Role of ASWRS and its adaptability on Watershed Management in Rarh Region of West Bengal- A GIS Based Hydro-geomorphological assessment

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Abstract: **The availability of water resources and their management and development are considered as most important aspect at present days environmental and climate change context particularly in drought prone Rarh Region like Purulia, Birbhum (Western Part), W. Medinipur, Bankura (Western Part) and Burdwan (Western Part) districts in West Bengal,India. Rarh region of West Bengal is charcterised by scanty amount of rainfall, high evapotranspiration rate, seasonal run-off, uncertain-geo-hydrological attribute, fluctuation of water label with short distance, overgrazed pastures, and forest degradation have resulted in the existing acute scarcity of water as well as soil erosion. Adaptation of AWWRS on integrated water resource perspective ensures that social, economic, environmental, and technical dimensions are taken into account in the management and development of surface waters (rivers, lakes, and wetlands) and sub-surface water. An in-depth study has been carried out regarding role of Artificial Surface Water Recharge Structure (ASWRS) towards water availability and their recharge pattern in Rarh Region (with case study of Dhobai watershed, Jharkhand state and Bandu watersheds, West Bengal state) for the concept of optimum sustainable livelihood.**

Keywords: ASWRS, Biogeochemical cycle, Drought, Hydro-geomorphology, Geospatial technology, Strategy, Sustainable Development, TIN, Watershed

INTRODUCTION

The creation of regional imbalance, inequalities and differentiation in India, is started by the physiographic element and ends with economic, & socio-cultural life of the human being. An emblematic north-south lateritic belt of West Bengal (geographically recognized as Rarh Bengal by [1]Bagchi and Mukherjee in 1983) with the ferruginous gravels and kaolinite deposits (from Rajmahal Hills to Subarnarekha Basin) borders this province to make the transitional diagnostic landforms and distinct sedimentation pattern in between the Archean- Gondwana Formation at west and recent Quaternary alluvium of Bengal Basin at east [2] Rarh region (western part of West Bengal and part of Jharkhand) which is drought prone in nature characterized by its poor and scanty sub-surface water resource aspect due to its crystalline basement which exhibiting highly dissected pedimental landscape and lateritic upland with skeleton soil. An attempt has been made to study the role of Artificial Surface Water Recharge Structure (ASWRS termed by author) for maintaining the surface and sub-surface water balance and flow pattern in this region. Detailed geo-spatial mapping and intensive ground truth verification has been carried out for sub-surface water fluctuation scenarios analysis. Water balance in this region implies the 'disturbed' natural linkage between meteoric water, surface water, and ground water and hence results the distorted and fluctuating flow pattern nature of water system under the process of hydrological cycle. The estimation of the surface water balance of a region requires quantification of all individual inflows to or outflows from a groundwater system and change in groundwater storage over a given time period through ASWRS. Implementations of ASWRS ultimately meet the need of certain modification of existing terrain based surface water management system incorporating with proper application of geo-spatial technology.

II. STATEMENT OF THE PROBLEMS IN THE STUDY AREA

Demand of water uses for various purposes i.e. domestic, agricultural, industrial, aquaculture, power generation, forestry, environmental &ecological and other uses is flowing very fast due to the improvement and development of economic activities in Rarh region. The main problem of this area is scarcity of water, fluctuation of water within short distances as well as soil erosion. Westernmost districts are not only a drought-prone sector of West Bengal but also the underground water reserve condition is very erratic and fluctuates remarkably within short distances [3] heading towards a fresh water crisis. Identification of surface and sub-surface water potential zone ever remains a mystery. In Rarh Bengal the processes of primary and

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secondary laterite formation are slightly different in the basis of magnitude of involving factors (i.e. type of weathered materials, source of ferrallitic materials, wet – dry type of climate, fluctuation of groundwater table, topographic positions, stability of favourable environment etc.[4]

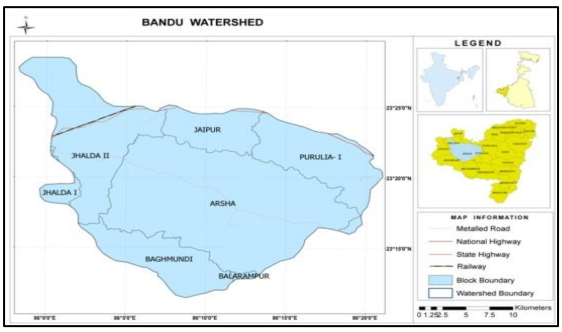
III. OBJECTIVE

The research work has covered the acute diagnosis and assessment of terrain based water scenario including their effective remedial measures of present water utilization system. Some other aspects are as follows:

- To study the hydro-geomorphological aspect of this region of watershed basis.
- To find out the water sources and utilization pattern
- To estimate of water usage and
- To assess sub-surface and surface water recharge pattern
- Site specific recommendation of aswrs for surface water resource management
- Adaptation of surface water resource management on socio-economic aspect their significance towards watershed.
- To generate up to date thematic information on basic natural resource potential on watershed basis, for facilitating land and water resources management designing towards sustainable development planning.
- Prioritization on identification of surface water prospect zones on mini-watershed basis (with case study of Dhobai watershed, Jharkhand state and Bandu watersheds, West Bengal state) through some geomorphic assessment and generate a complete digital database for planning and management aspect.
- to study the role of ASWRS and their socio-cultural adaptability towards watershed planning and management.

IV.LOCATION OF STUDY AREA

The present study area, Dhobai Watershed forms a part of Mayurakshi river basin in the State of Jharkhand. Politically, the study area is located covering parts of the Saryeahat and Ramgarh Blocks of District Dumka, Jharkhand with area is about 306.87 sq.km.[5]The Bandu watershed (geographical area: 648.24 sq.km) is lying between 23º20'00"N to 23º47'00"N and 86º0'00"E to 86º30'00"E, major part of Arsha block and some areas of Jhalda-II, Baghmundi and Jaipur block of Purulia district .



