Geoinformatics for Natural Resources Management vis-à-vis Environmental Justice

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ABSTRACT:

In natural resources and environmental management Environmental Impact Analysis (EIA) is an essential component to specify the guidelines for biodiversity conservation. Conceptually, 'Geo-environmental mapping' depicts EIA results in spatial format exemplifying the change in geosphere of the environment in human orientation. Easy-to-understand presentation of data in 'Geo-environmental mapping' requires identification of Geo-environmental indicators and unit, in relation to Natural System Unit (NSU) or Terrain Mapping Unit (TMU) through terrain evaluation procedure. In this respect, Geo-informatics (operational combination of RS and GIS technologies) play facilitator role in collection and visualization of up-to-date spatial data as well as integration and analysis of the same with aspatial database to generate application specific ***'strategic datasets'*** for technological adjustment (structural means) and social adaptations (non-structural means), towards environmentally sound landuse/ landcover practices, minimizing the adverse effects of natural hazards (e.g. droughts, floods, bank failure) land degradation etc. This paper speaks on applicability of 'Geo-environmental mapping' citing case history examples from eastern India towards agro-ecological characterization → agricultural environment analysis and biodiversity conservation.

1. INTRODUCTION

Core business of natural resources and environmental management vis-à-vis biodiversity conservation may be conceptualized in terms of management of ecosystem (i.e. Hydrodynamic circulation) in human orientation encompassing new demands and technological developments – i.e. balanced interrelationship between landcover and landuse practices.(Fig: 1)

In this regard, terrain evaluation is an essential prerequisite to unravel the bi-directional relationship between 'rock/soil – water – vegetation' and 'geo-bio-cultural' interactions in accordance with the morphogenesis of the land form/ terrain units for landuse/ landcover monitoring and management. In this context, 'Geo-environmental mapping' –

- unravels the impact of anthropic developments on biophysical environment through space and time and identifies the present and future consequences in the context of existing bi-directional relationship between

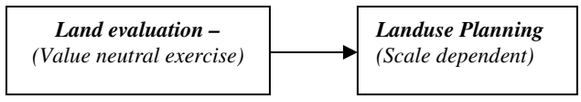
  Human subsystem ⇌ Environment.

- develops/ frames guidelines in maintaining rational balance between, Environment (E) and Human Capital & Mobility (HCM) through sustainable landuse planning based on the land evaluation procedure unraveling the interlinkages between geoinformation and EIA (Chakrabarti 1998).

2. LAND EVALUATION → GEO-ENVIRONMENTAL MAPPING

Terrain/ Land evaluation (LE) encompasses generation of spatial data (i.e. full featured 'real world' scenario in the form of a map) with morphogenetic approach and related functional datasets (i.e. aspatial data) which includes prototype physico-chemical attributes and societal parameters. Land evaluation procedure is a multidisciplinary demand oriented approach for landscape ecological analysis towards sustainable landuse planning vis-à-vis environmental management (Fig.2: Chakrabarti, 1999). In this bottom-up integral approach the environmental component plays an important role.

Conceptually, the Geo-environmental mapping is the spatial representation of the human activities (mainly dependent on socio-economic condition) on the nature's own built system (i.e. 'rock/soil-water-vegetation' interrelationships) exemplifying the suitability of different terrain units in relation to the existing utilization or selective alternate uses, i.e. sustainable landuse planning (Tri, 1994) :



Easy-to-understand presentation of data in 'environmental mapping' requires identification of Geo-environmental indicators (GEI) and Geo-environmental unit (GEU), in relation to Natural system unit or Terrain mapping unit (cf. Fabbri & Patrono, 1995).

3. GEO-ENVIRONMENTAL INDICATORS (GEI)

'Process-sensitive and easy-to-measure' physico-chemical characteristics of dynamic earth which help in identifying the various geomorphic environment in human orientation through space and time (cf. Cavallin et.al, 1995). GEI may be of two types – Qualitative indicators and Quantitative indicators :

Qualitative indicators allow to identify the specific characteristics of landform units(s) in terms of spatial change detection e.g. landslide/ soil erosion / flood prone areas, bankline shifting of a river or shoreline shifting etc.

