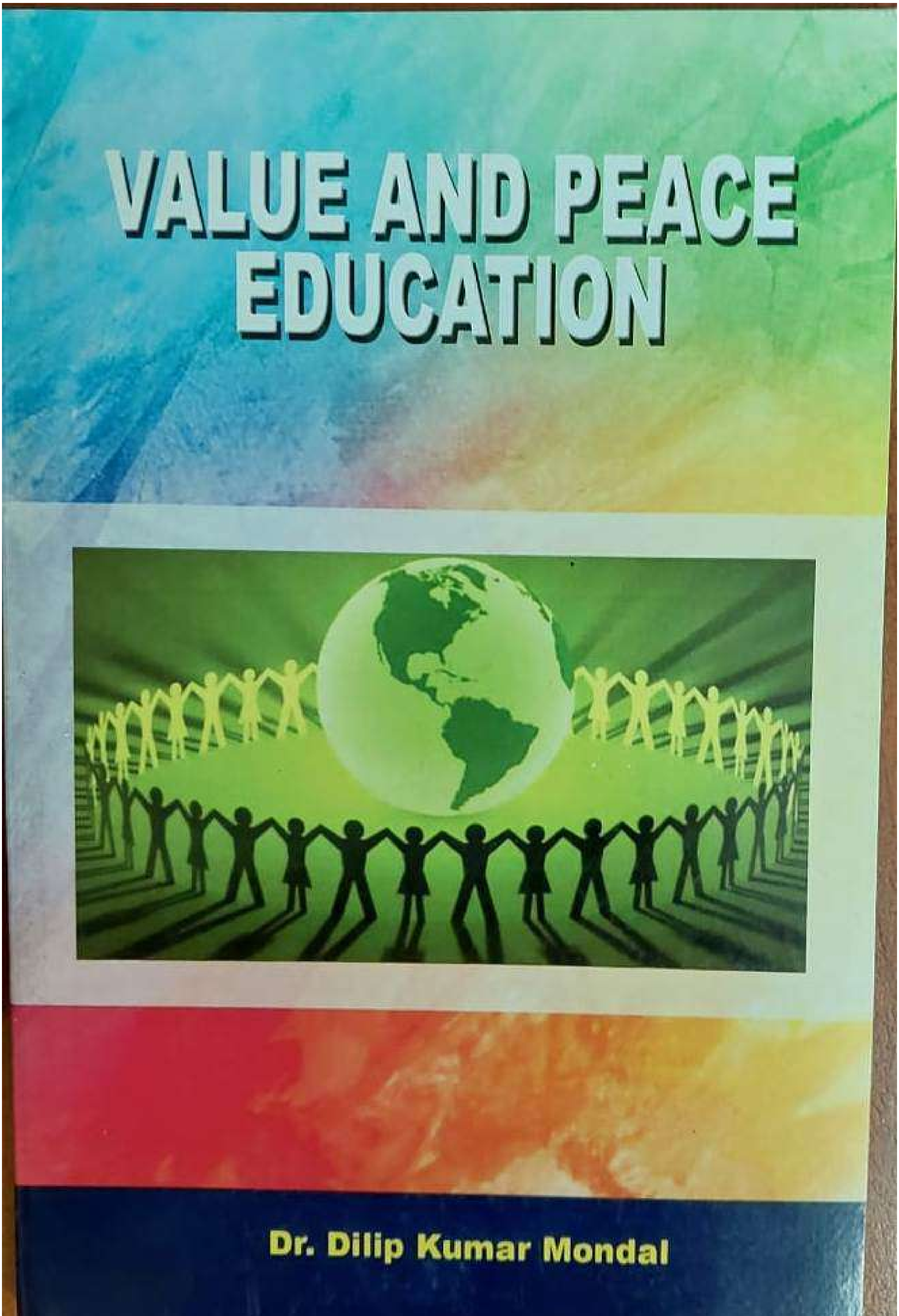
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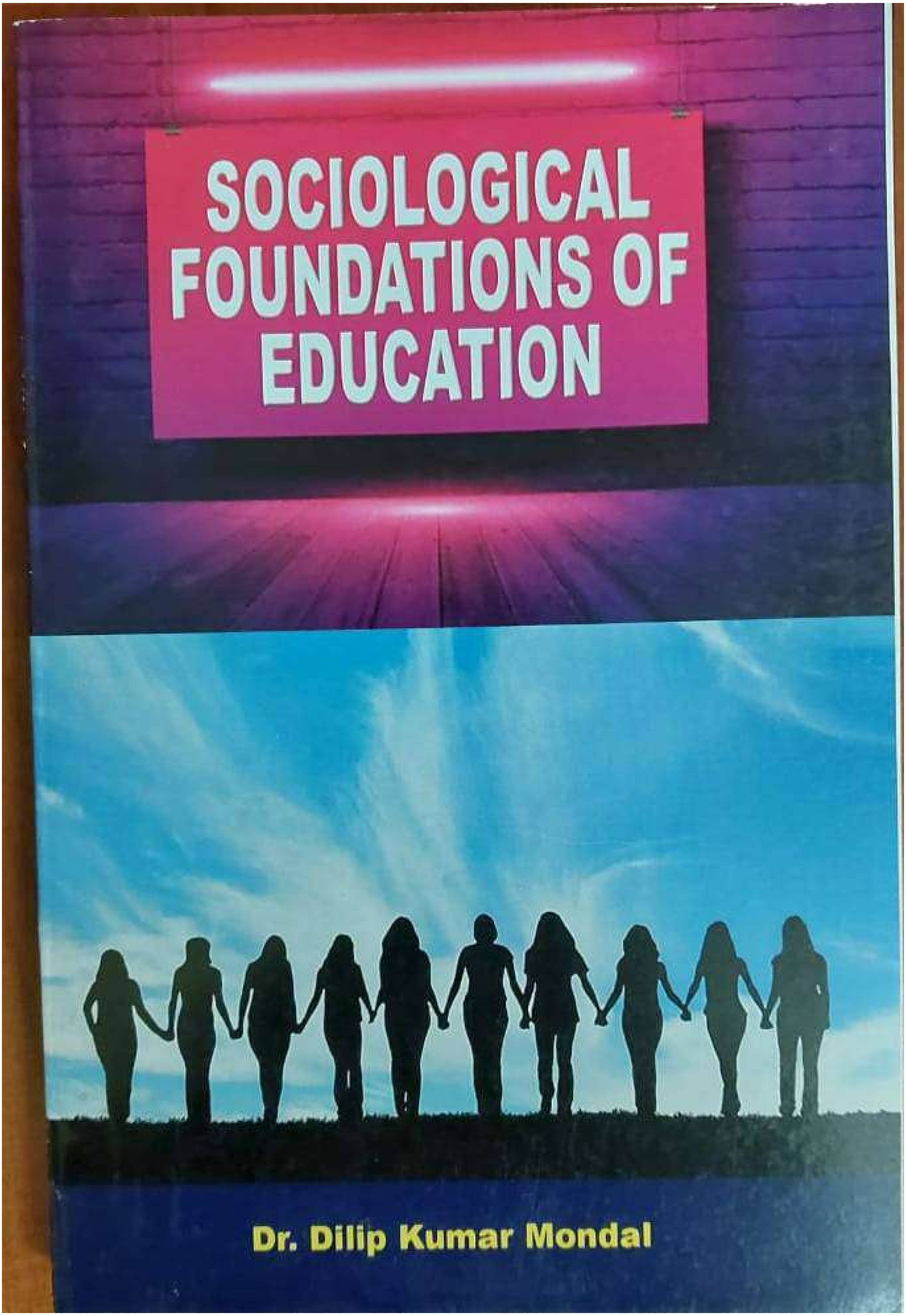
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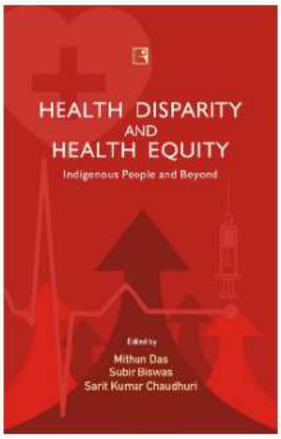

