many areas around the world (Hollis 1990, 1992; Hollis and Jones 1991; Jones et al. 1995; Sparks 1995; Wilen and Bates 1995; Foote et al.1996). The most notable example is the Aral Sea, the floodplain terminus of the Amu-Darya and Syr-Darya Rivers in Uzebekistan and Kazakhstan. Over a 27-year period from 1960 to 1987, diversion of water for upstream irrigation caused water levels in this huge inland sea (68 000 km^2) to drop by 13 m, decreasing the wetland area by 40%, and having a severe impact on biodiversity (Micklin, 1988). FAP 6 (FPCO, 1994) conducted a study on the availability of water in the Surma-Kushiyara river system considering the effect of upstream storage by a dam and diversion for Cachar Irrigation Project in India.

2. Study Area

Originating and flowing through India, the Barak river enters Bangladesh at Amalshid where the river bifurcates into the Surma and the Kushiyara. The Surma flows about 28 km as border river and the Kushiyara flows about 42 km as border river with India (BWDB, 2000). The Surma and the Kushiyara river basins are located in the northeast region of Bangladesh as shown in Figure 2 at Sylhet district. Considering the functions and problems of the Surma and the Kushiyara basins due to upstream water diversion and withdrawal from Barak river by India has been selected. From this basin a study area as shown in Figure 3 between two rivers for only analyzing the changes in the extent and depth of flooding that is how the inundation area of larger depths changes to shallower depths.

The climate of the study area is monsoon tropical with hot wet summers and cool dry winters. The highest temperature in the area is recorded at 40.6^{O}C in May and the lowest at 8.9^{O}C in December and February. Mean monthly rainfall varies from 9.2 mm in January to 916.5 mm in June, and mean annual rainfall is 3833.7 mm. Potential evapotranspiration is the lowest in December at 102.6 mm/month and the highest in March at 162.4 mm/month (FAP 6, 1993). The soils in the study area, which develop from alluvial sediments, lay down by the Surma and the Kushiyara rivers. Because both rivers originate from the Barak river, so parent materials of the soil are similar. Heavy clay soils occur in the deeply flooded basins. Silty clay soils occur on low, smoothed-out ridges and basin edges. Silty clay loams are found primarily on ridges, white medium texture soils (loam to silt loam) occupy the highest topographical positions (FAP 6, 1993).

The study area is subjected to seasonal flooding of varying depths and duration. On the basis of surface inundation by normal flood, four types of land classes were identified in the study area by following the standard classification of Agro Ecological Zoning (AEZ) System (FAP 6, 1993).

- Highland: Land above normal flood level
- Medium highland: Land seasonally flooded up to 90 cm deep
- Medium lowland: Land seasonally flooded between 90-180 cm deep
- Lowland: Land seasonally flooded more than 180 cm deep.

