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Viability of Rainwater Harvesting In Drought Prone Areas Of West Bengal: An Empirical Study On Bandu River Basin In Puruliya District

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Abstract: Puruliya is a drought prone district of India, situated in the state of West Bengal. Monsoonal vagaries along with ustic soils and poor groundwater availability augment the sufferings of the district's residents from acute water scarcity. In such a condition, rainwater harvesting is the viable solution of the problem, as the district gets ample of rain in the monsoonal months.

Bandu River is a tributary of river Kangsabati. Its basin area covers 14,764 hectares of land divided into four micro watersheds .The basin receives 1,150 mm of rainfall even in the driest years. The runoff available from that amount of rain is estimated through four empirical formulae postulated by Sir Aiexander Binnie, T.G. Barlow, Ingels- De Souza and Lacey. All of the calculations indicate the amount is a healthy one.

Key Words: *Water Scarcity, Rainwater Harvesting, Micro-watershed, vulnerability*

Introduction: Puruliya district in West Bengal is characterized by its immense water scarcity and recurrence of drought. Drought hazard, resulting from a combination of monsoonal vagaries, low retention capacity of soil and poor yielding capacities of groundwater tables of the district, have imposed a perpetual impact on its population restricting their future growth in economic and social sectors.

Rainwater harvesting may become the finest solution of the water scarcity of the district if implemented and worked out with utmost care and precision. Puruliya district receives ample rainfall at monsoon times. Normal amount of yearly rainfall is 1,426mm (Govt. of WB, 2004). The amount of water received by the district is enough to support vigorous human activities if collected and utilized wisely. Thus the processes and techniques of rain water harvesting and runoff collection become foremost essential for Puruliya district.

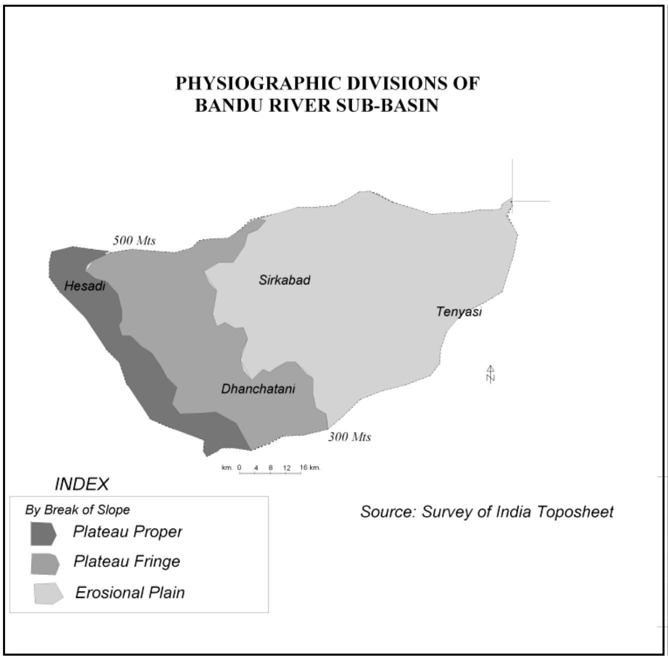
Rivers in Puruliya district drain into three major basins. The rivers of northwestern and northern part of the district drain into Damodar basin while those of southwestern and south portion drain into Subernarekha river basin. The central and eastern part which cover the largest area of the district, are drained by Kasai – Kumari river system. Apart from these three, there are upper catchment regions of Dwarkeswar and Silai rivers in the eastern boundary of the district. Thus Puruliya district contains numerous watersheds with variable size, slope, topography, soil, land cover and land use. Each watershed has its own characteristic features, hence cannot be addressed by a single strategy. Here ‘Bandu river basin’ is taken up as a case for detailed study.