A Quantitative indicator is supplementary to Qualitative indicator. In this context, numerical attributes related to change detection generated from insitu measurements are of basic importance e.g. round the year beach profiling data to specify the zone of erosion or accretion; sediment monitoring station may generate data on soil erosion; variation in chemical qualities of water in identifying the hydrological characteristics of an area.

4. GEO-ENVIRONMENTAL UNIT (GEU)

Spatial database with certain entity or bounds as defined by GEI. A GEU may contain one or more TMU (Meijrink, 1988) or Natural system unit (NSU) and vice-versa. For example –

i) In the Medinipore coastal plain, West Bengal, India erosion is present in the beach face of Digha-Shankarpur (Chandpur) sectors whereas accretional phenomenon is observed in the same beach face of Dadanpatrabar-Junput area (Chakrabarti, 1991, 1995). In both the cases, the terrain unit is 'beach face' but two GEU may be identified depending on erosional and accretional behaviours. (Photo – 1)

ii) In western upland of West Bengal, India forest/ social forestry is present in different terrain units viz. Buried pediment (shallow) and Lateritic upland (Chakrabarti et. al, 1996, 1998, 2002). In this case, with pragmatism two different terrain units may be clubbed under one GEU (e.g. 'Forest land') giving more emphasis on land cover/ landuse factor in comparison to other factors like degree of dissection, slope aspects etc. which may be considered for further subdivision in user orientation.

iii) In Jambudwip, (a tidal shoal in the Hooghly estuary), mangrove forest is fast deteriorating covering two TMUs (viz. Mangrove swamp and Supratidal core) due to human interactions (Chakrabarti, 1991). In this case 'Mangrove forest zone' may be identified as a GEU considering the geomorphic environment challenged by anthropogenic activities.

iv) Arsenic contamination in groundwater – Terrain analysis and classification reveals that in western part of Bhagirathi / Hooghly river (major distributary of Ganga river) arsenic toxicity in groundwater prevails in the Younger alluvial plain whereas the groundwater in the adjacent alluvial plain / fan areas of Ajoy and Damodar river are free from arsenic contamination (Photo-2). In geomorphological terms both are alluvial plain, however, two GEU may be identified based on the occurrence of arsenic contamination phenomenon.

v) In the Gondwana Upland two types of Coal mining activities are in operation: open cast mining and underground mining. In the context of environmental analysis three different GEU could be delineated viz. the ‘disused’ open cast mines, mining waste dump and areas of land subsidence (Photo–3) though geologically / geomorphologically the area is termed as Gondwana Group / Gondwana Upland.

5. APPROPRIATE TECHNOLOGY

Geo-informatics, operational combination of RS and GIS technologies (Fig-3; Chakrabarti & Nag, 2002) play facilitator role in collection as well as integration and analysis of the up-to-date spatial and aspatial database with the existing data sets to generate application specific ***'strategic datasets'*** for technological adjustment (structural means) and social adaptations (non-structural means) with future perspective, towards:

- Environmentally sound landuse/ landcover practices. In Indian scenario, Agro-ecological characterization → agricultural environment analysis and biodiversity conservation need special attention regarding socio-economic conditions (e.g. marginal farmers do not consider the environmental hazard created by them in the context of using pesticides etc. for their livelihood).

- Minimising the adverse effects of natural hazards (e.g. droughts, floods), land degradation etc.

- 'Easy to use' data format in digital mode to enable e-governance especially in a sector like rural poverty alleviation and food security as well as biodiversity conservation.

In the present scenario, the state-of-art technology of the high resolution 'operational' Earth Observing Satellites (EOS) provides multi-temporal/ time critical up-to-date 'real world' features in digital mode or in hard copy format. In this respect, the RS data are playing facilitator role in collecting or detecting spatial as well as thematic aspects of the changing earth's surface.