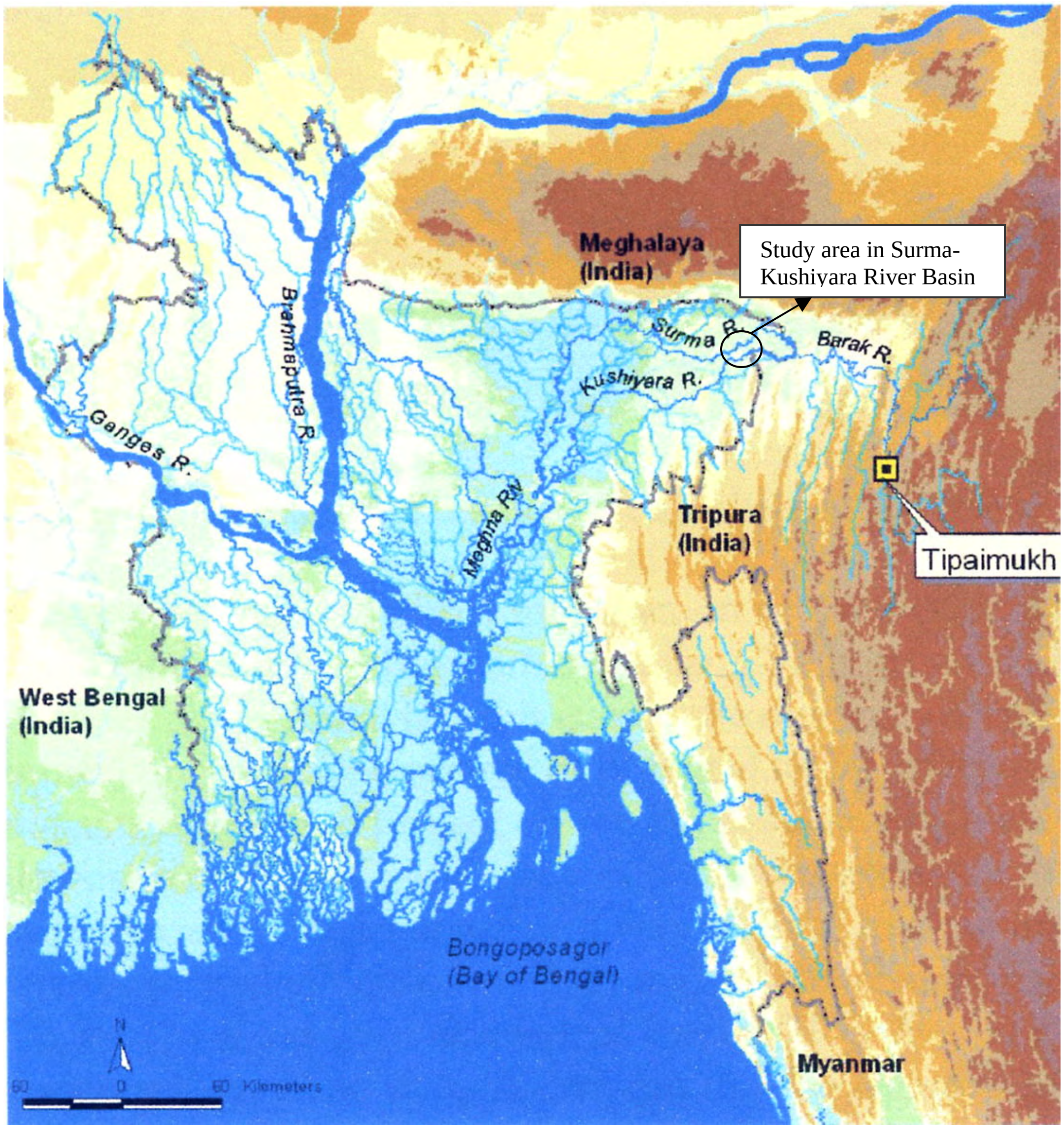

Fig. 2. Study area in Surma-Kushiyara River basin

2. Data collection and processing

A large amount of data of different types and maps are needed. All types of data, maps, and images were collected from various sources. To simulate the Model a huge amount of water level, discharge, rainfall, evaporation, and abstraction data were required; in general these were collected from the Institute of Water Modelling (IWM) at BUET.

In addition, observed discharge data for the base year 2000-2001 and for the average flood year 1996-1997 were also collected from the IWM. A summary of the hydrometric data collection is presented in Table 1.

Table 1
Summary of data collected from different sources

Type	Sources	Period	
		From	To
Rainfall	IWM	2000	2001
Evaporation	IWM	2000	2001
Groundwater abstraction	IWM	2000	2001
Water Level	IWM	2000	2001
Discharge	IWM	1969	2001

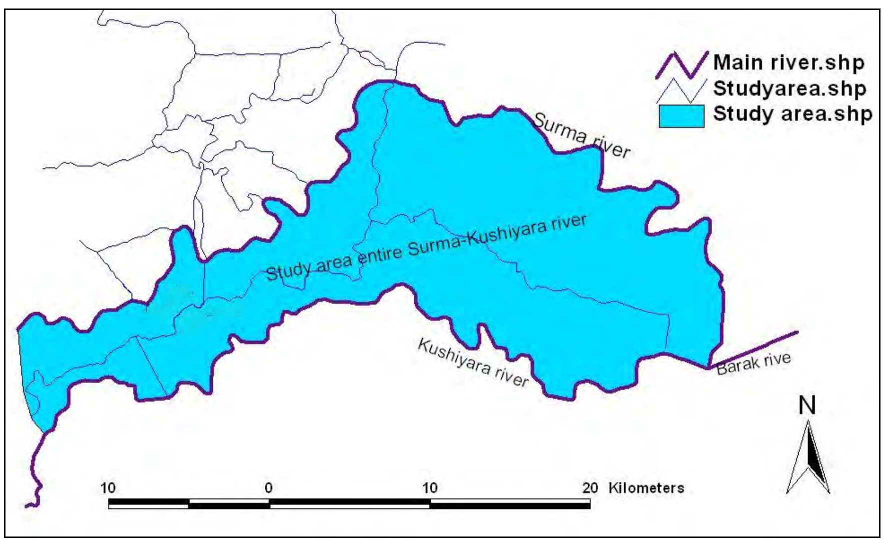

Fig. 3. Study area in the Surma-Kushiyara basin

For the period of 2000-01 and 1996-1997 water level and discharge data were collected from IWM. From the stations at Kanaighat, Sheola and Sylhet in the study area- the collected data have been used to generate boundaries. The discharge and the water level data that were applied at the boundary consist of:

- Constant values of *h* at downstream or *Q* at upstream boundary.
- Time varying values of *h* or *Q*
- A relationship between *h* and *Q* (e.g. a rating curve) (Should only be used at downstream boundaries)

The topographic data includes the cross-sections of river, khal, and beel and also the surface elevation with respect to datum in the study area. The cross-sections of the main river system and the beel[1] in the Surma-Kushiyara river basin were collected from IWM. From the field survey the cross-section data of the khals in the study area were collected.

River network map for the Surma-Kushiyara river basin and the DEM (Digital Elevation Model) of the study area were collected from IWM. The flood inundation RADAR images were obtained from Centre for Environmental and Geographic Information Services (CEGIS), Dhaka.

3. Analysis approach

The analysis comprises one- and semi-two-dimensional hydrodynamic model setup, calibration and finally model simulation for the selected scenarios as described below. One-dimensional model was used to simulate flows in the rivers and khals in the study area. This part of analysis was carried out using MIKE 11 model. Then the inundation pattern in the study area was simulated using semi-two-dimensional approach employing MIKE 11 GIS model. Discharge and water level for the hydrologic year 2000-01 were used for calibration of the one-dimensional model. The calibrated model was then used to test potential development scenarios, as stated below, to simulate the future dynamic response in respect of changes in the flooding pattern in the study area. Based on analysis of available yearly discharge volume of Barak river at Amalshid for a period of 30 years, 1996-97 year was chosen as the average year. Considering the possible storage and diversion in the upper reaches, the following three scenarios were chosen for simulation for the average year (1996-97) hydrologic condition:

- without dam, natural hydrological conditions of the average flood year April-March 1996-1997.
- with Tipaimukh dam, regulated hydrological condition of average flood year April-March 1996-1997.
- with Tipaimukh dam and Fulertal barrage, more regulated hydrological condition of average flood year April-March 1996-1997.

3.1 Selection of boundary discharge hydrographs for simulation of scenarios

As stated above using the statistical analysis of annual discharge volume of the Barak river at Amalshid for the last 30 years from 1971 to 2001, the year 1996-1997 was selected as an average year. According to FAP 6 (1994) due to Tipaimukh dam and Fulertal barrage, the wet season flows of the Barak at Amalshid would be decreased by 25% and dry season flow would be increased by 60% during an average flow year. The probable amount of monthly water withdrawal from the Barak river through Fulertal barrage for the irrigation project, as provided in the NEEPCO (2000), is shown in Figure 4.

The boundary discharge hydrographs of the Barak at Amalshid for simulation of different scenarios were obtained as follows:

(1) For without dam condition
Natural hydrological conditions of the average flood year April-March 1996-1997.

[1] Large water body

(2) For dam and barrage condition

For analyses to be performed in this study, considering the storage and diversion possibilities at the Tipaimukh dam and Fulrtal barrage as used in FAP 6 (1994) study, due to the dam and barrage the daily flows of the Barak at Amalshid is decreased by 25% for the wet season months (May-October) and increased by 60% for the dry season months (November-April).

(3) For dam only

For only the Tipaimukh dam condition, the boundary discharge of the Barak river at Amalshid was calculated by adding the amount of monthly withdrawal (m^3/s) at Fulertal barrage for the Cachar irrigation project with flow values as defined in (2) above.

The boundary hydrographs for the above three scenarios are shown in Figure 5.