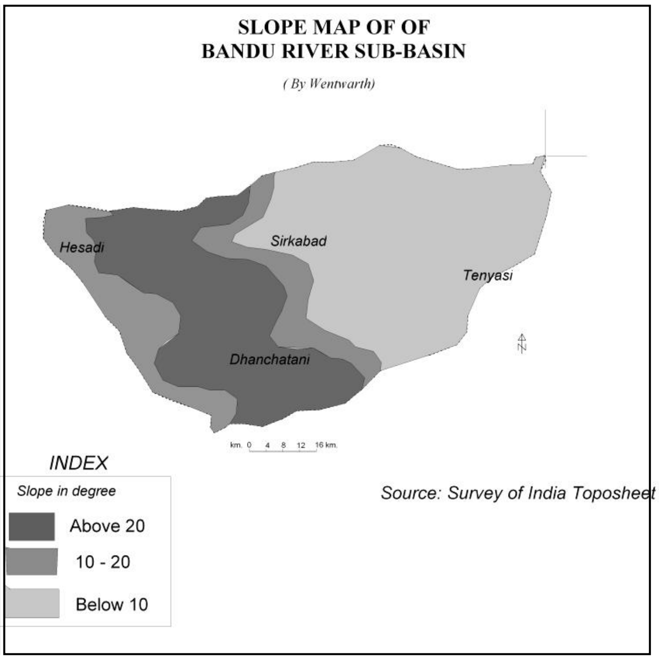
Location of the Study Area: Bandu is a right flank tributary of river Kasai that originated in the northern slopes of Ajodhya Hills (Fig 1). It flows at large through Arsha block and joined Kasai river just five kilometrs south-west of Puruliya town, near Beldih village. Some parts of upper Bandu catchment lie in Baghmundi block. A tiny part in the south-east of the basin falls in Balarampur block while its confluent region lies in Puruliya-I block. Shirkabad and Hensadih are two eminent villages on the bank of Bandu River. Confluence of Bandu and Kasai is located at 23º19´03´´north latitude and 86º19´22´´east longitude. Total area covered by the basin is14764 hectares. The basin is further subdivided into four micro watersheds; each of them covers an area between 250 and 400 hectares (Fig 2).

Physiographic Condition: Bandu basin contains an ideal, spontaneous admixture of slope forms separated by distinct break of slopes i.e. plateau proper with lower slope gradient, plateau fringe with sharp inclination and rolling plains with very lull gradient. The break of slope points is identified typically on 500 metres and 300 metres along the main river courses (Fig 3). Almost 50 per cent area of Bandu basin is undulating plain land. Of the rest 50 per cent, high slopes of fringe region comprises more than 35 per cent and only less than 15 per cent of total area is considered plateau proper (Fig 4).

The principal river of the basin, Bandu, is an ephemeral stream that originated at the northern slope of Ajodhya Hills somewhere near the foot of Gajaburu peak (620mts.). Three tributaries joined the main river from the right and one from the left. All of them carry water only in the monsoonal months. Bandu follows the regional slope from west-southwest to east-northeast (Fig 5).

Soils of Bandu basin are of two typical types. Soil in upper catchment region and over the plateau slope is skeletal, thin, gravelly and lateritic in character. While in the plains it is dominantly sandy loam. Both of the soils lack in clay components, thus non-cohesive in nature. pH value of these soils generally varies between 5.5 and 6.5 (Mondal, 2007).Tropical dry deciduous verities of *sal, kusum, simul, asan* and *palash* cover the plateau region. This dense mixed jungle typically restricts within the piedmont slopes and planes are almost devoid of forest cover. The vegetal complex shows characteristic dominance patterns i.e. *kusum* and *simul* dominate over the top while in fringe slopes it is *sal*. At the piedmont regions *palash* predominates over the other species. *Mahua, arjun, haldu, kul* etc. are some other tree species found in the plains. Grass lands occur on plateau tops that are either locally arid enough to support vegetal growth or posses too thin soil layer that restrict root penetration for larger vegetal species.