In global scenario, presently, two Indian 'civilian' satellites – IRS 1C and IRS 1D with 5.8m (PAN) and 23.5m (FCC) resolution are leading provider of satellite data for commercial uses and applications. Recent additions are IKONOS satellite, which provides image of 1m resolution in PAN mode and 4.0m resolution in FCC mode, Quick Bird with 90 cm resolution in PAN mode and Resource Sat 1 (IRS P-6) with 5.8m resolution in multi-spectral mode. The microwave satellites (viz. ERS, JERS, RADARSAT etc.) with all weather and all time capabilities facilitate the operational use of RS data for real-time monitoring of disaster prone areas in terms of flooding, coastal surges, landslides etc. In near future, with the introduction of 'Hyper spectral imaging' system (with more spectral bands and narrow band widths) scope of separability of different objects/ materials will be enhanced significantly (Skidmore et.al, 1997).

In response to the 'PIXEL⇌RASTER FORMAT' inherent relationship the RS data are being widely used in GIS (Geographic Information System) environment for integration and analysis of spatial and related non-spatial attributes as per users choice.

Rational and optimal utilization of RS and GIS for identification, integration and analysis of thematic aspects of terrain units in relation to the generated / existing numerical attributes (by insitu/ conventional methods) may be considered as the most holistic approach to conclude on decision rules/ norms for GEI and GEU.

6. GEO – ENVIRONMENTAL MAPPING: APPLICATION FIELD

'Technology Push' rather than 'Application pull' leads to import/ implement technology not appropriate to the social settings/matching solutions → 'Ethno-Science' to be improved by 'Techno-Science' (i.e. 'Technology push') for more responsive landuse/ landcover practices to protect natural resources in relation to changing socio-economic environment.

Case history examples from eastern India –

• Interlinking of rivers: 'inter basin'/'intra basin transfers' → existing big dams/ reservoirs to combat floods and droughts as well as to increase agricultural production – a subjective approach? In eastern India Gandak barrage, Kosi barrage, Farakka barrage exemplifies salinization, water logging, soil degradation, bank erosion, river bed level rise etc. – reflects on the change in landuse/ landcover pattern through space and time. For example, the Ganga River has shifted towards east in the upstream of Farakka Barrage causing bank failure since 1975 i.e. after construction of circuit embankment in the Bhutnir Char (encircling river island / permanent channel bar) in 1972 and Farakka Barrage subsequently, as revealed from the analysis of sequential satellite images and Survey of India (SOI) toposheets of 1970's (Chakrabarti, 1998). In this regard, it may be mentioned that the words 'inter basin' / 'intra basin' invite special attention towards nature's own built system as a river basin / watershed is a distinct hydrological unit in the context of 'Hydrological Cycle'. Any change in water – sediment – vegetation regime of the watershed due to natural or anthropogenic reasons may cause substantial changes in river morphology as well as stability of the area which in turn may badly affect the present day landuse/ landcover i.e. built up land, crop land, forest etc. For example, in the later part of the 18th century (1787 ?), due to some geological reasons (tectonic activities coupled with landslides), the Tista river changed its course and joined Brahmaputra river instead of debouching in the Ganga river (cf. Ferguson, 1912; Roy, 1952; Bhattacharyya, 1959; Chowdhury and Kamal, 1996) and the three distributaries of the Tista river viz. Punarbhava, Atrai and Karotoya rivers were not receiving any water from the Tista river as it was earlier (Chakrabarti, 2004). As a consequence, one may find shrinkages in channel width, cut off meanders/ wet lands and change in cropping pattern in the area. Historical accounts also reveal that the changing course of Kosi, Mahananda rivers in the Himalayan foot hill region of eastern India made the 'Gauda – Lakhmanbati – Pandua' kingdom uninhabited due to water logging etc. (cf. Roy, 1952).

In this context programmes viz. "Integrated Mission for Sustainable Development" (IMSD), "Natural Resources Information System" (NRIS), of Deptt. Of Space and "Natural Resources Development & Management System" (NRDMS), Department of Science & Technology, Govt. of India are ideal examples.

