Influences of changes in Land use/Land cover and Precipitation Variability on Hydrology and Morphology of Middle Course of Damodar River in East India

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Abstract: In a river basin, the two most prominent factors rainfall variability and changes in land use and land cover in the upstream basin drives the long-term discharge modifications in the river hydrology and morphology. The Damodar River (known as DeonadNadi in its upstream) is a sub-system of Ganga River System. The study area falls under the area in between Panchet and Maithan dam and Durgapur Barrage in Durgapur. It is extended up to 23º28' N to 23º41'N latitude and 86 º 44 'E to 87 º 18' E longitudes. The data are taken from Indian Meteorological Department (Rainfall), Maithon and Panchet hydrologic station, River Discharge Database, Centre for Sustainability and the Global Environment, SAGE (Discharge), Landsat 5 –TM (Satellite Images- 1990 & 2010). Whole time period are divided in two phase: 1958-1980 and after 1980. Relationship between rainfall (Asansol and Dhanbad) and discharge has been found. The statistical tool such as t-test is used to use the difference in mean of rainfall and discharge. The effects on morphology of the river are shown with the help of Landsat TM image of 1990 and 2010 of the study area. Trend of discharge and rainfall is high in post 1980s. This may be for the change of land use and urbanisation is high in the latter time period. From the values of t-test, it is claimed that annual rainfalls and discharge is greater in period 2 than period 1 in the Damodar River Basin. From 1990-2010, in the Damodar Basin Area, vegetation have been reduced and build up areas are increased. These will increase the discharge of the river flow and further change the morphology of the river. Agricultural lands occupy the vegetation areas in the basin areas. Agricultural lands occupy the river bed also that will increase the no of bars in the basin area. Several new bars have been formed due to the on-going construction work in the river itself and the bank areas. Reduction in the Riparian vegetation leads to erosional activity in the bank side areas. Dam construction in the river and its tributaries leads to the development of several bars in the river basin. Reduction in infiltration after the removal of vegetation cover and changes in land cover causes an increase in surface flow during the rainy season that increase the tempo of river discharge. If the current pace of changes and industrialisation and urbanisation is going on, it can be expected to further changes in the hydrological and morphological regime of Damodar River System.

Keywords: Land use/land covers change, Precipitation variability, discharge, t-statistics, river morphology,

1. Introduction:

The Damodar River (known as DeonadNadi in its upstream) is a sub-system of Ganga River System. Meaning of the word Damodar is "womb" or Udar, which is "full of fire". That means Damodar flows through a coal-rich area in the part of Jharkhand and west Bengal. The river rises in the Chhotanagpur Plateau at 23°37'N and 84º41'E and the geographical boundary of the basin lies between 22º15'N to 24º30'N latitude and 84º30'E to 88º15'E longitude. The tadpole shaped river basin is under the control of hard rock geology in upstream and alluvium in the downstream (Bhattacharya, 2011).

In a river basin, the two most prominent factors rainfall variability and changes in land use and land cover in the upstream basin drives the long-term discharge modifications in the river hydrology and morphology. Conversions of vegetation to build up areas can hydrology and morphology of the rivers. Although the study is mainly satisfied in the small scale areas but it could not be satisfied or could not get similar relationship in the large scale areas in the river basins (Costa, 2003). The industrial outputs can mainly effects on the water quality of rivers but it cans also effects on the hydrology and morphology of the rivers.

2. Study Area:

The study area falls under the area in between Panchet and Maithan dam and Durgapur Barrage in Durgapur. It is extended up to 23º28' N to 23º41'N latitude and 86 º 44 'E to 87 º 18' E longitudes. Total length of the area is approximately 70 km. the 5avg. height of this area is 110 m from the sea level. The study area covers the districts of Bokaro, Dhanbad district of Jharkhand and Bankura and Burdwan District of West Bengal.