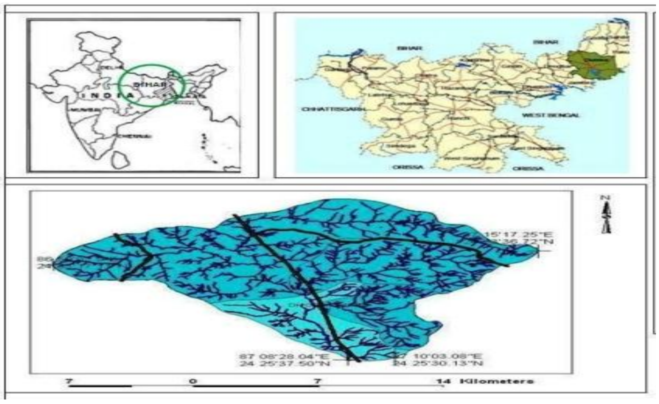


Fig 1: Location Map

V. METHODOLOGY

The micro level interpretation through integration and analysis of the various thematic information [6]provided by the IRS LISS-III and LISS-IV satellite image (precision geocoded images), Quickbird satellite data has been used as the input for preparation of thematic maps or layer. In order to prepare the maps with attributes as stated in methodology, will be three phases for carrying out the whole work –

i) Pre-field information and study, ii) Field verification, iii) post field data generation and thematic layers integration errors which normally creep-in during the creation of vector data from tracing film drawing by digitization

Creation of various thematic layers with geodatabase

For proper application of geo-spatial technology towards watershed demarcation the input satellite image in digital format (IRS-P6, LISS-III and LISS-IV Precision geocoded, FCC-2005-06 and 2014-15 with scale of 1:50000) and quickbird satellite data and georeferenced SOI toposheet (for Dhobai watershed-72P02,72P03,72L14 and Bandu watershed 73I/3, 73I/4, 73I/7, 73I/8, 73I/10 with scale of 1:50000) has been used and the various geomorphological features as well as hydrological parameter drainage, soil, land use/ land cover, transport and settlement with attribute information and extraction techniques also has been stepwise followed. To compare and interpret all these theme maps overlay analysis has been done. After that final theme maps have been prepared of the present study for surface water potentiality zone. The advantage with on screen interpretation and mapping is that the smaller objects such as valley fill, sill, dyke, hill, ridge etc. can be easily detect and identified with classification by zooming (1:20000) the image. Some of the features were also identified and discriminated easily by individual band data.

VI. HYDRO-GEOMORPHOLOGICAL ASPECT

a) Weathered mantle which attains a maximum thickness of 25m. and its water table condition is mainly developed by dug/open well. During peak summer

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season these dug well become dry with poor yield rate of 2.75 lps at some places. [7]

b) Saprolitic zone which is sandwiched between weathered mantle and fresh rock mass in granite terrain. The depth of this zone varies between approximately 10 – 30 mbgl. with an average thickness of 4m.Ground water occur under semi confined condition and yield up to approximately 2.5 lps is recorded.[8]

c) Fractured zones of hard rock where ground water explorations have been conducted down to approximately 50 to 110 mbgl. Deeper fracture is encountered at around 100-110 m depth, yielding around 3 lps as observed at Manabazar block, Purulia District.

d) Unconsolidated sediment zone along the river valleys are of limited thickness of fall within approximately 5-13 mbgl with spatial extent of 1-2 km across river valley. Saturated thickness of alluvial tract varies from 1 m -5.5m. Seasonal fluctuation shows rise in level decadal rising water has been observed at Arsha, Baghmundi, Barabazar, Banduan, Jhalda-I &II and Puncha blocks of Purulia district and some eastern part of Jharkhand. Since the regional fluctuation is restricted within approximately 2.00 mbgl observed through out of this District. [9]

VII.WATER SOURCES AND UTILIZATION PATTERN

Following the natural slope, all the rivers in this Rarh region are intersected have an easterly or south-easterly course developed dendritic or radial drainage pattern.[10]. Only the Subarnarekha flows south and receives west and south-west flowing tributaries. The Kasai is the master-stream of the District, draining more than three-fifth of the District. All the tributaries of the Damodar, Dwarkeswar, Kasai, Kumar and the Subarnarekha are non-perennial and subject to flash floods.[11] Except where they run over exposed rock, their beds are usually deep in gravel and sand; their banks are abrupt and broken into deep gully's wherever drainage from the surrounding country finds its way to the level of the stream[12].

There is a range of water bodies such as perennial ponds, seasonal ponds, dobas, nala bunds, water harvesting tanks, check dams and others for supporting the water utilisation activities bodies

Table: 1:Existing water resources with their features (*Source: field observation by author ,2014)*

Sl No	Existing Water Resources	Specifications
1	Gully head bund	Small seasonal bunds are situated mostly in congestion of two or more 1st order stream. During rainy season most of the parts of the pond gets inundated. These bunds are relatively deeper and slope. The size of bunds is relatively higher than tank or pond.
2	Pond / Tank	These ponds retain water throughout the year. During rainy season most of the parts of the pond gets inundated while in winter and summer seasons the water holding area becomes smaller. Very small seasonal water bodies are called tanks.
3	Irrigated seasonal pond	These ponds retain water mostly during the rainy season while in summer season they dry up. Their water holding period varies from 4 to 10 months. Seasonal pond may be irrigated in case of its proximity to river in which water from the river is drained into the pond to increase its water holding period. In West Bengal ponds are named as Bandhs which may be seasonal or perennial while very small seasonal ponds are called hapas and tanks.
4	Doba	Small seasonal ponds situated mostly in nearer to habitation areas. These ponds are relatively deeper and slope.
5	Natural steam /Jor	A natural water body with a high gradient of flow.
6	Paddy field	The paddy fields retain water for 3 to 4 months during Kharif season.
7	Water harvesting tank	It is formed by raising the ground level at one side of a small depression with considerable potentiality of inflowing water from the high water catchment areas.
8	Check dam / Nala bund	Water impoundment's created by raising bunds across a flowing water or water coming out through seepage.
9	Irrigation canal	Canals draw out from a river or a large perennial source of water to irrigate the agriculture fields.
10	Khal	These are the abandoned, elongated, narrow strip of waterbodies found in the roadside or on other places
11	Spring	Groundwater seepage, may be seasonal or perennial

for irrigation, domestic purpose and other uses. The majority of water bodies is seasonal and has the very limited potentiality to be used for irrigation for rabi cultivation. (Field observation by author) Canal irrigation system has been found both side of Kangsabati reservoir and Panchet Surface water in this region used for drinking and sanitation purposes.[13] However, at few places bore well and gully head bund water is also used for irrigation. The quality of water is good for both the irrigation and for potable use. The occurrence and movement of sub surface water depend upon the rock formations present and ground water storage in the region.[14] The different types of water resources available were identified during the study of surface water resource profiles. A comprehensive country-wide survey was conducted in1991-92 to ascertain the status of drinking water availability on habitation basis. In the survey, habitations were identified in three categories, namely NC (Not Covered having supply of less than 10 litre per capita per day), PC

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(Partially Covered having supply of 10-40 litre per capita per day) and FC (Fully Covered having supply of 40 litre per capita per day or above) [15].