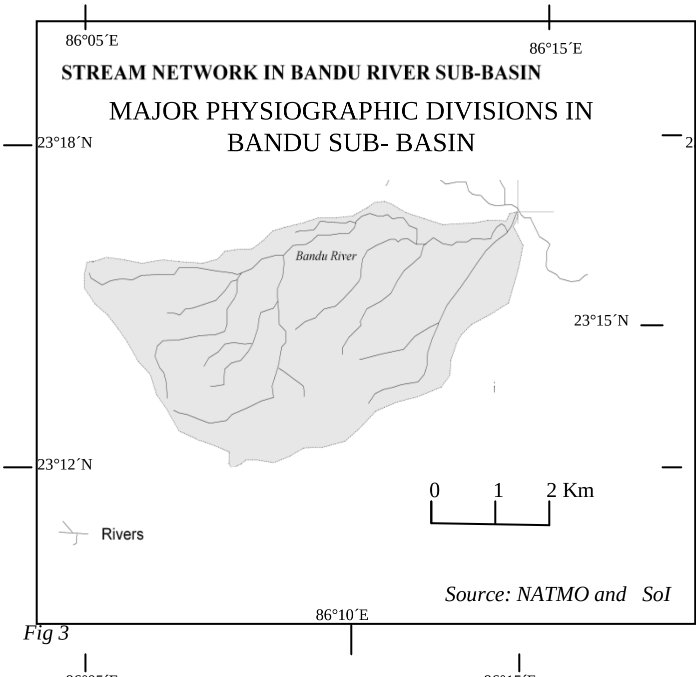


Fig 3

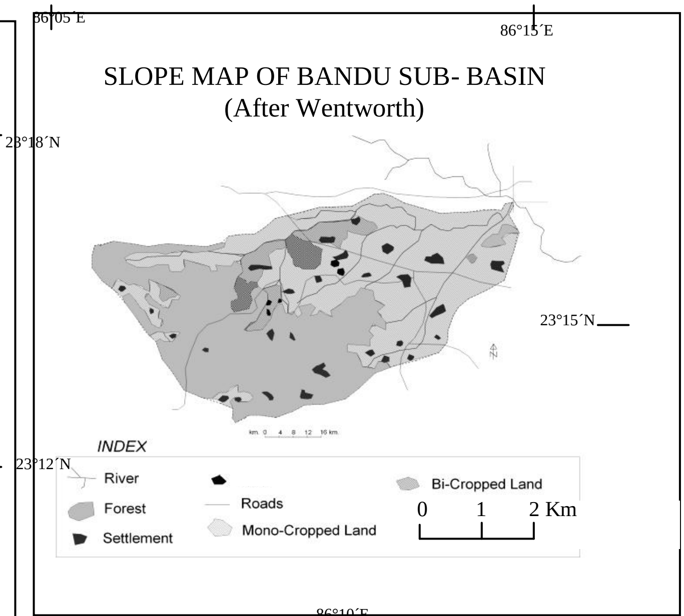


Fig 4 Source: NATMO and SoI

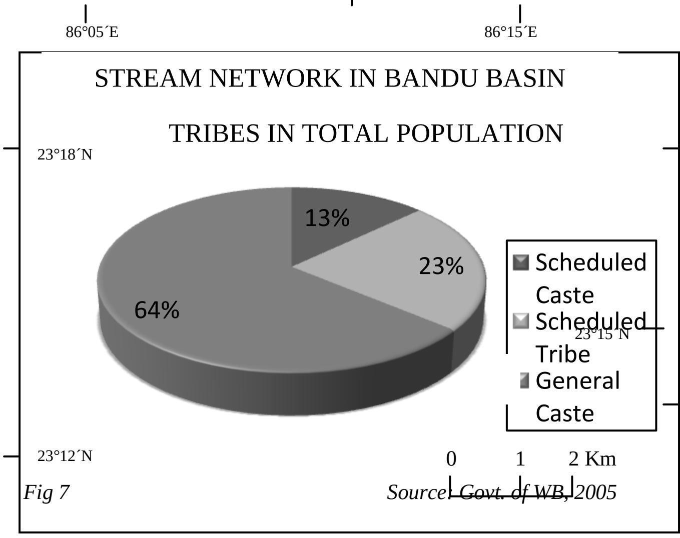


Fig 7 Source: Govt. of WB, 2005

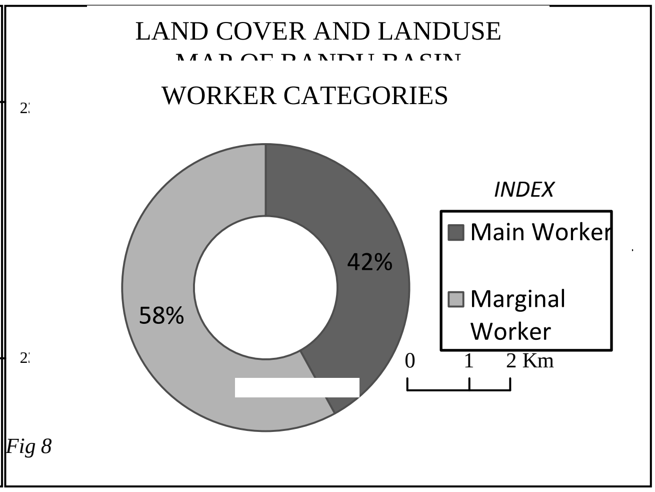


Fig 8

Fig 5 86°10´E Source: NATMO and SoI

Fig 6 86°10´E Source: NATMO and SoI