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In recent years, the term 'Health Disparity' and 'Health Equity' have become increasingly familiar, particularly in the field of public health. The editors of this book have brought together a variety of articles from researchers of diverse fields in anthropology to focus on the importance of health equity among the indigenous peoples, including those who are marginalized or underprivileged. This will help the reader to understand the problem that arises out of health disparity and the various ways to overcome it.

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CONTENTS

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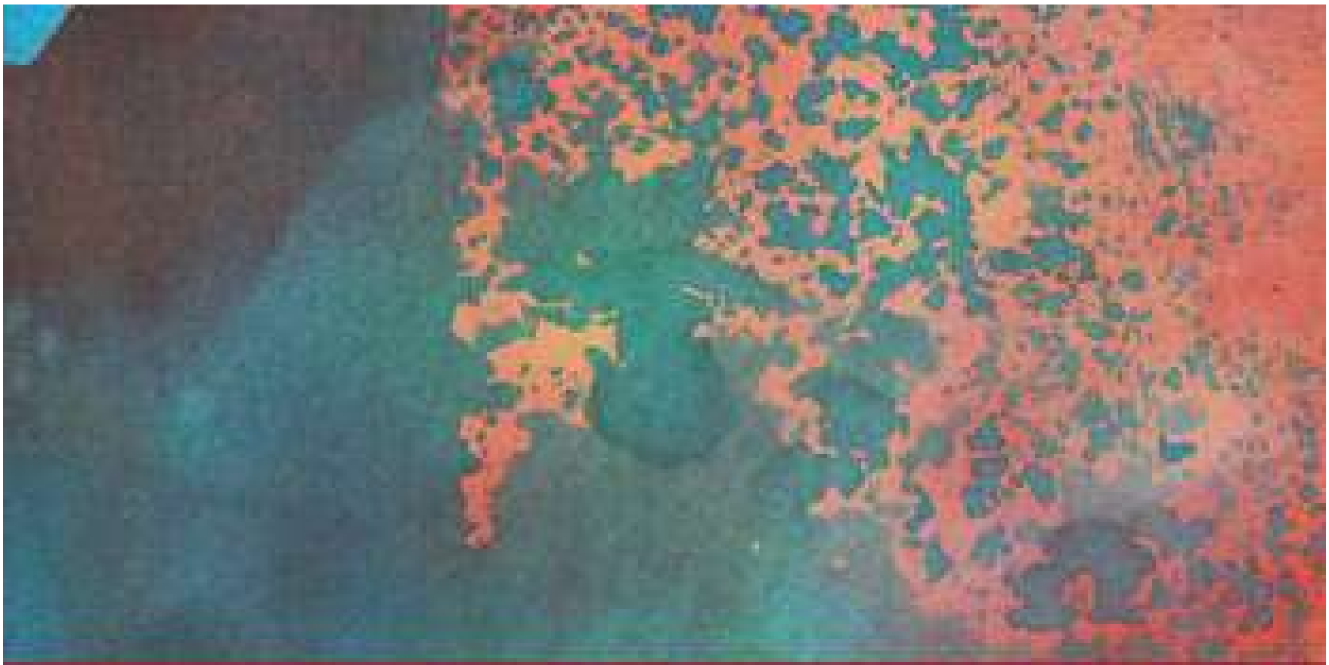