Under these programmes 'geoinformation' in village/ mouza level (i.e. the lowest administrative unit) on micro-watershed basis have been generated for agro-ecological development minimizing the adverse effect of drought and flood hazards mainly through technological adjustment and social adaptations (Table – 1, 2, 3)
Pilot scale implementation of the 'generated database' (both physical and socio-economic) have proved successful in Indian scenario with agro ecological characterization → agricultural environment analysis and biodiversity conservation, minimizing the adverse effects of natural hazards (e.g. droughts, floods), land degradation etc.

In view of that developmental planning on watershed basis may be considered as a form of maintaining the landscape ecology where a compromise is sought between the development in catchments and conservation of natural resources (both land and water resources) including biological diversity (cf. Meijerink, 1990).

However, it may be mentioned that terrain based 'area specific' intra and/or inter-basin transfer of river water seems unavailable to support 'watershed development' programme.
• Along the east coast of India, cultivable land / salt pans of the lower estuarine plain/ coastal belt
• Are being used for brackish water fish farming, especially, prawn cultivation (e.g. Digha Mohona; Bengal salt factory area, Dadanpatrabar, Medinipur district (E), West Bengal) – 'easy-to-fetch' money but likely to increase salinity of the surrounding fields and groundwater as well as accelerate long lasting water logging situation during cyclone/ storm upsurge.

The aforesaid discussion reflects on the necessity of the 'Geo-environmental mapping' concept as 'Application pull' rather as 'Technology push' through fine tuning of the baseline data already generated under the above mentioned programmes towards sustainable landuse planning in human orientation.

7. CONCLUSION

Geo-environmental studies being a multivariate/ multiscale approach the following steps may lead to success in reality:

- Systematic identification of the TMU/ NSU and GEI/GEU using RS data with ground truthing – need knowledge-based expertise.
- Selection and proper weight input to the 'indicators' to construct index model – require basic scientific rigour.
- Appropriate integration of different parameters (both spatial and non-spatial) in GIS environment – demand trained multidisciplinary personnel in handling and processing the data.

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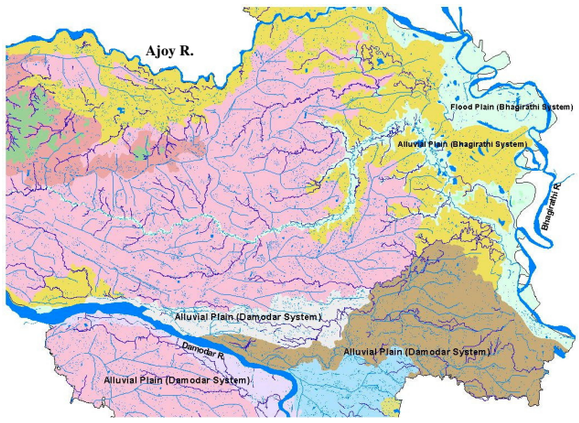

Photo2. Arsenic contamination in Groundwater exists only in Bhagirathi alluvial plain