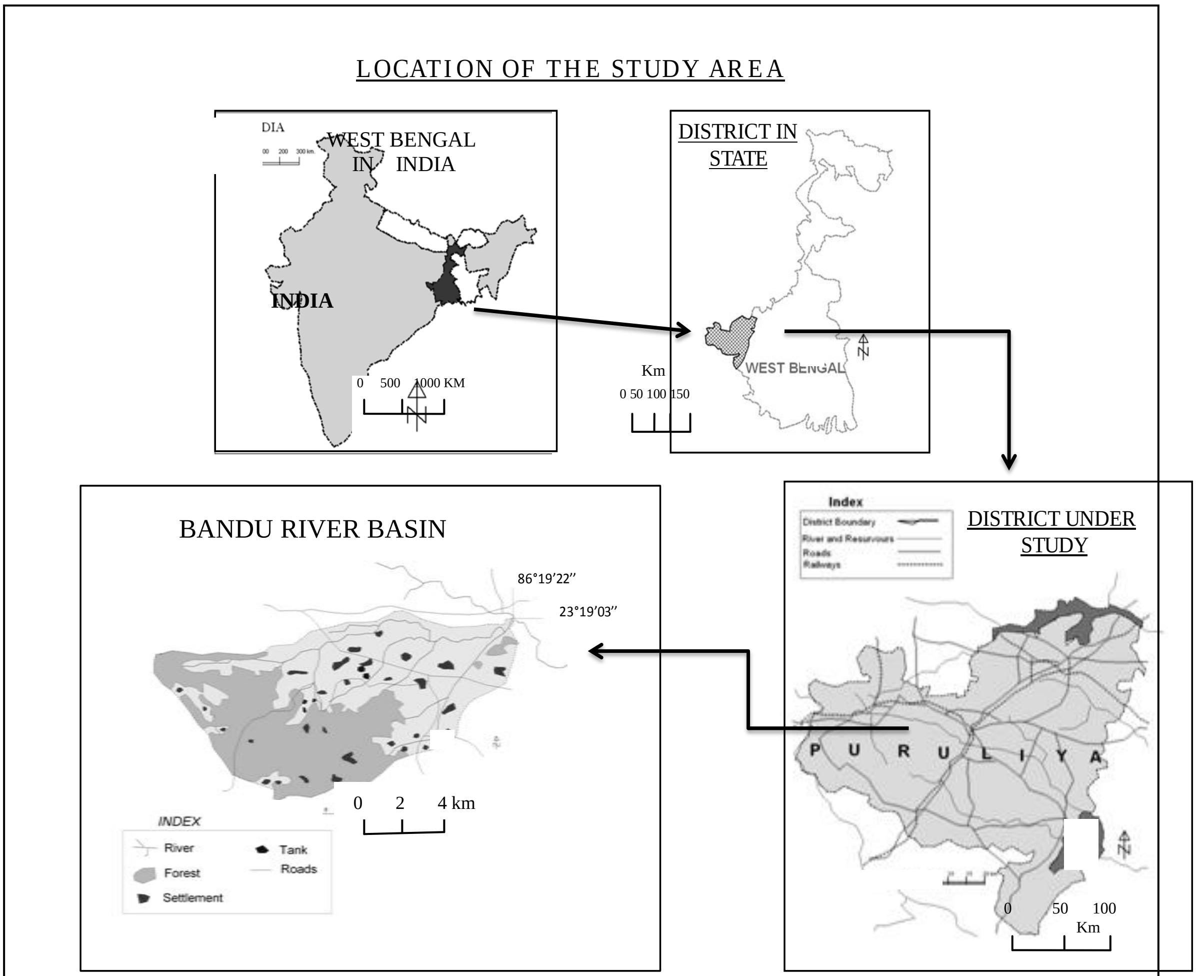

LOCATION OF THE STUDY AREA
WEST BENGAL IN INDIA
INDIA
0 500 1000 KM
DISTRICT IN STATE
Km
0 50 100 150
WEST BENGAL
N
BANDU RIVER BASIN
86°19'22''
23°19'03''
0 2 4 km
INDEX
River
Forest
Settlement
Tank
Roads
Index
District Boundary
River and Reservoirs
Roads
Railways
DISTRICT UNDER STUDY
P U R U L I Y A
0 50 100
Km