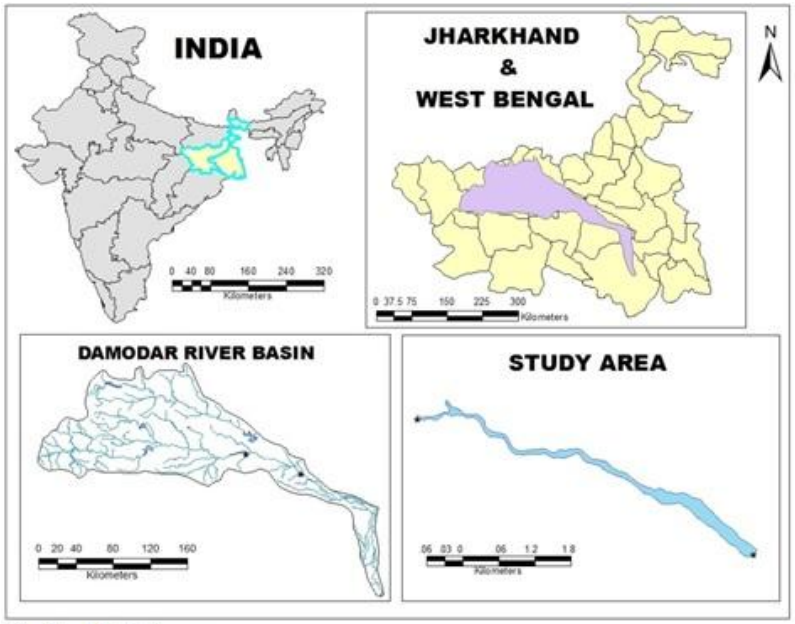

Fig. No.1 Study Area

This region is very densely populated area as the major cities such as Asansol, Ranigang, Durgapur are in this area. The study area includes the downstream river of Panchet Dam and upstream river of Durgapur Barrage. The land use /land cover has been severely modified in this region by the rapid urbanisation of the Asansol-Durgapur Industrial Belt and the coalfield area of Ranigang.

3. Objectives:

- To show the climatic impacts on the hydrology of the river
- To give some highlights on the land use changes in the River Basin
- To show the changes in the morphology of the River due to the change in the land use in the river basin

4. Data source:

Table No. 1: Data source of the Study

Rainfall Data	Discharge and Hydrological Data	Satellite Images	
		1990	2010
Indian Meteorological Department	Maithon and Panchet hydrologic station, River Discharge Database, Centre for Sustainability and the Global Environment, SAGE	Landsat 5 -TM	Landsat 5-TM

5. Methodology:

The data are collected from the various sources. As the river is the dam affected that is why the inflow data of the Panchet and Maithon are considered. Whole time period are divided in two phase: 1958-1980 and after 1980. The changes in population density and urbanisation are more prominent after 1980 rather than 1958-1980. Both rainfall and discharge data are divided in two time periods. The rainfall data of two cities such as Dhanbad and Asansol are considered. The trend of rainfall and discharge are shown. Then the relationship between rainfalls is also constructed. The amount of vegetation cover are analysed and try to found a relationship between the vegetation cover and the discharge. The effects on morphology of the river are shown with the help of Landsat TM image of 1990 and2010 of the study area. The changes in the position of the bars and erosion and deposition are also shown with the help of the above mentioned satellite images. The statistical tool such as t-test is used to use the difference in mean of rainfall and discharge.

6.1. Trend of Variability of Rainfall in Asansol and Dhanbad:

Rainfall is a major factor that influence on the discharge and hydrology of any river system. Asansol and Dhanbad are the two stations that are considered as the rainfall station under study area. These two cities are in the proximity of Damodar

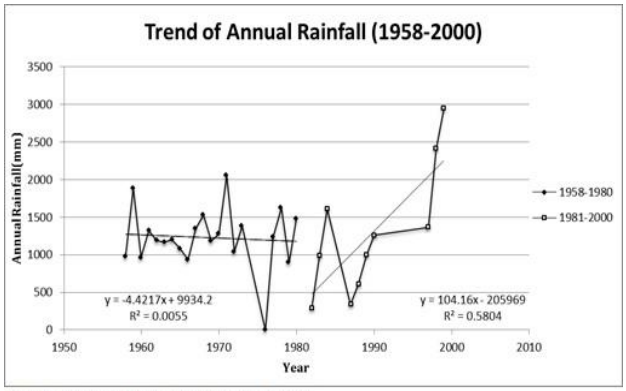

Fig. No. 2 Trend of Annual Rainfall in Asansol

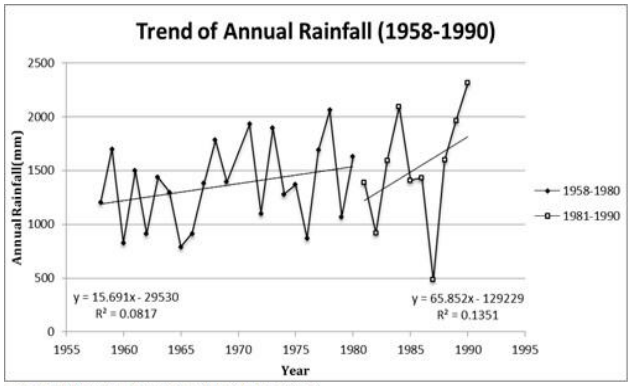

Fig. No. 3 Trend of Annual Rainfall in Dhanbad

River. The rainfall data are collected from 1958-2000. For the analysis of changes the whole time periods are divided in two time periods: Period 1(1958 to 1980) and Period 2 (1981 to2000). In Asansol (fig. no.2) station, Period 1 have experienced with the slightly decreasing amount of rainfall as the value of R^2 is 0.005. But, it is more or less in a similar trend in comparison with the period 2 where there are drastically increasing amount of rainfall.