Table 2: Existing water availability and utilisation scenario in Rarh Region (*Source: field observation by author,2014)*

Sl No	Water Resource Type	Seasonality	Ownership	Users	Uses
1	Gully head bund	Post monsoon period	Individual, Group, Govt., Community	Community	Irrigation, Bathing, Washing, Fisheries, Animal use
2	Pond / Tank	Throughout the year	Individual, Group, Govt., Community	Community	Irrigation, Bathing, Washing, Fisheries, Animal use
3	Irrigated seasonal pond	6 to 8 month	Group &Community	Community	Irrigation, Bathing, Washing, Fisheries, Animal use
4	Doba	Water available generally up to 5 to 8 months	Individual, Group,	Community	Domestic use, Irrigation of homestead, Fisheries, Bathing
5	Natural steam /Jor	Water available during monsoon, perennial	Common	Community	Rabi cultivation (Partial)
6	Water harvesting tank	Water available from July to October	Individual and Govt.	Community	Soil water conservation, Irrigation and Fisheries
7	Check dam / Nala bund	Throughout the year	Community	Community	Paddy cultivation(Partial), Fisheries
8	Irrigation canal	Water available from 8 to 10 months	Group, &Community	Community	Irrigation & Fisheries
9	Khal	May be perennial or seasonal	Govt.	Community	Irrigation,Bathing,Washing, Animal use

It is also observed that ground water utilization is yet very little or limited in agriculture and industrial sectors. Domestic consumption of water has generally done through dug and bored wells drafting. The ground water draft for all uses has been calculated to 13.78% out of which 8.55% is for irrigation only and rest for domestic and industrial uses. The of paddy cultivation has been seen in the Kharif season at BPM and in-filled Valley area.[16]

VIII. ESTIMATION OF WATER USAGE

The demand for water is increasing due to population growth, economic and technological development, and increasing modernised ways of life in this region. Of the total available surface water consumption rate, agricultural use accounts for approximately 70%, industrial use accounts for 3%,and domestic use accounts for 27%. The expected water consumption should be 60-150litres per day in this District. Today, drinking water is even privatised and commercialised in many regions. There have been discussions on the monopolisation of water for commercial use that may violate human rights by taking away a basic human need. However, there are also arguments that pricing places a value on water and therefore results in its sustainable use or conservation [18].

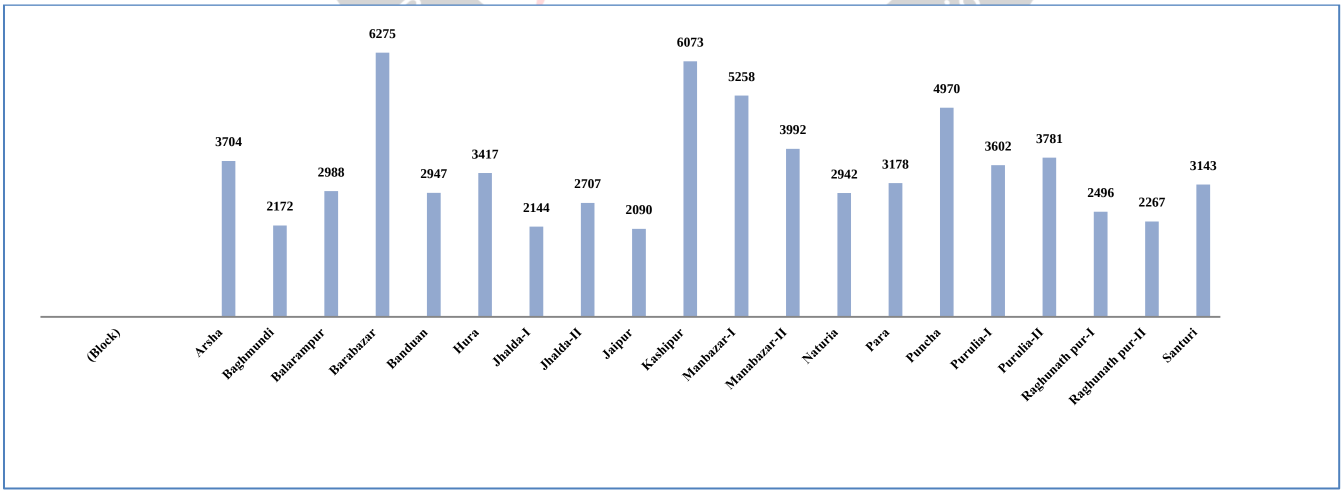

Fig 2: Net Ground Water Availability (in ha.m), Sample Block, Purulia District

Due to seasonal rainfall, for much of the year the only water available for domestic and agricultural purposes is that retained in water bodies, or sources such as springs or rivers. The social factors which influence the potential use of water resources for drinking as well as agricultural and irrigation include ownership, control, users, associated uses and rights of use[19].

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Table- 3: Pre- intervention and post- intervention ground water scenario,2014 (Source Author & SWID)

Pre-intervention groundwater (GW) scenario (in MCM)				Post-intervention groundwater (GW) scenario (in MCM)		
Rainfall year	*Total Surface &Sub surface water recharge*	*Total surface water requirement for irrigation & Drinking Purposes*	*Net surface water balance*	*Total Surface &Sub surface water recharge*	*Total water requirement for irrigation& Drinking Purposes*	*Net ground water balance*
Good	3.02	2.08	0.96	7.13	4.53	2.6
Average	1.63	1.22	0.41	5.29	3.14	1.61
Lean	0.78	1.21	-0.43	2.11	1.32	0.79