Fig. 1

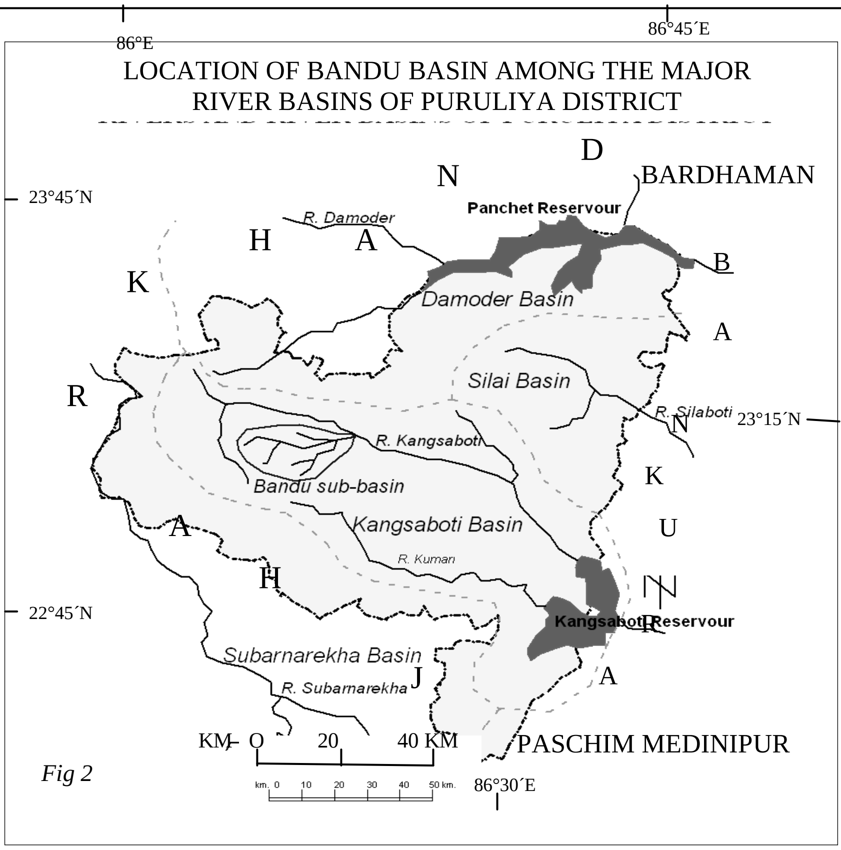

86°E
86°45´E
LOCATION OF BANDU BASIN AMONG THE MAJOR RIVER BASINS OF PURULIYA DISTRICT
23°45´N
22°45´N
23°15´N
BARDHAMAN
Panchet Reservour
R. Damoder
Damoder Basin
Silai Basin
R. Silaboti
R. Kangsaboti
Bandu sub-basin
Kangsaboti Basin
R. Kumari
Kangsaboti Reservour
Subarnarekha Basin
R. Subarnarekha
KM O 20 40 KM
PASCHIM MEDINIPUR
86°30´E

Fig 2

Social setup: There are 31 villages in the Bandu river basin inhabited by 55,329 persons. Total 28,353 of them are male and 26,976 are female (Census-2011). Population density of the area is 375 persons/sq.k.m. Scheduled Caste (SC) and Scheduled Tribe (ST) population jointly comprise 36 per cent of the total population. Characteristically, STs are superior in number than SCs in Bandu basin. SCs form 13 per cent of the basin's total population while STs comprises 23 per cent of the same (Fig 7). Typically SC, ST and general population tend to concentrate in separate places. There are several villages with distinct caste dominance. Villages like Bhuda, Pathardih, Jhariadih, Piskapahar, Tanyasi and Bandudih have no SC population at all. On the other hand, Bhursa and Satra villages have no ST population and villages like Ramjibanpur and Patuara have a few of them. Haranama village has only general caste population. Apart from these caste segregated villages, there are large villages like Sirkabad and Hensla where all three castes live in harmony.

Villages in the Bandu basin can be divided into two categories according to their economy i.e. forest based villages and agriculture based villages. Forest based villages are typically located in the higher plateau regions or in the piedmont parts and encircled by dense forests. Hensadih, Pangada and Dhanchatani are three of them. These villages are small in population size and dominated by ST people. They depend on forest for their livelihood and generally do not cultivate. On contrary, villages in plane are large in population size. These villages depend totally on agriculture though some people earn their bread from household industries. Sirkabad, Dhatikdih, Satra, Tennyasi and Beldih are such agricultural villages. They are well connected with the outer world in contrast to their forest counterparts and possess several facilities like schools, banks, health centres and bus routes. Scheduled tribes are also present in the plains but they are fewer than scheduled caste and general caste population.