In this period highest amount of rainfall are found in 2000 that is about to 3000 mm/day. The value of R^2 in the period 2 is 0.5804 that signify the trend of increase in rainfall is high about 58 percent. This high amount of increase in rainfall may be due to large amount of human interference and the increasing amount of urbanisation in the Asansol- Durgapur Industrial Complex.

On the other hand, other station Dhanbad (fig. no.3) have enjoyed with the escalated amount of rainfall in both period 1 & 2. The changes in period 2 are more significant than period 1. In the period 1 there are slightly increasing amount of rainfall as R^2 value is 0.082. But in case of period 2 the rainfall are drastically increased at as the value of R2 is 0.135 that means about 13.5 %.Both Dhanbad and Asansol cities are connected with main line of train route and National Highway No.

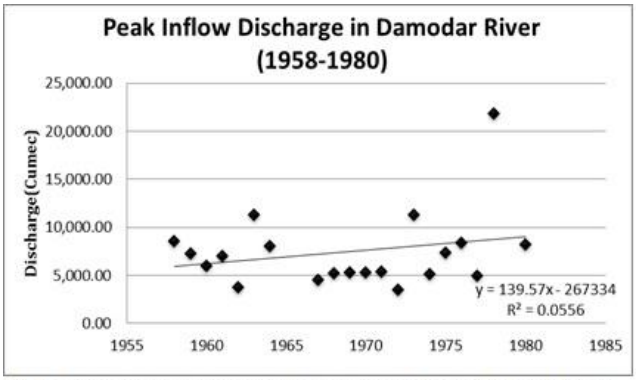

Fig. No. 4 Peak inflow discharge in Damodar River at Panchet (1958-1980)

2 between Kolktata and Delhi. That is another cause for the changes in the land use of the areas. The increase amount of rainfall is may be due to several causes. The Evapotranspiration have the positive or linear relationship with the rainfall.

6.2. Trends of Peak inflow discharge of Damodar River

Damodar River is a river that has been largely modified by several dams. Maximum amount of discharge is modified by the dams. That is why peak inflow in the dams is considered as the discharge. Dataare found from the Panchet and Maithon where two dams are present. The discharges are availablefrom the 1958 after the construction of the dams. To show the changes more precisely in discharges whole time periods

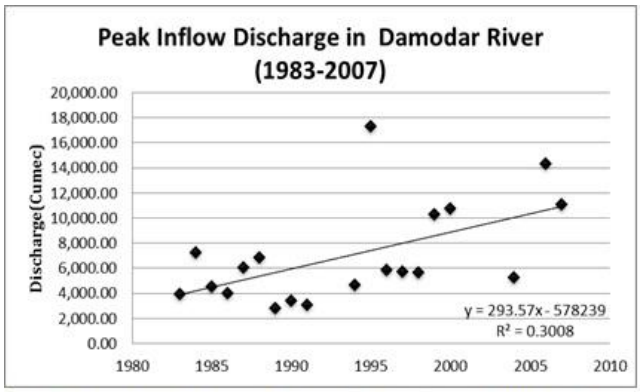

Fig. No. 5 Peak inflow discharge in Damodar River at Panchet (1983-2007)

are divided in two time periods: Period 1 (1958-1980) and Period 2 (1983-2007). From 1958 – 1980, (fig. no. 4) the trend of discharge is increasing as the highest amount of discharge is above 20000 cumec in 1978. The value of R^2 is 0.056. The increasing tendency of discharge is 5 %. But the scenario is totally different in the period 2 where the tendency of increase in the discharge is high in comparison to the period 1.The R^2 value is 0.30 that is about 30 percent. This is trend is more steep than the previous one. The discharge of most of the Monsoon fed Rivers is largely dependent on the precipitation especially on the rainfall. In this tropical area there are a positive relationship between precipitation and discharge. But it is hardly found in the large river basin. Other factors such as snow melting vegetation covers are present there. Evapotranspiration is large affected by the vegetation cover. Reduction in vegetation cover is related with increase amount of rainfall and discharge of river and vice-versa. Inverse

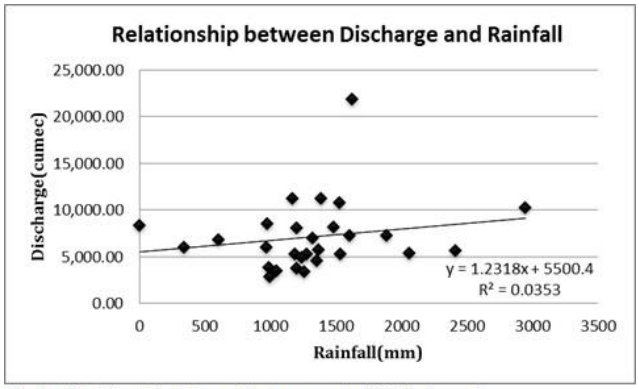

Fig. No. 6 Relationship between Discharge and rainfall in Asansol

relationship indicates the influences of other factors in the river basin area.