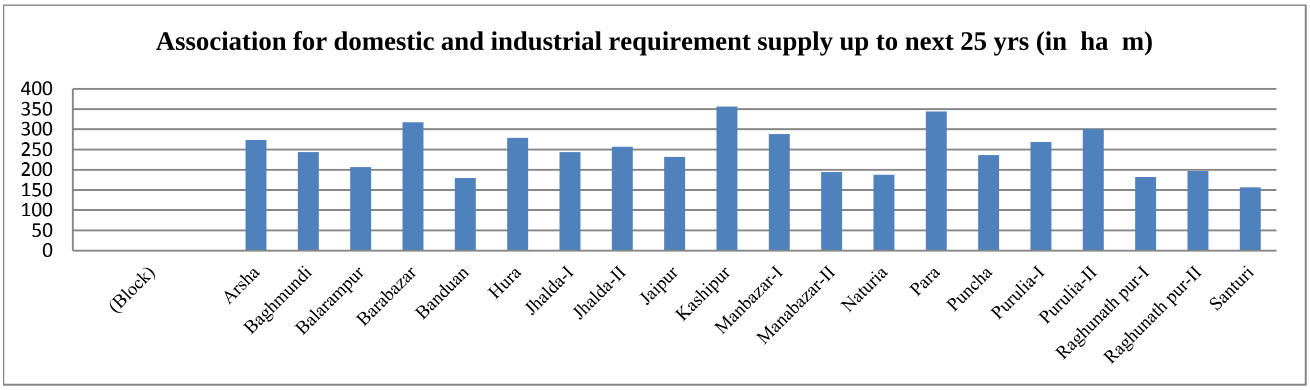

Fig 3: Estimated domestic and industrial water requirement & supply up to next 25 yrs (in ha m).(Source: Author)

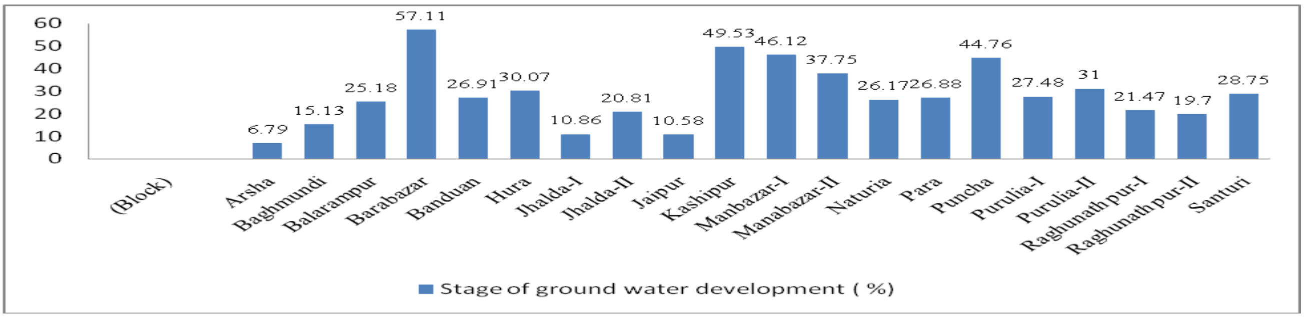

Fig 4: Stage of ground water development, (unit in ha m) Purulia Distrct

IX. SUB-SURFACE AND SURFACE WATER RECHARGE PATTERN

The zones where the groundwater level is higher than the surface water level groundwater can discharge into a stream (called a gaining stream).Where the surface water level is higher than the groundwater level the river can leak to recharge the groundwater system (losing stream)[20].

Rarh region is very poor in her underground water resources because of her crystalline basement. Where surface water is not readily available, the inhabitants resort to extraction of groundwater dug wells. During periods of normal precipitation (about 1,000 mm. to 1,200 mm. in a year) the groundwater which is stored in the zone of weathering and below it, is adequate for domestic consumption.(21) However, during summer of each year, heavy withdrawal of water vis-à-vis a low permeability of water bearing horizon results in the drying up of many public drinking-water wells in the area. For ground water, rainfall is the principal source of recharge. The other are the pre-existing or existing drainage system, canal system and return flow of irrigation practices. Due to hilly and undulating terrain river water more than 75% water flow down towards low area and some portion of surface[21]

- ✓ Terrain based construction of public tube wells and their periodical maintenance
- ✓ Renovation of existing ponds, bunds, jor(small stream) ,and dug wells through proper system.
- ✓ Construction of alternative surface water recharge structures in in-filled valley area

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- ✓ Estimation of evapotranspiration loss and component of rejected recharge in this region.
- ✓ The farmers have to adopt paddy cultivation during postmonsoon period at Weathered Pediment Shallow and in-filled vally area. There is an urgent need to change the cropping pattern in these areas and to adopt cultivation of those crops which require less irrigation.

The entire region has a highly diversified hydrogeologic settings and variations in the availability of ground water resources that leading to call for a holistic approach in budding some proper management strategies.[22]The prominence on management of bothe the surface and sub-surface water resources needs effective management of available water resources with an integrated approach, combining both the demand and supply side aspect.

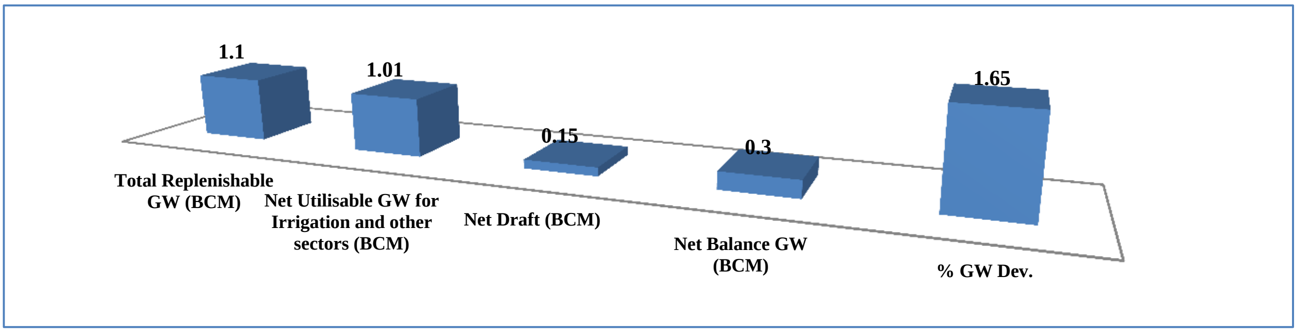

Fig 5:Annual groundwater resource and irrigation potential of sample watershed(Source:SWID 2014)

X.A. CASE STUDY- Dhobai Watershed in Dumka District, Jharkhand

Watershed Concept

Watershed is not simply the hydrological unit but also socio-political-ecological entity which plays crucial role in determining food, social, and economical security and provides life support services to rural people[23]. Watershed is a technical term used by the British to denote a common drainage point. It is a hydro geological unit. In American terminology, it is referred to as Catchment Area. Watershed is the line separating neighboring drainage basins (catchments).