Economic setup: Economic condition of residents of Bandu river basin is by large miserable. Total workers are 48 per cent of the total population and only 42 per cent of total workers are considered as main workers (Fig 8). Agriculture is the principal source of livelihood. Here 57 per cent of main workers are cultivators and 29 per cent of the same are agricultural laboures. There are also a large number of marginal farmers and agricultural laboures present in the basin. Marginal agricultural laboures alone comprise 25 per cent of the total work force of the basin (Census-2001). Return from agriculture is too low to sustain a prosperous life. Most of the agricultural fields in the Bandu basin are mono-cropped. Cultivation of *aman* paddy at the time of monsoon rains remains only activity in these fields. Uncertain rainfall often leads to crop failure. Besides, highly erosive soil cannot provide enough yields. Peoples of the basin have to depend on other sources of income; like cattle ranching, poultry rearing, *lac* cultivation etc. for their livelihood. Residents of agricultural villages also depend heavily on the forest for supply of food, fodder, fuel, medicine, house building materials and other everyday needs.

Problems in Bandu River Basin: Perception of problem differs from person to person. So it is not easy to measure various physico-cultural problems of the Bandu basin. Generalization becomes inevitable to address the problems that have relevance in regional as well as in district level. In this regard, problems of this basin are listed below:

- Acute scarcity of water restricts agricultural prospect of the region. Most of the arable land remains mono-cropped due to unavailability of water in dry periods.
- Although the basin receives ample of rainwater, 1,150 mm per annum (CGWB-2006), its distribution is unequal. Most of the rain occurs in three months i.e. July, August and September. Rest of the year remains dry. So prolonged dry season

sweeps away the moisture from the soil profile and thus incurs agricultural practices.

- Vagaries of monsoon often result in crop failure in *kharif* season. Though there is no 'cycle' but most of the farmers face that curse once in a three to five year span.
- Most of the year's total rainfall occurs in three to four intense storms with 48 to 72 hour lifespan. As a result, amount of surface runoff increases cutting down the availability of water for infiltration. Thus, the ground water recharge is poor and the aquifers are low in yielding capacity (Govt. of India, Meteorological Department, 2007).
- High amount of runoff escalates the problem of soil erosion in agricultural and forest lands. Gully formation in bare slopes and grass lands are frequent. Badland formation is evident along some parts of the Bandu and its tributaries. A considerable stretch of such degraded land can be seen on the left bank of the Bandu, just behind the Sirkabad irrigation bungalow.

Hypothesis: Consideration of aforesaid problems clearly indicates that scarcity of water is the key to all of them. The scarcity has two parts i.e. inadequate supply and improper management. To deal with the first one, inadequate supply, it will not be wise to depend on the ground water potential as the aquifers in the Bandu basin are low in yielding capacity. The more prudent way, it seems, to harvest the rain. Harvesting the incessant rain will reduce the amount of runoff, thus check soil erosion and probability of flash flood in the basin. On the other hand, proper management and utilization of water resources can secure the yearlong supply of potable and irrigation water. Moreover, all these can possibly be implemented by virtue of indigenous knowledge through the effort of the local people.

Objectives: The prime objectives of the present study are: identification of the needs of rainwater harvesting in Bandu river basin, estimation of the amount of runoff available for harvesting in the Bandu basin, establishing the need of distributional planning at a priority basis and evaluating the need and the possibilities of group based water distribution policy for the basin area.

Methodology: To satisfy the aforesaid objectives, the following methodology has been adopted in the present study:

1. Collection and consultation of information, from secondary data sources i.e. government reports, NGO reports, books and articles, to build up the hypothesis.
2. Preparation of the base map from survey of India topographical sheets, NATMO maps and satellite imageries.
3. Extensive field surveys to check the ground reality.
4. Estimation of the collectable runoff in the basin through some empirical formulae.
5. Representation of the fact through suitable cartographic and statistical techniques.