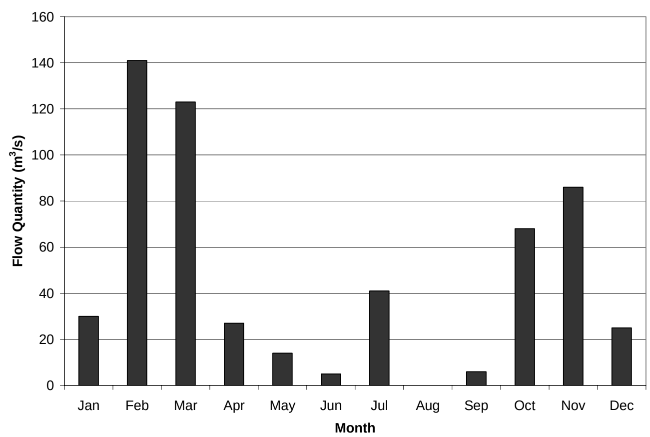

Fig. 4. Probable withdrawals from the Barak riverat Fulertal Barrage, India

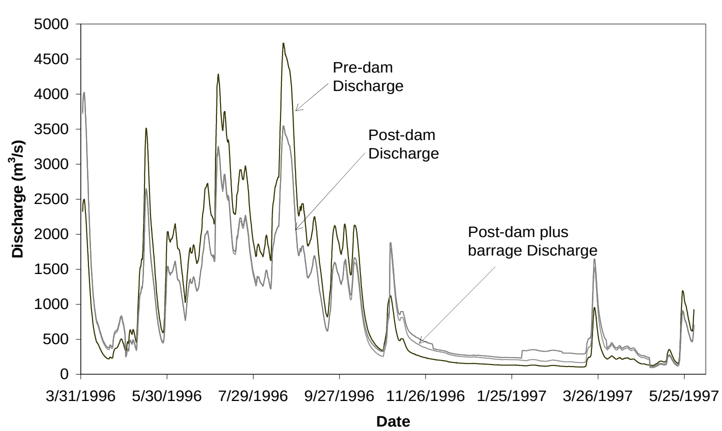

Figure 5 Boundary discharge of the Barak at Amalshid point for the average year pre- dam, post-dam and barrage, and only post-dam.

4. Results and discussion

The flood propagation model MIKE 11 GIS was used to examine the changes in the inundation pattern in terms of flood extent and depth due to regulation of the Barak flow by dam as well as combined operation of dam and barrage. This simulation was done for an average hydrologic year which was found to be 1996-97 water year based on an analysis of the yearly volume of flow for 30 years of discharge record. This part of analysis will provide some insight into the likely changes that might occur on the natural inundation pattern of the wetland.

4.1 Generation of flood maps

As described in Table 2, three flood maps were generated for three scenarios of store and diversion using MIKE 11 GIS module for the average year peak flows for the pre-monsoon, monsoon and post-monsoon seasons for the following three scenarios:

(i) Average year without dam,
(ii) Average year with dam, and
(iii) Average year with dam and barrage

Table 2
Dates of peak flows in the Barak at Amalshid used for generation of flood maps for the indicated scenarios in three chosen seasons.

Scenarios	Period	Peak Discharge
Average year without dam	Pre-Monsoon	16-May
	Monsoon	19-Aug
	Post-monsoon	8-Oct
Average year with dam	Pre-Monsoon	19-May
	Monsoon	19-Aug
	Post-monsoon	8-Oct
Average year with dam and barrage	Pre-Monsoon	16-May
	Monsoon	19-Aug
	Post-monsoon	8-Oct

4.2 Changes in extent of flooding

The Flood extent maps for the entire Surma-Kushiyara basin for three chosen seasons: pre-monsoon, monsoon and post-monsoon are shown separately in Figures 6, 7, and 8 respectively depicting the flood extents in different colors for three selected scenarios. Due to the effect of the dam, in the pre-monsoon season the extent of inundation shows a decrease of about 60%, the corresponding decrease being about 22.5% and about 63.4% in the monsoon and post-monsoon season respectively. A further inspection of the three figures shows no additional changes in the inundation extent in any of the seasons due to effect of the barrage in addition to the dam.