Geomorphologycally the enter terrain into various homogeneous units which are termed as terrain units/geomorphic units. These terrain units are very much useful for the optimal and scientific utilisation of natural resources and environmental management. The geomorphologic units that are identified are-

a) Valley Fill
b) Denudational Hill
c) Residual Hill
d) Pediment
e) Lateritic Upland Upper
f) Lateritic Upland Lower
g) Burried pediment shallow

Hydrologically the master stream, Dhobai river has its source near Chihutiya village in the north western part of the study area. It flows in a general SE direction, broadly parallel to the general strike trends of the prevalent rock formations, but locally guided by major joints and faults.[24].The Hardia Nala originates near Kanjo village and Murko Nala originates near Madhuban, both these Nalas joins the master stream as left-hand tributaries. This combined flow is known as Dhobai Nadi and it ultimately joins Matihara Nadi near Jhilua village, a tributary to the Mayurakshi River [25].Two important drainage patterns have been identified in the study area are Dendritic Pattern and Radial Pattern. So the effect and impact of socio – cultural and economical life is fully determined by the Dhobai river and little effect by Hardia Nala.

Co-Relation Regarding Process of Land and Watershed Management

The purpose of co-relating Process of Land and watershed management is to improve, rehabilitate and conserve the land and water resources in these areas for food and livelihood security[26]. One of the greatest advantages of using remote sensing data for hydrological investigations and monitoring is its ability to generate information in spatial and temporal domain, which is very crucial for successful co-relation analysis, prediction and validation[27].

Table 4: Co-relation between sub-surface water and irrigation aspect (Source-Author)

Block	Utilisable ground water resources (Ha.M)	Net irrigation requirem ent (m.)	Net draft (Ha.M)	Irrigation potential created (Hact.) (4/3)	Ultimate irrigation potential to be created (Hact.) (2/3)	Ground water balance (Hact.)(6-5)
Sareayahat	1,731	0.4	66	165	4328	4163
Ramgarh	2586	0.4	25.2	63	6465	6402

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Contour Map has been prepared by taking contour information by Survey of India Toposheet No: 72P02, 72P03 and it has been digitized using Arcview 3.2a software, in GIS Platform.

Triangulated Irregular Network (TIN) Map has been prepared with the help of contour information.

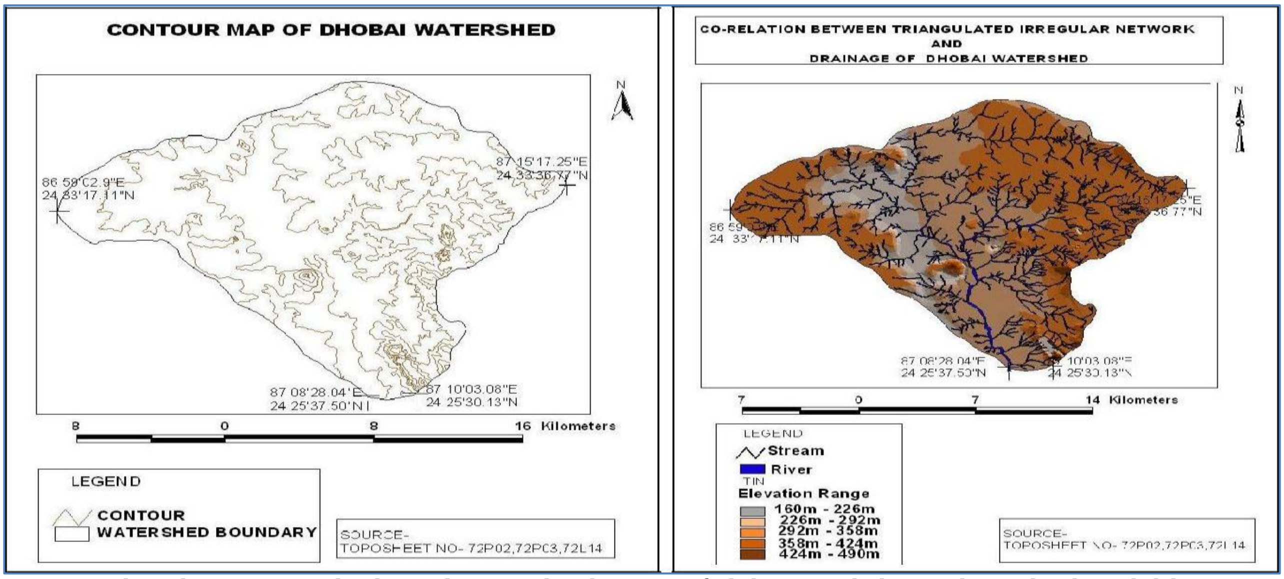

Fig 6: Co-relation between Triangulated Irregular Network and Drainage of Dhobai Watershed region depicts that the Radial drainage pattern is observed around the Residual and Denudational Hills of this watershed and also the regional surface water flow along slope aspect (Source-Author,2013)

Interpretation and assessment

(i) *Changes in flow* has been observed due to excessive abstractions of water from rivers and water bodies for irrigation, urban supply, small industrial requirement significantly decrease downstream flow rates and diminish aquifer recharge in Dhobai watershed region.

(ii) Watershed degradation at downstream areas can become blanketed in sediment due to changes in land use in watersheds can release large loads of sediments and attached contaminants into waterways.

(iii) Detoriation of water quality is also a major cause of contamination in many areas, especially where there is little enforcement over the use of agro-chemicals sources are a threat to human health and environmental health.

(iv) Healthy riverine and estuarine systems require pollutant removal, amelioration of floods, and provide habitat for economically important fauna and flora corresponding through unscientific agricultural and grazing activities and land use conversion.

(v) Uncontrolled, unplanned, unscientific land use and interventions lead to deterioration of the watershed area.

X.B. CASE STUDY- Bandu watershed, Purulia, West Bengal

In order to precise hydrogeomorphological assessment of surface water prospect zoning and management in this district, an intensive watershed prioritization and management procedure of Bandu watershed , Purulia district has been carried out.