Water Harvesting: a viable solution: Rain water harvesting is the technique of collection and storage of rain water at surface or in sub-surface aquifers, before it is lost as surface runoff. The augmented resource can be harvested in the time of need (Ministry of Water Resources-2003). The portion of precipitation that makes its way towards rivers or oceans as surface or subsurface flow is called runoff. It occurs only after the losses of precipitated water through infiltration and evaporation. The excess water flows down through the small natural channels to meet the main drainage channel and is called 'surface flow'. A part of the infiltrated water moves parallel to the ground surface and reappears on the surface somewhere else and called as 'interflow'. A part of infiltrated water moves down to form groundwater tables and then moves laterally to emerge in depression and rivers. This is called as 'subsurface flow' or 'ground water flow' (Ministry of Water Resources-2007). Precise estimation of runoff is the basic and foremost input requirement for the design of recharge structures of optimum capacity. Unrealistic runoff estimates of catchment often lead to the construction of oversized or undersized structures. So, estimation of runoff, which is generated at the time of monsoonal rain or by intense storms, constitutes the first step of water harvesting effort in Puruliya.

Estimation of runoff: Several methods are there for estimation of runoff in a catchment area. For the present case some empirical formulae and tables are used to determine the amount of water availability through runoff in the Bandu basin. Besides, runoff estimation based on land use and treatment is also done.

i) Binnie's coefficient method: Sir Aiexander Binnie expressed runoff as a per centage of rainfall by the following formula-

R= KP where, R= Runoff in cm, P=Rainfall in cm and K is the runoff coefficient that varies with land cover change. Usual values of K are given in table-2

Table 2: Usual values of runoff coefficient (K)

Type of area	K
Urban Residential	0.3- 0.5
Forests	0.05- 0.2
Commercial and Industrial	0.9
Parks, Farms, Pastures	0.05- 0.3
Asphalt or concrete pavement	0.85

Source: Ministry of Water Resources, GoI, 2007

So, for the forest lands and the farm lands, the equations are -

R= 0.125×P ………………. (I) [For forest lands]

R= 0.175×P ……….......... (II) [For farm lands]

Taking up different precipitation values the available amount of runoff is computed in table 3.

Table 3. Availability of runoff in Bandu basin according to Binni

Land Type	Runoff generated by			Average availability of rain water for Runoff (cm)
	Normal rainfall in Puruliya (142.6 cm)	Rainfall in Puruliya in 2003 (126 cm)	Rainfall in Bandu basin according to CGWB (115 cm)	
Forest	17.825 cm	15.75 cm	14.375 cm	15.98
Farm	24.955 cm	22.05 cm	20.125 cm	22.38

Source: Rainfall Data- Meteorological Department, GoI, 2006

ii) Barlow's table: T.G. Barlow carried out studies on small catchments and divided them into five categories, Christianized by the alphabets A –E, to calculate the per centages of runoff generated by them. The Bandu basin comes under the category D i.e. hills and plains with little cultivation and the coefficient for this kind of catchment is 35 per cent of the total precipitation. Therefore, the equation stands for the average type of monsoon is:

R= 0.35×P ………………… (III)

Now the amount of water available from runoff for different amount of rainfalls is given in table 4.

Table 4: Availability of water from runoff according to Barlow

Land Type	Runoff generated by			Average availability of rain water for Runoff (cm)
	Normal rainfall in Puruliya (142.6 cm)	Rainfall in Puruliya in 2003 (126 cm)	Rainfall in *Bandu* river basin according to CGWB (115 cm)	
Total basin	49.91 cm	44.10 cm	40.25 cm	44.753

Source: Meteorological Department, GoI, 2006

Taking up the runoff coefficients for different seasons, as proposed by Barlow, availability of runoff in various times of the year is computed below.

R= 0.35×Cs×P ………….. (IV) Where Cs is seasonal runoff coefficient.

Table 5. Amount of seasonal runoff according to Barlow

Season	Normal Rainfall (cm)	Seasonal coefficient for D-type catchment	Runoff (cm) R= 0.35×Cs×P
January – March	7.3	0.80	2.044
April – June	38.5	1.00	13.475
July – September	83.4	1.70	49.623
October - December	13.4	1.00	4.69
Total	142.6	-	69.832

Source:Meteorological Department and Ministry of Water Resources, GoI, 2006, 2007

iii) Ingles and De Souza's formulae: Ingels and De Souza postulated two separate equations for hills and the plains to calculate the runoff, based on their study in Western Ghats in South India. The equations are –

R= 0.85P- 30.5 …………. (V) [For hilly areas]

R= (P-17.8) P/254 ……………… (VI) [For plains]

Based on the above formulae, runoff is calculated for various amounts of rainfalls as shown in table 6.