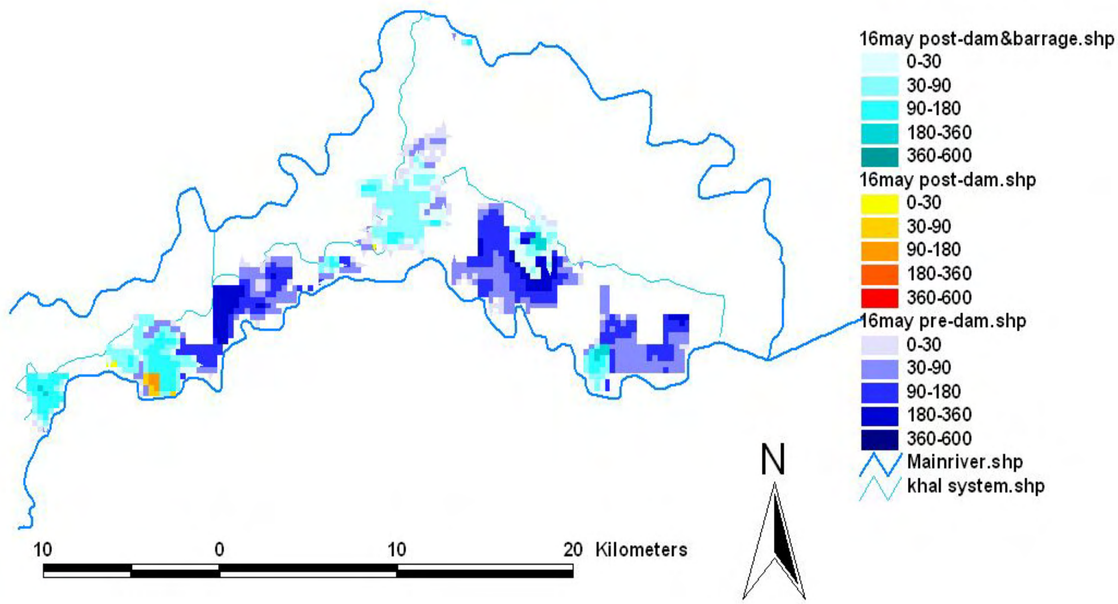

Fig. 6 Comparison of flood inundation pattern in the study area for the pre-monsoon season for three selected scenarios.

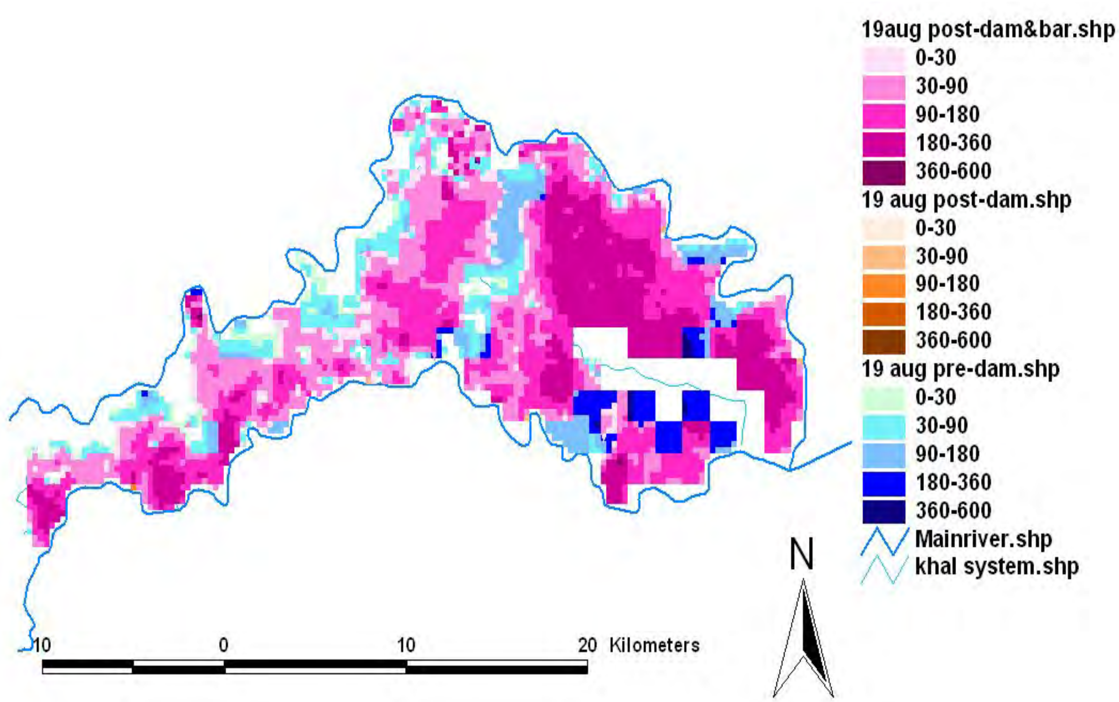

Fig. 7. Comparison of flood inundation pattern in the study area for the monsoon season for three selected scenarios