Issues and Problems

i. Scanty rainfall, high evaporation, scarcity of surface and sub-surface water
ii. Poor ground water yield and water level fluctuation within short distances
iii. Deterioration of water quality i.e. Fluoride contamination of water
iv. Unscientific and improper surface water utilisation & management system
v. Traditional and unscientific irrigation system
vi. Soil erosion and encroachment of wasteland (i.e. Gully /Sheet erosion etc).
vii. Siltation of existing ponds, tanks and gully head bunds
viii. Unawareness about sustainable socio-environmental resource perception

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Surface water Potential zones of Bandu watershed

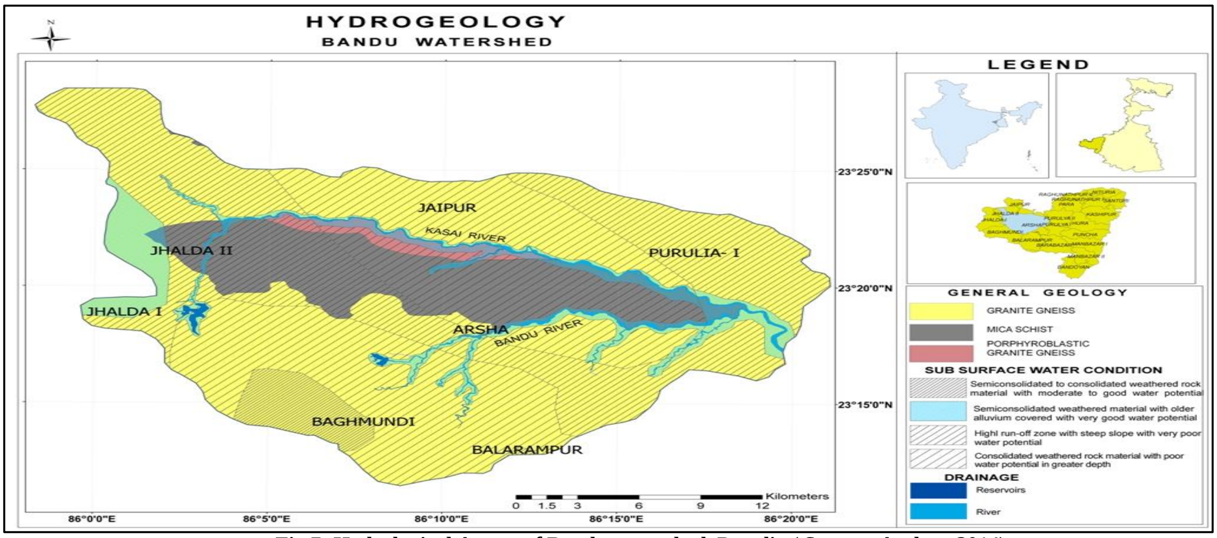

Fig 7: Hydrological Aspect of Bandu watershed, Purulia (Source- Author, 2014)

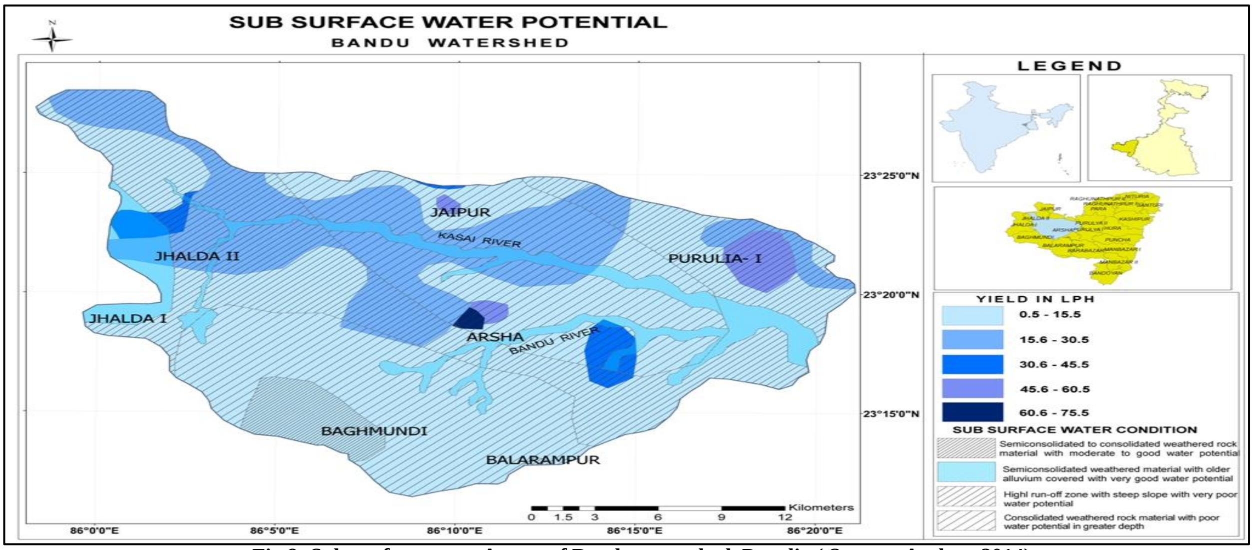

Fig 8: Sub-surface water Aspect of Bandu watershed, Purulia (Source- Author, 2014)

Surveillance and assessment

On the basis of above mentioned observation it can be concluded that Remote Sensing and GIS techniques are efficient tools in drainage delineation and their updatation. These updated surface water potential zones are treated as input data for morphometric analysis. These analyses were carried out through measurement of linear, aerial and relief aspects of micro-watersheds. This morphometric analysis reveals dendritic to sub-dendritic, parallel, radial drainage patterns with moderate drainage textures of the entire Bandu watershed. The variation in stream length ratio reflects the change in slope and topography. The bifurcation ratio of sub-watersheds indicates normal basin category and the area having moderate drainage density reflects that it has highly permeable sub-soil and coarse to moderate drainage texture. The values of stream frequency indicate that all the micro-watersheds show positive correlation with increasing stream population with respect to increasing drainage density. The values of form factor and circularity ratio evolve that almost all micro-watersheds are elongated in shape. Elongation ratio indicates that Bandu watershed is a region of very low relief whereas other micro-watersheds are characterized by moderate to high relief and steep ground slopes relief and steep ground slopes.[28].

Regarding ground water level fluctuation between the pre – monsoon and post monsoon, water level measured in the month of May and November respectively is one of the measures of rainfall recharge and in turn gives the volumetric estimate of replenishable ground water resources of the area. The other input to the ground water includes seepage from water bodies, canals etc. The fluctuation of water table is 6.1 m. The ground water flow direction is towards south-east i.e. towards Damodar river with hydraulic gradient of 0.01 to 0.008 [29]while it has been also inferred to be towards Damodar river in the buffer zone which controls the master drainage of the area. The average fluctuation in water levels

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between the two extreme seasons is around 6.1 m in the area. In respect of the confined/semi-confined aquifer in the core zone area, the piezometric head is at deeper level in relation to potentiometric levels of dug wells tapping the unconfined aquifer inferring hydrological discontinuity or low pressure head in deep aquifers [30].