7.1. Effects of Precipitation Variability on Hydrology of the River:

Climatic element such as rainfall, evapotranspiration effects on the both hydrology and morphology of a river system. High rainfall can accelerate the discharge of the rivers. But it can

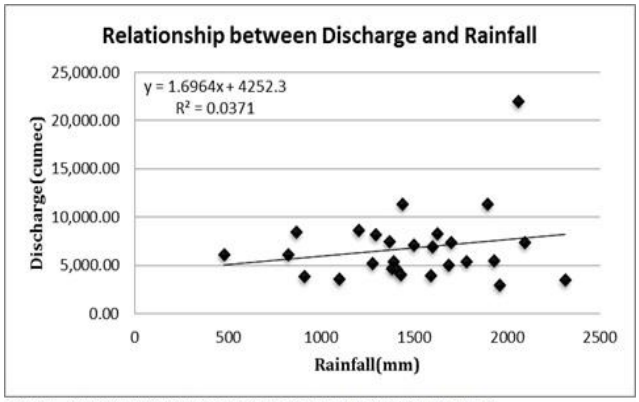

Fig. No. 7 Relationship between Discharge and Rainfall in Dhanbad

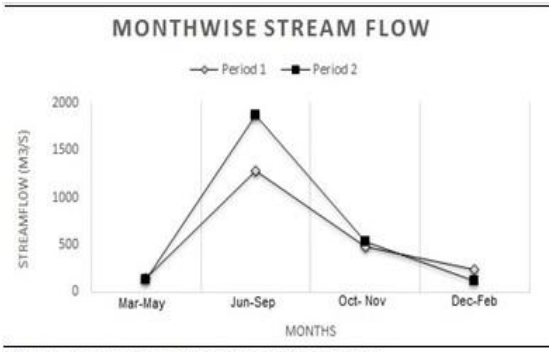

Fig. No. 8 Monthwise Streamflow in Panchet Dam

only found in a small scale area of a drainage basin rather than large river basin. Generally, in the tropic-monsoon area, there are positive relationship between rainfall and discharge. Both cities (Asansol and Dhanbad) are in the Damodar river basin. So the precipitation of these cities and the surrounding largely affects the hydrology of the river system. A relationship is found between the rainfall of these two cities and the discharge of the Damodar River. In Asansol (fig. no 6) the trend of discharge is increased with the increase of rainfall. Positive correlation is observed. The value of R^2 is 0.035 that indicate there are weak relationship are found. 3% data can be explained. This is simply because of the discharge are severally modified by the dams.

On the other hand in the case of Dhanbad has also the same result. There are also exist a weak positive relationship between rainfall and discharge in the Dhanbad and surrounding.Here also the value of R^2 is 0.037. This weak relationship is the reflection of several anthropogenic activities and increase of urbanisation.In future, this relationship can be further affected if the current rate of urbanisation and population growth is going on.

In case of month wise stream flow of Damodar River at Panchet, the amount of flow is greater in period 2 than the period 1 in the rainy season (June- September). The amount of stream flow is 1283.33 m^3s^{-1} in the period 1, on the contrary, later period have enjoyed with 1863.20 $m^3s^{-1.}$ This clarifies that rainfall is greater in the period 2. In the post rainy season, this result have also been observed but the different is not significant. In the dry season, the stream flow is totally reservoir controlled but in the rainy season it is most controlled by rainfall. That is why, stream flow is more or less same in dry periods.

8. Staistical t test:

To examine the differences in mean statistical tool like t-test is used. All the parameters have the no

of observation is below 30. That is why t-test has been used rather than z-test. Table 2 shows t-test for the comparison of mean annual rainfall of two stations and discharge. The annual rainfalls is greater in period 2 than period 1 and mean annual rainfall of two stations is taken as hypothesis. Another hypothesis is taken for demonstrating that the annual discharge is higher in period 2 than the average discharge of whole period and period 1. Both of these hypotheses are taken at 0.05% significance level. Although there are a weak relationship are found between annual discharge and rainfall but the trend of both of these are increasing than in period 2 than the period 1. Here, t- statistics with one tail are used for the testing the hypothesis with the help of different degree of freedom. Degree of freedom are d.f. = n-1.