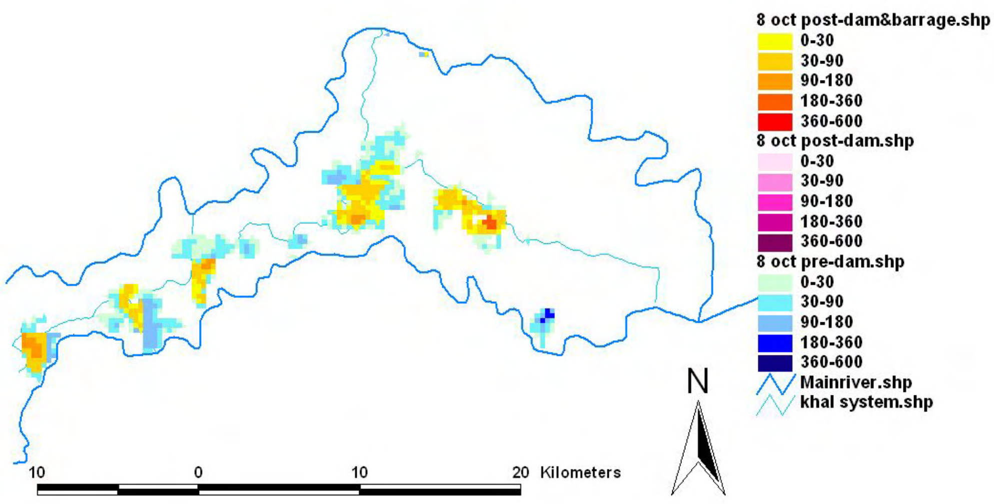

Fig. 8. Comparison of flood inundation pattern in the study area for the post-monsoon season for three selected scenarios

4.3 Changes in depth of flooding

(MPO, 1988) land classification into F0, F1, F2, F3 and F4 types corresponding to the depth of inundation of 0-30 cm, 30-90 cm, 90-120 cm, 120-360 cm and > 360 cm respectively are used for analysis in changes of flooding depth over the entire Surma-Kushiyara basin.

Changes in Pre-monsoon Season -- As shown in Table 3 (a), due to the effect of dam in the pre-monsoon season area of F0 land type shows an increase of 18.58% whereas F1, F2, F3 and F4 areas decrease by 46.08, 76.06, 93.52 and 100% respectively. This means that the deeply flooded area disappears. Additional changes in land types due to the effect of barrage in addition to the dam are listed in Table 4 (a). F0 and F1 land areas show a slight increase, F2 shows of slight decrease, and F3 and F4 do not change.

Changes in Monsoon Season **--** Table 3 (b) shows that the F0 and F1 land areas increase by about 110 and 39% respectively, but F2, F3, and F4 areas decrease by 29, 49 and 97.7% respectively due to the effect of dam in the monsoon season. As seen in Table 4 (b), no additional changes in land types occur due to the effect of barrage in addition to the dam.

Changes in Post-monsoon Season – Referring to Table 3 (c), areas under all land types are found to decrease by amounts ranging from 54.68 to 82.76% in the post-monsoon season. This manifests a significant decrease in the extent of inundation in the post-monsoon season. Due to the effect of barrage in addition to the dam, F0 land area slight decreases, F1 type slightly increases and other classes remain unchanged as shown in Table 4 (c).

Table 3
Changes in land type based on depth of inundation in the study area in the pre-and post-monsoon and monsoon seasons due to the effect of dam

(a) Pre-monsoon season

Flood Depth		Inundated Area (ha)		Changes in Inundated Area	
Class	Inundation depth(m)	Pre-dam	Post-dam	ha	%
F0	0-0.3	82.96	98.38	(+)15.42	(+)18.58
F1	0.3-0.9	330.69	178.30	(-)152.39	(-)46.08
F2	0.9-1.8	307.35	73.57	(-)233.78	(-)76.06
F3	1.8-3.6	180.58	11.70	(-)168.87	(-)93.52
F4	>3.6	4.18	0.00	(-)4.18	(-)100.00