XI. SITE SPECIFIC RECOMMENDATION OF ASWRS FOR SURFACE WATER RESOURCE MANAGEMENT

The only effective way to meet the high demand of water in Rarh region could be managed through adaptation of some conscious scientific approaches, construction of rain water harvesting structures as well as some terrain specific Artificial Surface Water Recharge Structures (ASWRS). This should be followed mainly in the zone of 1st order streams and Weathered Pediplain (moderate type) geomorphic zone.

Table-5: Terrain specific recommended and proposed ASWRS (Source: Author through field observation,2016)

Geomorphic Unit	Physiographic characteristics	Soil characteristics and existing land use /land cover	Surface water potentials	Recommended and suggested structures
Weathered Pediplain (WPP) / Tanr	Mainly stony wasteland/wasteland with rocky knob having flat to gentle slope topography	Brown to reddish skeletal soil, Dense / Scrub Forest covered	Very Poor	Conservation and improvement of existing forest areas. No recommendation of ASWRS
	Gullied or Ravenous land	Brown to yellowish fine loamy soil , Dense / Scrub Forest covered	Very Poor	Social forestry
	Land with or without scrub	Brown to reddish coarse loamy soil	Very Poor	Social forestry
Weathered Pediplain (Shallow type-WPS) - Bahal	Gentle to moderate slope topography	Brown to reddish skeletal soil, Dense / Scrub Forest covered	Poor	Conservation and improvement of existing forest areas. No recommendation of ASWRS
	Gullied or Ravenous land	Brown to yellowish fine loamy soil , Dense / Scrub Forest covered	Poor to moderate	Social forestry
	Land with or without scrub	Brown to reddish coarse loamy soil	Poor to moderate	Social forestry silvi-pasture
Weathered Pediplain (Moderate type-WPM) -Canali	Gently sloping to flat topography	Brown, Brown to reddish fine loamy soil ,Single cropped / Double cropped	Good	Social forestry, Agro- horticulture with proper agronomic practices, Recharge pit and recharge shaft, Gully head bund , percolation tank
In-filled valley (VFS)- Baid	Zone of 1st order stream	Deep gray, Grayish brown fine loamy soil , single cropped / double cropped, vegetable	Excellent	Double cropped areas should be utilised for intensive agriculture with proper agronomic practices , Recommendations of ASWRS like Check dam, nala bund, gully head bund, tank ,weir etc.
Bazada Shallow (BS)	Hill wash deposit with moderate slope	Weathered wash materials composed soil profile , partly low height scrub forest covered	Good	Recommendations of ASWRS like Check dam, nala bund, percolation tank,recharge pit, Hill toe trenches etc.
Residual Hill (RH)	Small remnant hill with high slope	Brown to deep brown with Weathered soil profile	Poor	Conservation and improvement of existing forest areas. No recommendation of ASWRS

Some terrain specific ASWRS which can boost the sub-surface aquifers through suitable structures like:

Some suitable structures, which can be recommended, as follows:

(i) Check dam/low height weir: Construction of check dam has been recommended on the existing earthen or stony nala/jor on the 1st order streams and in the areas having 0º-6º slope gradient. The low height weir is also recommended at the congestion point of more than two road crossing on the 1st order streams along foothill zone and in the areas having 0º-3ºslope gradient in the respective terrain areas.[31]

(ii) Nala Bund: Construction of Nala Bund has been recommended on the pre-existing earthen bund and in the zones of the 1st and 3th order streams/jor flowing through the undulation plain and valley areas. Here some water has been stored in the river bed for a considerable time of the year which can increase recharge possibilities of surface water.

(iii) Percolation Tank: Percolation Tank has been recommended for construction on the 1st and 3rd order streams/ jor flowing through the undulation plain and stream valley characterised by steep slope with loose soil profile. This is characteristic in lineament crossing zones in both the blocks.[32]

(iv) Recharge well and Invert well: In the areas where transmissivity of the upper surface rock strata is quite poor (e.g. in the area shale underlain by sandstone), the weathered pediplain (shallow and moderate type) zone with low permeability of the top soil and thick impervious rock layers may be considered as the most

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suitable site for the construction of recharge wells and invert wells.[33]

(v) ***Rooftop Rainwater Harvesting:*** Rooftop rainwater harvesting structures are also recommended in the places having sufficient roof area (Pond area), like the Municipality building, school building, College building, institutional and administrative buildings in this region.[34]

(vi) ***De-siltation of water bodies i.e. Tank and Pond:*** Considering the terrain condition and slope aspect, depth of all the tanks should be 14-25 feet to get impervious layer towards sub-surface. The upslope side of tank must be kept open to allow surface flow of water to be collected in the pond. The dumped material forming barrage on the down slope side should be planted with grass or bamboo for checking soil erosion and siltation.

(vii) ***Sub-surface dyke:*** The vesicular, weathered and fractured gneissic terrain where the ground water seepage and base flow is dominant, construction of sub surface dyke is considered effective for artificial water recharge into the aquifer[35].

(viii) ***Recharge Pit:*** The recharge pits are also recommended and preferred in the pre-existing tank and weathered pediplain (shallow type) zones.

(ix) ***Recharge Shaft:*** In the area where shallow aquifer is located below clay complied surface Recharge Shaft is considered effective for surface water potentiality.

(x) ***Hill Toe Trenches***: Hill Toe trenches can be effective as significant rainwater harvesting structures, which can be constructed at the bottom of the slopes of Ajodhya Hill and Jaichandi Pahar as well as in the villages having high and low rainfall in these two blocks. The water retained in the hill toe trenches helps to boost water table [36]

(xi) ***Conserving the soil moisture and surface water storage***.

The intersections of lineaments have been regarded as suitable sites of retention of potential surface water and best suitable zones for construction of dug wells. The areas adjacent to intersection of lineaments, if scanned by Vertical Electrical Sounding (VES) techniques, could be very much effective for delineation and demarcation of depth and nature of aquifer. The sub-surface lithological condition and corresponding level of sub-surface water table also can be understood using this technique.[37]

A wide spectrum of techniques are in vogue to recharge ground water reservoir.
Similar to the variations in hydrogeological framework, the artificial recharge techniques
too vary widely. The artificial recharge techniques can be broadly categorised as follows:-

a. Direct surface techniques
• Flooding
• Basins or percolation tanks
• Stream augmentation
• Ditch and furrow system
• Over irrigation

b. Direct sub surface techniques
• Injection wells or recharge wells
• Recharge pits and shafts
• Dug well recharge
• Bore hole flooding
• Natural openings, cavity fillings.

c. Combination surface – sub-surface techniques
• Basin or percolation tanks with pit shaft or wells.

d. Indirect Techniques
• Induced recharge from surface water source.
• Aquifer modification.