Table No. 2: Table for t-test analysis

	Rainfall (mm day $^{-1}$)				**Discharge (m^3s^{-1})**	
	Asansol		Dhanbad		Period 1	Period 2
	Period 1	Period 2	Period 1	Period 2		
Mean	1291.615	1303.291	1363.945	1402.354	7,419.13	7,082
Variance	26.38	38.051	88.033	124.443	424.63	87.5
Standard Deviation	307.5481	819.2223	380.7914	644.8775	4148.575	3897.371
Degree of Freedom	18	10	21	10	18	19
t-statistics Critical value at 90 % confidence interval	+1.734 to -1.734	+1.812 to -1.812	+1.721 to -1.721	+1.812 to -1.812	+1.734 to -1.734	+1.729 to -1.729
P(T≤t) one tail	0.374	0.147	1.06	0.61	0.434	0.10

The formula of t-test is as follows:

$$t = \frac{mean\ of\ x - \mu}{s/\sqrt{n}}$$

Where, mean of x is observed mean in a given period, μ =hypothetical mean of total period, s = standard deviation of the observation, and n = no. of observation.

From Table 2, the values of t-test are obtained and the values are matched with the t-table. If the values are lied beyond the table value that mean tabulated value greater than calculated value then null hypothesis is accepted otherwise it is not accepted and alternative hypothesis is accepted. In the table 2 it is observed that all of the calculated values are lie in between the tabulated values. That is why it is easily mentioned that the nullhypothesis are accepted and there are enough evidences to accept the claim that annual rainfalls isgreater in period 2 than period 1 and mean annual rainfall of two stations and annual discharge is higher in period 2 than the average discharge of whole period and period 1.

9. Land use Land cover Changes in Damodar River Basin:

Land use and land cover (LULC) is an important component in understanding the interactions of the human activities with the environment. Land use/ land cover mapping is essential component where in other parameters are integrated on the requirement basis to drive various developmental index for land and water resource. Land use and land cover change in a river basin is an important tool for the study of hydrology and morphology of a river system. The land use land cover change of Middle Damodar River Basin are analysed with the help of Landsat TM data of 1990 and 2010. Lots of changes are noticed in between 1990 to 2010 in the Damodar River Basin. In this basin area, there are mainly 6categories of land use /land covers are presents, these are: Vegetation Cover, Rivers and Water bodies, Agricultural land, Build up Areas that includes settlement and industrial set up, Barren Land and Bright Areas that includes Sands of the river. Due to heavy industrialisation and urbanisation huge amount of increase in agricultural land are observed. Lots of vegetation cover is reduced due to increase in Build-up Areas and Urbanisation. In this highly industrial area, Agricultural land, Build up Areas and Bright Areas are increasing from 1990 to 2010.Due to increase of population in the major cities and surroundings of the River Basin, huge amount of Agricultural land are increasing (about 15%).In 1990, Agricultural lands shares 11 percentages of total land, but in 2010 it have enjoyed with about 26 percentage of total land use.Build up areas are also increased positively roughly about 1 % of total changes.In Bright Areas, there are not significant changes are noticed.Some land use categories have experienced with the negative change with respect to time. Vegetation, Rivers and Water bodies and Barren Land are those land use categories that have changed negatively with the time. In 1990, Vegetation Covers are 36 percentages out of total land use but in 2010, it is reduced to 30 percentages.This is due to increase in Agricultural Lands. Reduction in Vegetation can reflects on the hydrology and morphology of the rivers.This can increase the amount of rainfall and it put consequence with the discharge of the river.This reduction related with the reduction of Evapotranspiration that further increase in discharge throughout the year.Barren lands are also reduced with the increasing of population. Amount of Barren land reduction is about 8 percent from 1990 to 2010.A slightly reduction (2%) in Rivers and Water bodies has been noticed in this time period. Settlements are growing as both of the bankside of Damodar River are occupied with the human habitats. From the fig. no. 10, in Asansol, there are drastically increase in population are noticed than the other cities in the river basin area.Asansoland Durgapur are the only million cities in West Bengal after Kolkata.