(b) Monsoon Season

Flood Depth		Inundated Area (ha)		Changes in Inundated Area	
Class	Inundation depth(m)	Pre-dam	Post-dam	ha	%
F0	0-0.3	86.58	182.05	(+)95.47	(+)110.27
F1	0.3-0.9	550.92	766.28	(+)215.36	(+)39.09
F2	0.9-1.8	1165.38	824.30	(-)341.09	(-)29.27
F3	1.8-3.6	1206.35	614.16	(-)592.19	(-)49.09
F4	>3.6	72.73	1.67	(-)71.06	(-)97.70

(c) Post-monsoon Season

Flood Depth		Inundated Area (ha)		Changes in Inundated Area	
Class	Inundation depth(m)	Pre-dam	Post-dam	ha	%
F0	0-0.3	142.84	64.74	(-)78.10	(-)54.68
F1	0.3-0.9	313.43	124.26	(-)189.17	(-)60.35
F2	0.9-1.8	106.71	18.39	(-)88.32	(-)82.76
F3	1.8-3.6	17.56	5.02	(-)12.54	(-)71.43
F4	>3.6	0.00	0.00	unchanged	-

5. Conclusion

Based on the analyses performed and results obtained thereon it is clear that as a result of implementation of the Tipaimukh Dam and Fulertal barrage flow regime in the Surma-Kushiyara basin will change, the degree of which will depend upon the operating rules for the impoundment and diversion which is not known yet. Simulation of flows in rivers and flooding were done for an assumed inflow hydrograph of the Barak at Amalshid for an average hydrologic year which was based on some previous reports. The following conclusions are drawn about the extent of flooding and changes in land type in the study area.

Table 4
Changes in land type based on depth of inundation in the study area in the pre-and post-monsoon and monsoon seasons due to the effect of dam and barrage

(a) Pre-monsoon Season

Flood Depth		Inundated Area (ha)		Changes in Inundated Area	
Class	Inundation depth (m)	Pre-dam	Post-dam and barrage	ha	%
F0	0-0.3	82.96	99.52	(+)16.55	(+)19.95
F1	0.3-0.9	330.69	168.27	(-)162.42	(-)49.12
F2	0.9-1.8	307.35	76.91	(-)230.44	(-)74.98
F3	1.8-3.6	180.58	11.70	(-)168.87	(-)93.52
F4	>3.6	4.18	0.00	(-)4.18	(-)100.00

(b) Monsoon Season

Flood Depth		Inundated Area (ha)		Changes in Inundated Area	
Class	Inundation depth(m)	Pre-dam	Post-dam and barrage	ha	%
F0	0-0.3	86.58	182.05	(+)95.47	(+)110.27
F1	0.3-0.9	550.92	764.61	(+)213.69	(+)38.79
F2	0.9-1.8	1165.38	824.30	(-)341.09	(-)29.27
F3	1.8-3.6	1206.35	614.16	(-)592.19	(-)49.09
F4	>3.6	72.73	1.67	(-)71.06	(-)97.70

(c) Post-monsoon Season

Flood Depth		Inundated Area (ha)		Changes in Inundated Area	
Class	Inundation depth(m)	Pre-dam	Post-dam and barrage	ha	%
F0	0-0.3	142.84	68.08	(-)74.76	(-)52.34
F1	0.3-0.9	313.43	120.92	(-)192.51	(-)61.42
F2	0.9-1.8	106.71	18.39	(-)88.32	(-)82.76
F3	1.8-3.6	17.56	5.02	(-)12.54	(-)71.43
F4	>3.6	0.00	0.00	unchanged	-

- In the post dam situation, the extent of inundation shows a decrease by about 60% in pre-monsoon, 22.5% in monsoon and 63% in post-monsoon seasons. For the barrage in addition to the dam no further change in inundation extent was evident from the simulation results.

- Also there will be some redistribution of F0, F1, etc. land types. In the pre-monsoon season the area of F0 land type shows an increase of about 18% whereas F1, F2, F3 areas decrease by 46, 76, 93% respectively and F4 type disappears. This means that the deeply flooded area decreases. Some additional changes in land types due to the effect of barrage in addition to the dam were seen to occur. F0 and F1 land areas show a slight increase, F2 shows a slight decrease, and F3 and F4 types do not change.

- In monsoon the F0 and F2 land areas increase by about 110 and 39%, respectively, but F2, F3 and F4 areas decrease by 29, 49, and 97% respectively due to dam. On the other hand, areas under all land types exhibit decrease by amounts ranging from 54 to 82%. For the barrage in addition to the dam, the F0 area slightly decreases, the F1 type slightly increases and the other land classes remain unchanged.

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