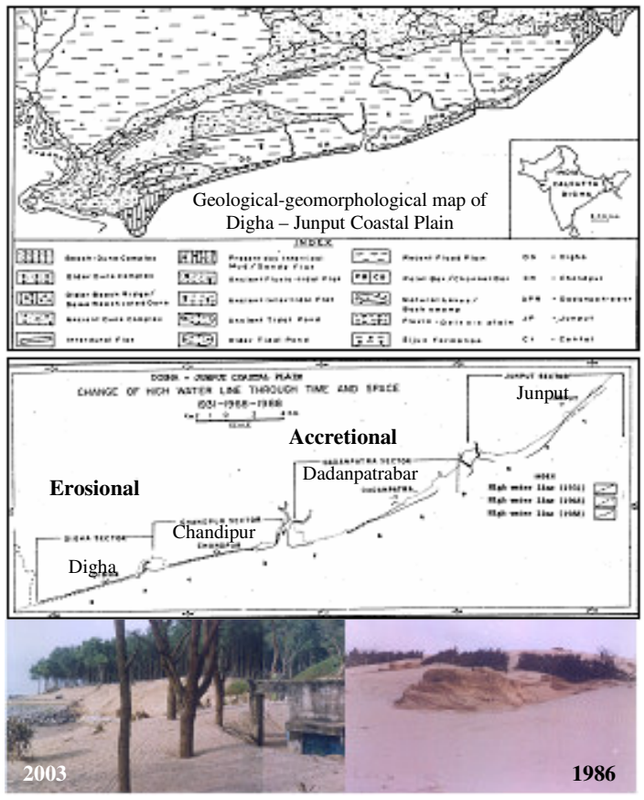

Photo 1. Erosional regime in Digha area, Medinipur (E) district, West Bengal, India.

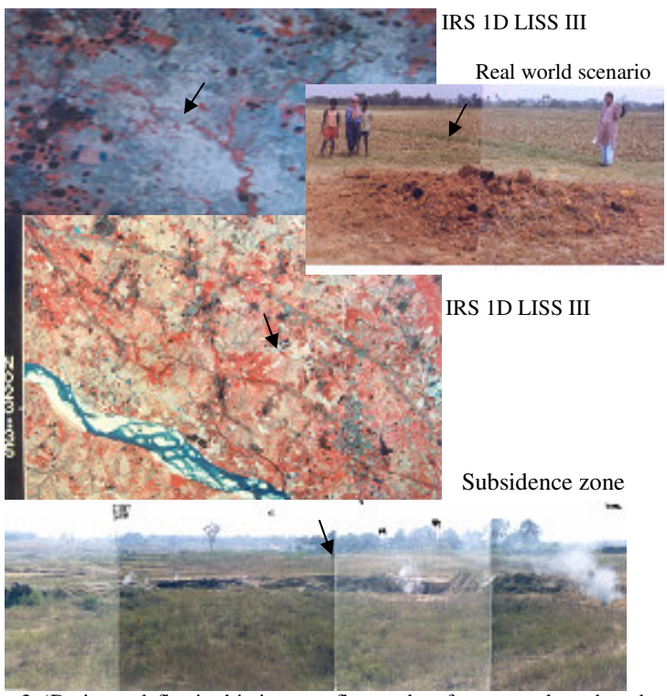

Photo 3. 'Drainage deflection' in image reflects subsurface anomaly and earth degassing; Mahira,
'Geomorphic anomaly' image – subsidence zone in real world; Kankardanga, Barddhaman district, West Bengal, India.

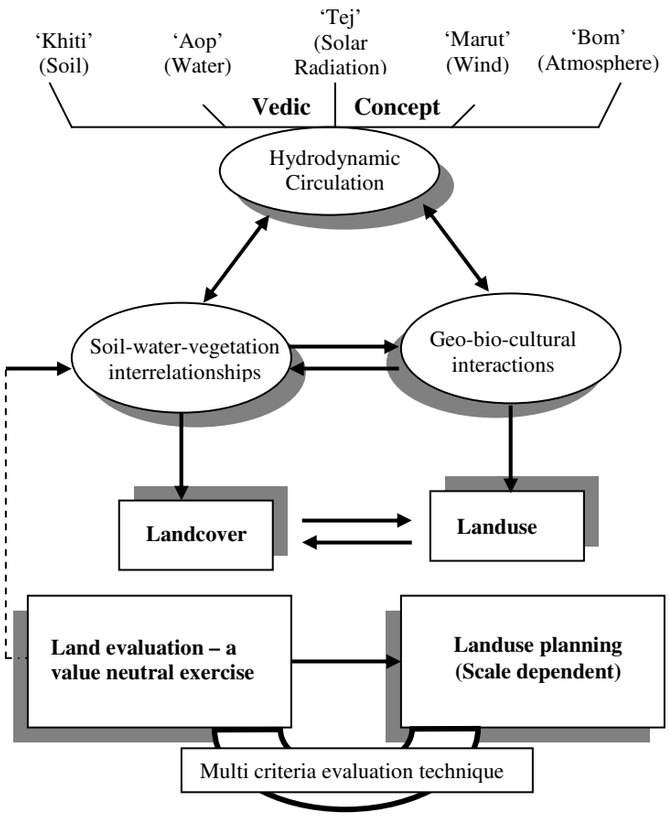

Fig: 1. Interrelationship between Hydrodynamic Circulation and Natural Resources Evaluation