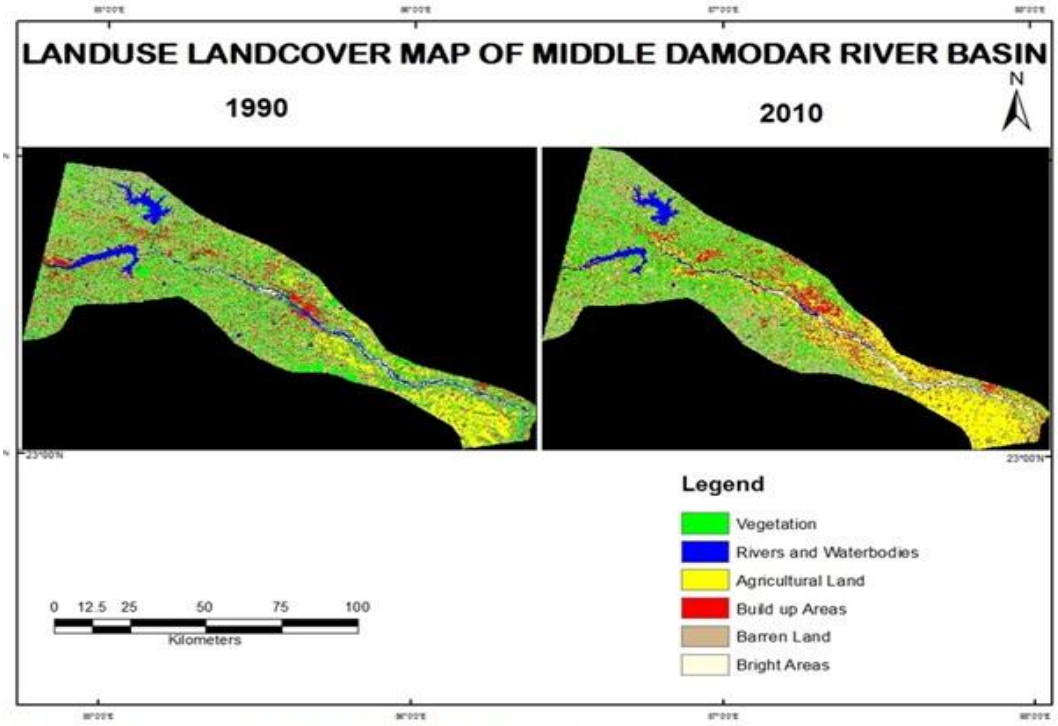

Fig. No. 9 Land Use and Land Cover map in 1990 and 2010

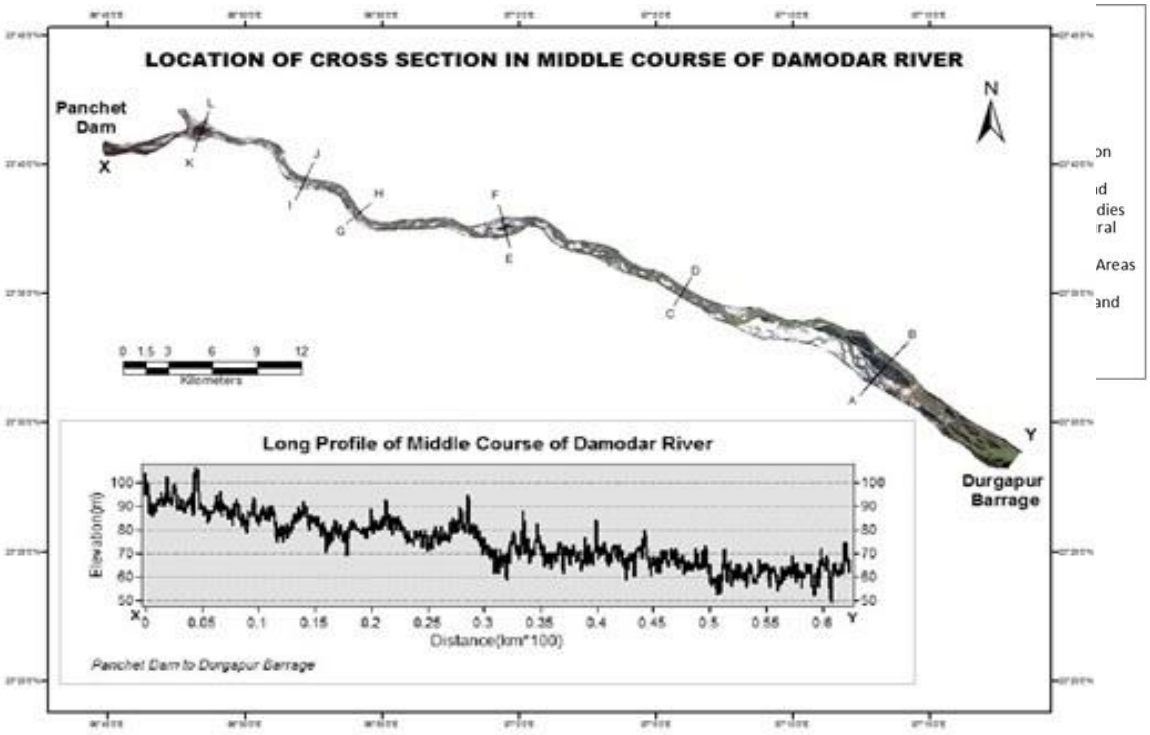

Fig. No. 11 Cross section Location and Long Profile in Middle Course of Damodar River