Table 6: Availability of runoff according to Ingel and DeSouza

Land Type	Runoff generated by			Average availability of rain water for Runoff (cm)
	Normal rainfall in Puruliya (142.6 cm)	Rainfall in Puruliya in 2003 (126 cm)	Rainfall in *Bandu* river basin according to CGWB (115 cm)	
Hills	90.71 cm	76.60 cm	67.25 cm	78.187
Plains	70.065 cm	53.674 cm	44.008 cm	55.916

Source: Meteorological Department, GoI, 2006

iv) Lacey's formula:

As per this formula, runoff (R) can be computed as

$$\frac{P}{1+\frac{304.8}{P}\left[\frac{F}{S}\right]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(VII)}$$

Where, S= a catchment factor, F=monsoon duration factor

Lacey's value for the F/S factor for Bandu basin i.e. Barlow's 'D-type' catchment for a standard length of monsoon is 0.58 (Ministry of Water Resources-2007). Runoff generated by different amounts of precipitation can be calculated as below.

Table 7: Availability of runoff according to Lacy

Land Type	Runoff generated by			Average availability of rain water for Runoff (cm)
	Normal rainfall in Puruliya (142.6 cm)	Rainfall in Puruliya in 2003 (126 cm)	Rainfall in *Bandu* river basin according to CGWB (115 cm)	
Total basin	63.669 cm	52.433` cm	45.325 cm	58.809

Source: Meteorological Department, GoI, 2006

v) Direct runoff from rainfall: In this method, the effects of the surface conditions of a watershed area are evaluated by means of land use and treatment classes. The classes consist of use and treatment combinations actually to be found on the watershed. They can be easily obtained by observation and measurements on sample areas (Ministry of Water Resources-2007). For the measurement purpose, soil covers are broadly divided into four hydrological soil groups considering their permeability, infiltration rate, etc. Soils of Bandu basin in particular and that of the Puruliya district in general comes under the 'A-group' i.e. soils having high infiltration rates even when wetted thoroughly and consisting chiefly of deep, well to excessively drained sand and gravels (ibid).

The rainfall- runoff equation for this method is:

$$\frac{(P-0.3S)^2}{(P+0.7S)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(VIII)}$$

Where, S= potential maximum retention in mm. 'S' values are transformed into 'Curve Numbers' using the following equation –

CN= 25400/ (254+S) ………………….. (IX)

Different CN values are obtained for fallow land, land under small grain cultivation, pasture, meadow, woodlands and farmsteads according to their treatment classes and hydrologic conditions for the A-type hydrological soil group. Now the actual runoff from different parts of the watershed can be measured by equation number VIII.

Table 8: Availability of runoff in Bandu basin according to direct method

Land Use/ cover	Treatment / Practice	Hydrologic Condition	Curve Number	Amount of precipitation (mm)	Runoff (mm)
Fallow	Straight row	-	77	1426	1329.91
Small Grain	Contoured and terraced	Good	59	1426	1351.67
Pasture	-	Fair	49	1426	1363.94
Meadow (Permanent)	-	Good	30	1426	1387.62
Woodlands	-	Good	25	1426	1393.93
Row Crops	Contoured and terraced	Good	62	1426	1348.02
Farmsteads	-	Good	59	1426	1351.67

Source: Meteorological Department and Ministry of Water Resources, GoI, 2006, 2007

It is evident from all of the above estimations that a good amount of runoff is generated in the Bandu basin that can be collected, stored, used for groundwater recharge and harvested in need. Excess runoff of the monsoon season should be restored for use in dryer periods. Different types of terrains e.g. hill slopes, plains, forests, pastures and farmlands generate diverse amount of runoff. On the other hand, different land classes have separate water need. So, plan should be made for collecting the runoff water keeping in mind the nature of the land.

Conclusion:

Puruliya district ranks first in vulnerability to drought hazards within the state of West Bengal. Thus the district is called *"Ahalya Bhumi"*- the land with a stony heart. Micro watershed planning with a particular view of rain water harvesting seems to be the viable answer to the threat possessed by drought situation in Puruliya. Proper management of the land and estimation of runoff from a particular piece of land is essential in this process. The equitable share of water for each rural poor family through 'distribution group' method should be followed all over the district. It will help the district's population not only to overcome the drought situation but also bring prosperity to their life.

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