Besides above, the ground water conservation structures like ground water dams, sub-surface dykes or locally termed as Bandharas, are quite prevalent to arrest sub-surface flows. Similarly in hard rock areas rock fracturing techniques including sectional blasting of boreholes with suitable techniques has been applied to inter-connect the fractures and increase recharge. Cement sealing of fractures, through specially constructed bore well has been utilised in Maharashtra to conserve sub-surface flow and augment bore well yield.

XII. ADAPTATION OF SURFACE WATER RESOURCE MANAGEMENT ON SOCIO-ECONOMIC ASPECT

In order to know the socio-economic adaptability of the Artificial Surface Water Recharge Structure (ASWRS), a series of field investigations have been carried out to test and implement socio- economically viable technologies of surface water management in these two blocks. Assessment has also been made to know the perception of the people to accept the impact of ASWRS. Proper assessment and socio-economic impact analysis of the study area shows the mentality of the people to adopt the effective alternative solution of surface water stability. They are not in a position to assess the tentative economical result of condition of post-adaptation status of such ASWRS. If the residents can make differentiation between the viability of artificial and non-artificial recharge systems in practicing agriculture, irrigation, sanitation and other domestic uses then they can develop mentality of adaptation.

It is observed during field investigation that to meet the household and sanitation demand, women usually traveled 2-5km distances for collecting water. This problem has been partially solved after construction of check dams and dug wells in selected areas. So ASWRS can be very much effective for various domestic activities, farm-oriented economical activities, levels of cleanliness and overall health status of the communities. The inhabitants of these two blocks are supposed to learn the art of sustainable water utilisation approach like construction and conservation of rainwater harvesting structures,

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preservation of weirs and check dams etc. Limited numbers of villages have received benefit of varied application of ASWRS structures. The people of some villages remain very much concerned about the topographic condition of the landscape and therefore they tend to be selective about faming of crops and vegetables in respective plots of land with surface water bodies as available.

Some other socio-economic activities that can be implemented in both the blocks are suggested as follows:

(i) Development of wide range of scope for benefit generation:
(ii) Development of community based benefit generation:
(iii) Development of financials susceptibility
(iv) Land acquisition problem and suggested method for its solution:
(v) Development of community based participation
(vi) Impose restriction on extraction and utilisation of water through unscientific measures
(vii) Re-orientation of agricultural practices through the year

Impact on socio-environmental parameters

a. Restriction of depletion of surface water

On the basis of investigation upon more than 50 wells and 56 surface waterbodies in both the sample blocks, it is observed that there was gradual depletion of surface water before the construction and modification of ASWRS. But after construction and modification of 4 check dams and some dug wells, partial depletion of surface water have been restricted. Pipe line water supply also can be effective for providing potable drinking water without low risk of fluoride contamination, water evaporation and water leakage to the villages. Construction of boreholes and dug wells with durable technologies have been observed for conserving depletion of surface water

b. Control of land erosion and subsidence

After the pilot study in these sample blocks regarding control of land erosion and subsidence, some construction of surface water harvesting structures have artificially restrict the land erosion. Some areas also have been nourished and enriched with soil moisture after the construction ASWRS.

c. Control of deterioration of water quality in the aquifer

The water quality is relatively good at greater depth (130-180m) of aquifers, but it is costly for purification of drinking water drawn from that depth for drinking and other household purposes as well as agricultural practices. Under the scheme for supplying fluoride-free water under the directive as “each block of India should contain at least one water supply tank”, the Arsha and Raghunathpur – I blocks have not yet reached the level of success. The potable water can be served by pipeline water supply network.

d. Partial mitigation of existing drought condition

During extended periods of drought and dry climatic conditions ASWRS have played important role for storing and holding the surface water. Therefore it may be said that these structures are very much useful and beneficial to overcome the hazard of drought condition and meet water demand during pre-monsoon period.[38] Constructions of terrain-specific recharged structures have to be durable enough with high capacity to retain water level in such dry condition.

e. Improvement of standard of living and social behavior

It has become even more apparent during field investigation and literature review that economic level of the people gradually increased after adaptation of ASWRS which ultimately increased their standard of living and social behavior.

f. Improvement of land use system / farming practices

Some low-moisture sustainable crops like ragi, kado or black gram etc., alternate to rice, wheat and sugarcane, have been successfully cultivated in the areas of in-filled valleys and moderate type buried pediplain zones. Mixed cropping is also practiced adjacent to the existing local check dams. The irrigated area has been gradually increased using the services of new water-harvesting structures and by re-excavating and desilting the existing tanks, ponds through different schemes. More than 24,000 hectares of land has now been converted from wasteland to cultivable agricultural land and for social forestry in this region.

g. Improvement of cropping intensity pattern

It is observed that about 82% of the total populations in these blocks are directly or indirectly dependent upon ground water lifting and existing surface water based agricultural practices. Many farmers have been continued the traditional agricultural practices with poor amenities resulting low crop production. In some villages the cropping intensity pattern also has been increased considerably through implementation of micro-irrigation processes.

h. Improvement of soil and sub-surface water relationship

After intensive study in these sample blocks regarding improvement of soil and sub-surface water relationship some areas have been considerably nourished and enriched with soil-moisture content after adaptation of artificial surface water recharge structures and renovation programmes.

XIII. CONCLUDING REMARKS

Sustainable groundwater development and management through ASWRS in the Rarh region needs to be taken up by incorporating artificial recharge to groundwater from in-situ and ex-situ sources. The rainwater harvesting process through integrated watershed interventions, management of

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salinity ingress in coastal aquifers, conjunctive use of surface- and groundwater, management of poor/marginal quality groundwater, water conservation by increasing water-use efficiency, regulation of groundwater development and extraction, etc are some benefitted alternative water sources. In order to improve the sub-surface and surface water table, proper application of ASWRS could be highly effective to increase the depleted ground water aquifers. These mentioned techniques are easy, cost-effective and sustainable in the long term sustainable water utlisation. Community based adaptation or adopted by the individuals with terrain specific recommended location and local knowledge based manpower, surface water resource would be the key to achieve breakthrough in agricultural production and food security and also in livelihood.

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