Table no. 3 LULC changes in between 1990 and 2010

Land use Land cover Categories	1990		A
	Area (Ha.)	Area (%)	
Vegetation	196126.86	36	1
Rivers and Water bodies	34239.3428	6	
Agricultural Land	62685.6374	11	1
Build up Areas	73685.4518	13	7
Barren Land	183006.91	33	1
Bright Areas	4882.51598	1	

10. Plan form of Middle Course of Damodar River (Panchet Dam to Durgapur Barrage):

For the analysis of plan form, six cross section and a long profile (fig. no. 11) have been done of the studied section. From the long profile along XY axis clarifies that the slope of the studied section of the river is more or less constantly declined. There are slightly break of slope has been found in the middle reach (Sahebdanga to Kalla) of the studied

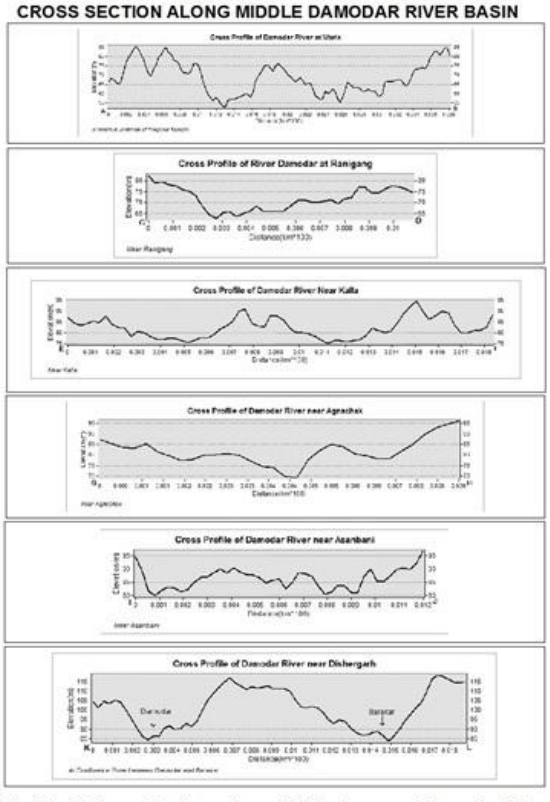

Fig. No. 12 Cross Sections along Middle Course of Damodar River

section. This changes may be due to the presence of hard landmass in those area. Then the downstream area is smoother. The downstream area are totally alluvial channel of Burdwan and Bankura districts. Six cross sections (fig. no. 12) along the studied area depict different plan form in the river. Just before Durgapur barrage at Waria, cross section of AB illustrate the braided condition of the reach. Construction ofBarrage is the solely cause for the braided condition of the reach. But just slightly upstream area (Near Ranigang), the flow is in the centre of the channel as shown in cross section CD. A longitudinal mid-channel bar has been developed along the cross section of EF near Kalla. Stream flow is both side of the bar and just below the cross section a sharp meander has been developed. Another typical morphological character have been observed in the cross section of GH near Agnachak. The convex bend of the meander is characterised with stream flow, on the contrary, concave bend is The length and width of the bar is 1.2 km and 0.8 km respectively.

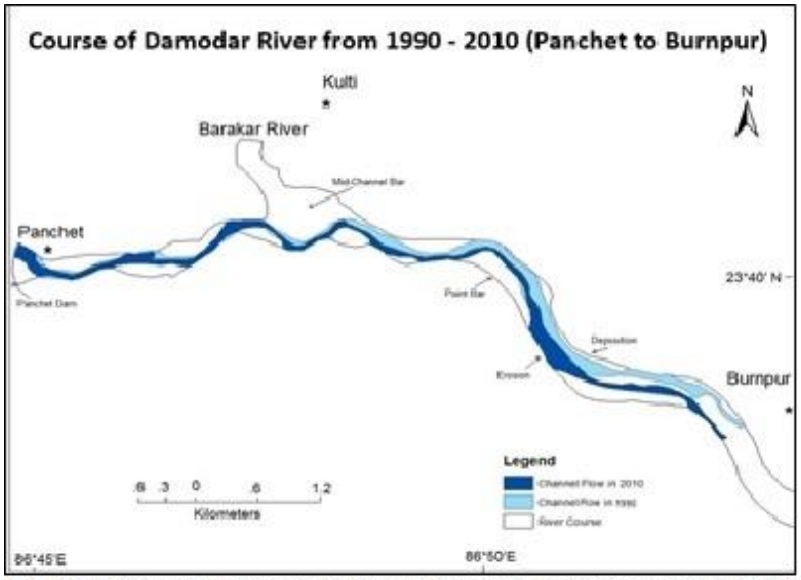

Fig. No.13 Course and Channel flow of Damodar River (Panchet to Burnpur)

Too much urbanisation and industrialisation in the Damodar River Valley is harmful for the morphology of the river. Large scale impact of Industrialisation on River morphology is found in between Panchet to Durgapur. The river courses are shown in fig. no. 13 and 14 from the Landsat TM satellite images. Two reaches of the river are characterised with the bars. Cross section of IJ near Asanbani have not so much distinct morphologicalcharacteristics. The cross section along KL near Dishergarh shows the confluence zone between Damodar and Barakar River with the presence of a transverse bar in the confluence point. The right side flow is of Barakar River and the other side have the Damodar River.