Geoinformatics– 'the Directed Eye': RS + GIS – Spatio – thematic operational approach include:

The Aided Eye	Remote Sensing (RS) data (i.e. Aerial photos & Satellite Imagery) analysis	Provide site specific up-to-date geo-spatial information with regional perspective through synoptic viewing
	+	
	Survey and Geodesy	For ground truthing
	+	
	Map and Cartography	Enhance creative sensibility through 'private visual thinking' towards conceptualization and analytical approaches.
	+	
The Educated Eye	Spatial Decision Support System (SDSS) – Geographical Information System (GIS) Environment	Harmonization and Standardization of spatial and aspatial data to frame decision rules with specific perspective based on criterion weights

Fig: 3. Geoinformatics

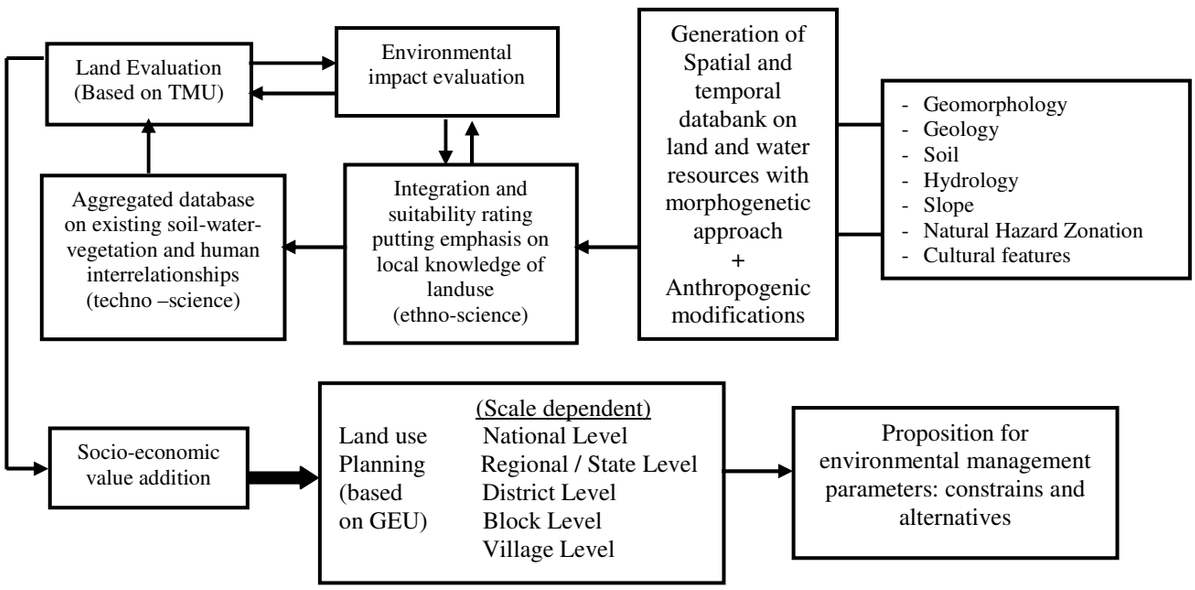

Fig: 2. Land Evaluation for Environmental Management

Village Name	Aspatial Data (Census 1991)								Spatial Data	Suggested Action Plan through GIS
	Demographic Composition (%)				Basic Amenities					
	TP	GN	SC	ST	Drinking Water	Education	Medical	Communication (Rly Stn / Bus Stop)		
Sosokhas	1297	69.5	4.5	26.0	TW	P(1), M(1)	-(-5)	>10km	***Physiography:Ajodhya Hill Complex with rolling topography of Chhotanagpur Plateau*** TMU: Buried Pediment Shallow (BPS) Existing Landuse/Landcover: Wasteland (Land with Scrub) Soil: Shallow, generally sandy loam to loamy sand; Typic Ustochrepts; Land capability subclass – IVes Slope: 1-3% Groundwater Prospect: Depth to Water Level – 5-7m.b.g.l. (Pre-monsoon) Transport Network: Cart track mainly, partially unmettaled road	1. Lac – culture 2. Agro - horticulture 3. Silvipasture ***Decisive Factor:*** *Lac – culture: local adaptability* *Agro-Horticulture: marketing facilities available through up gradation of existing unmettaled road to black top one connecting the major road (SH4)*
Karru	1767	84.0	10.0	6.0	TW, W	P(2)	-(-5)	>10km		
Birgram	2651	68.0	25.0	7.0	TW	P(2), H(1)	RP(1)	5-10km		
	TP: Total Population GN: General SC: Schedule Caste SC: Schedule Tribe				TW: Tube Well; W: Dug Well; P: Primary School; M: Middle School; H: High School RP: Registered Practitioner -(-5): More than 5 Kms, from the village					

Table1 Subarnarekha Watershed, Baghmundi Block, Purulia District, West Bengal, India