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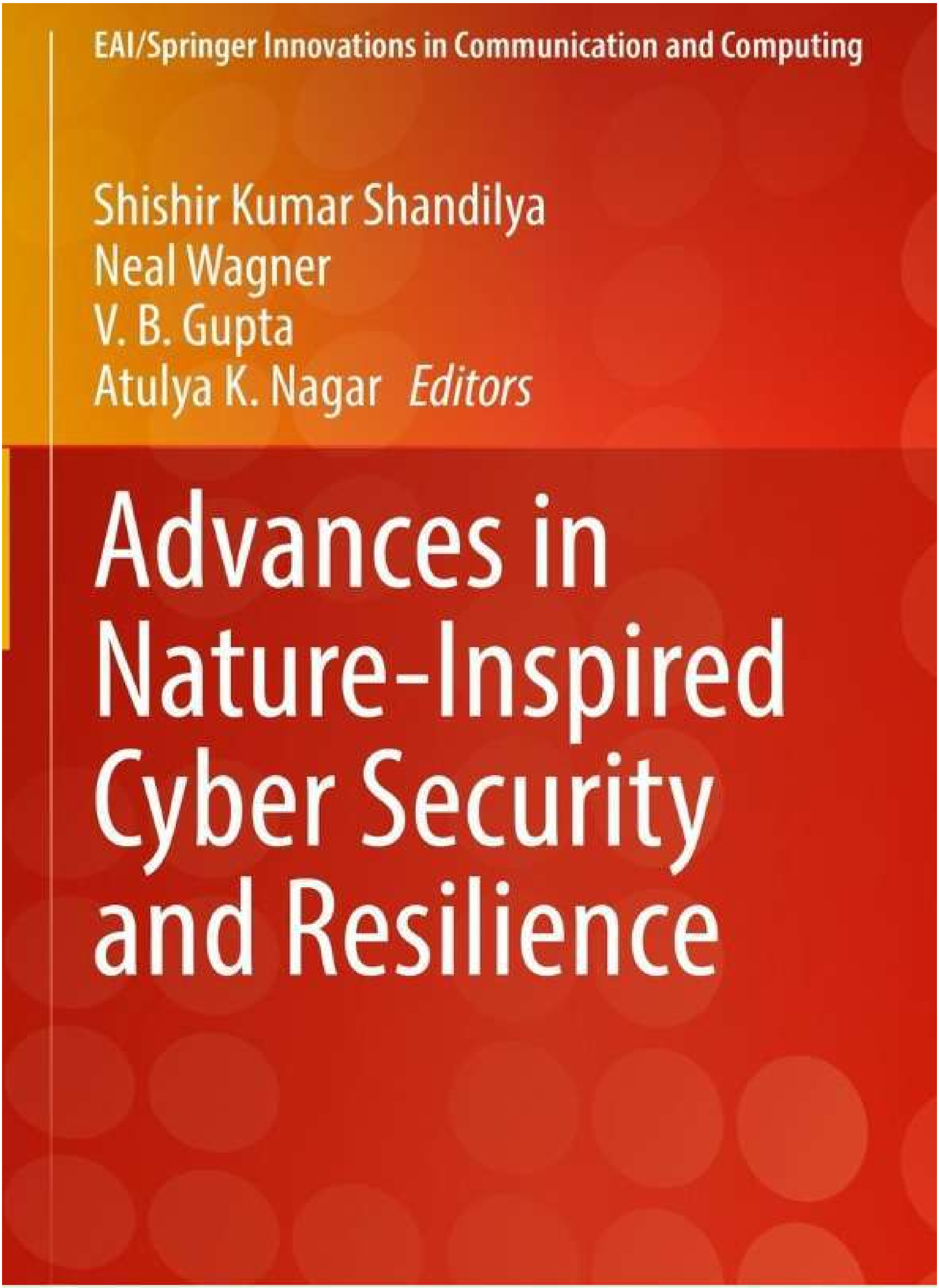

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Partha Sarathi Goswami, Tamal Chakraborty & Abir Chattopadhyay