11. Effects of Land use Land cover on Morphology of Damodar River:

analysed. One is from Panchet to Asansol andBurnpur and another one is from Ranigang to Durgapur. Due to several land use change and the anthropogenic activities the river courses and channel are modified in the reaches of the river. Though the changes are not as significant as the time period is short(1990-2010).

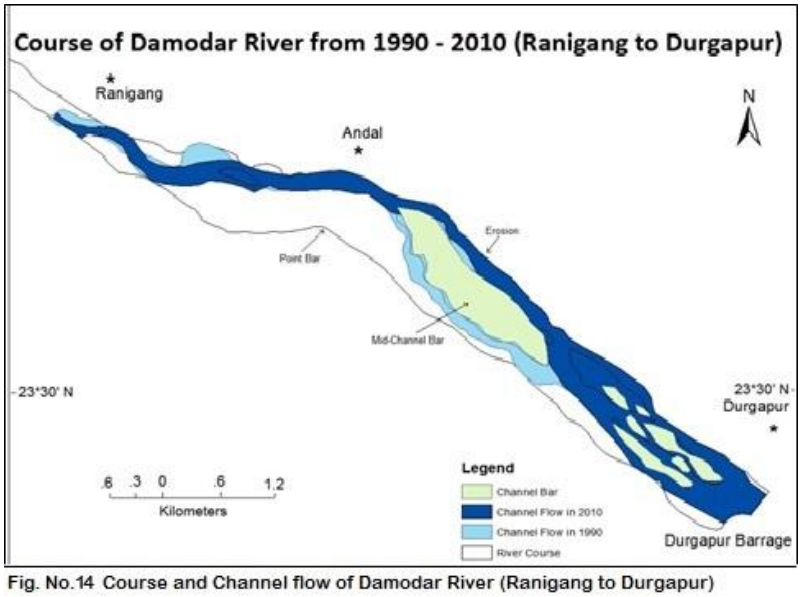

Fig. No.14 Course and Channel flow of Damodar River (Ranigang to Durgapur)

This can be much more significant if the data has been taken in long time period. In the fig. no. 13, whole linear feature represents the river course ofDamodar River. Sky and Blue coloured linear features represents the channel flow in 1990 and 2010 respectively. No. of Point Bar has been developed. A mid channel bar is developed at the confluence point where it's tributary Barakar river have met with the Damodar River. The main channel flow of the river is slightly shifting toward right side from Barakar to Asansol and Burnpur. In 1990, the left bank side has been familiar with erosional activity but

in 2010. The right bank side has faced the erosional activity. The former bank is facing with the depositional activity in present time.

The reaches between Ranigang and Durgapur (fig. no 14) have also experienced with the modification of morphology of the river. Few amounts of Bars are present in the both time periods in the just upstream of Durgapur barrage. Just before and after Andal, there are change in channel flow are observed. In 1990, the flow was in both side of the mid channel bar but in 2010, this is only found in the left side of the river. Right bank have not experienced with the any kind of major channel flow from 1990 to 2010. This change is due to several factors. Dam construction is one of the major causes. It can intensify deposition and erosion in the upstream and downstream of the dams respectively. Just before the Durgapur barrage there are several bars are present as a result of depositional activity in the upstream areas. Changes in vegetation in the basin area can also increase the probability of bar formation. Riparian vegetation is related with the stability of the river bank side. Reduction in infiltration after the removal of vegetation cover and changes in land cover causes an increase in surface flow during the rainy season that increase the tempo of river discharge. These are the major changes due to changes in land use/land cover and anthropogenic activities.

12. Conclusion

Damodar River is severally modified by the several projects of Damodar Valley Corporation (DVC). Braiding of Damodar River is associated with variable discharge and incompetent to bed load. From the land use study it is to be mentioned that the rate of conversion of Agricultural land from barren land is much more significant. This can influence the river systems also. The bars of the river are also occupied by the agricultural practices. Climatic Variability also further can put effects on the rainfall. In the last 40 years, agriculture practices, land use changes, climate changes have modified the hydrology and morphology of Damodar River systems. If the current pace of changes and industrialisation and urbanisation is going on, it can be expected to further changes in the hydrological and morphological regime of Damodar River System.

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