Village Name	Aspatial Data (Census 1991)								Spatial Data	Suggested Action Plan through GIS
	Demographic Composition (%)				Basic Amenities					
	TP	GN	SC	ST	Drinking Water	Education	Medical	Communication (Rly Stn / Bus Stop)		
Suyaria	212	50.5	49.5	-	TK,TW,W	P(1)	-(-5)	BS	***Physiography:Chhotanagpur Plateau fringe area with rolling topography.*** TMU: Buried Pediment Shallow (BPS) Existing Landuse/Landcover: Wasteland (Land with Scrub) Soil: Shallow to moderate; Ultic Haplustalfs; Low to medium fertility; Land capability subclass – IVes Slope: 0-1% Groundwater Prospect: Depth to Water Level – 5-7m.b.g.l. (Pre-monsoon) Fluctuation: 2-4m Transport Network: Black top road connecting two adjacent Block H.Q.	1. Sericulture 2. Plantation ***Decisive Factor:*** *Local adaptability – Existence of Sericulture farms in the surroundings* *Good road connectivity*
Narayanpur	803	50.2	27.8	22	TK, TW, W	P(1)	-(-5)	BS		
	TP: Total Population GN: General SC: Schedule Caste SC: Schedule Tribe				TK: Tank; TW: Tube Well; W: Dug Well; P: Primary School; BS: Bus Stop -(-5): More than 5 Kms, from the village -(5-10): Within 5-10 Kms, from the village					

Table2 Dwarkeswar Watershed, Kashipur Block, Purulia District, West Bengal, India

Category	Affected Villages	Total Area	Total Population	Affected Crop Area	Potential Losses	Remarks Information from Villagers
Deep and Long Lasting Inundation 16.63 Sq. Km.	***CD Block: Mangolkot***					
	Kogram (58)	57.43	290	Totally affected, 42.43 Hec.	Kharif crops mainly, damage of village houses and roads.	*Water level rises 10 feet for 3 full days.* *3 – 5 feet for 10-12 days*
	Sitahati (52)	339.31	1700	85% affected, 311.81 Hec.		
	Pilsoan (46)	309.51	915	78% area, 241.43 Hec.		
	Aogram (48)	377.23	1628	75% area, 182 Hec.		
	Deulia (51)	665.07	2767	35% area, 233 Hec.		
	Chndra (47)	52.14	162	30% area, 15.65 Hec.		
	Atghara++ (54)	199.72	1247	30% area, 59.79 Hec.		
	Mangolkot (64)	1875.51	9647	20% area, 372.72 Hec.		
	CD Block: Bhatar					
	Mandardihi (36)	94.99	972	30% area, 19.2 Hec.	Kharif crops mainly	

++ 15% of Settlement affected

Table3. Societal Aspects of Flood Hazard Zonation Map, Ajay-Kunur Confluence, Barddhaman District, West Bengal,