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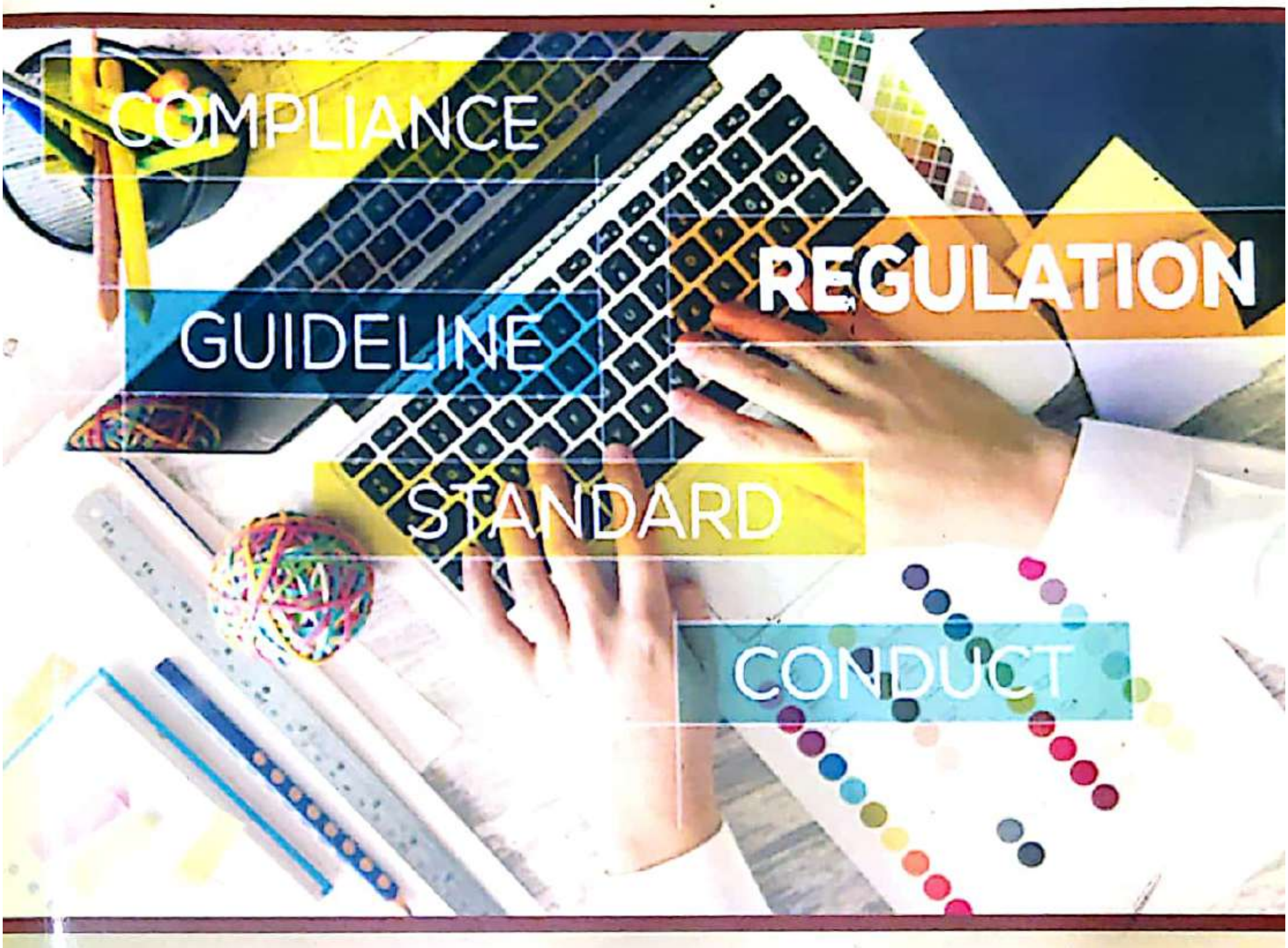

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The book explores how the human life has changed due to onset of the pandemic caused by corona virus. It scrutinises the commotion brought about by the pandemic from various perspectives. It also recommends ways for mitigating the current adversities by means of social work interventions. Individual chapters have tried to look up to noticeable and decipherable changes in our daily lives and society caused by the pandemic and link them to an appropriate social work intervention. The topics in individual chapters ranges from the psychological and emotional impact of pandemics in the life of women, to the hardships faced by different professionals whose services were integral part of civilized society. There are chapters addressing discrete topics like policing and adolescent education during pandemic. The book is intended for Social Work faculties, researchers and students in their academic pursuit as well as for Professionals working in the field of Social Work including development professionals and policy makers.

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Contents

Chapter 6

Influence of Remote Working on Employees' Life

- Rituparna Basak, Senjuti Bandyopadhyay

Outline

Covid-19 blurred the lines between personal and professional world and a rising trend of remote working has been observed. This chapter focuses on the probable impacts and outcomes of remote working. Different studies conducted on various sectors across the world where impacts were categorised into more supportive environment, effects on productivity and change in attitude towards work from home. Moreover, it was noted there were widespread mental health concerns.

1. Introduction

Started as a health crisis the corona virus (COVID – 19) pandemic becomes an unprecedented global crisis in humanitarian sector. This worldwide disaster devastated the human life in all sectors with high rates of mortality and morbidity, loss of job, halt in education, economical strain, and maintained social isolation for all over the world. This global disaster compelled people to take immediate safely measures of social distancing, mobility reduction through lockdown to reduce the virus spread without having knowledge of exact mechanism of action. The Prime Minister of India announced a nationwide lockdown on March 24 (The Hindu. 25 March 2020) for implementing an emergency safety to prevent the infection spreading. Lockdown was considered the global emergency protocol that restricted people movement. People were not allowed to leave their home except for emergency purpose. All public places were shut down, all activities except essential ones were discontinued, and travelling by all modes was suspended during the lockdown period (Economic times, 2020). In this context, all educational institutions, cinemas, museums, restaurants had been closed, public gatherings and events were cancelled, closed borders and cancelled flights from and to countries with a high level of contamination.

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Contents

Chapter 3
Social Vulnerability of Arsenic Contaminated Groundwater in the Context of Ganga-Brahmaputra-Meghna Basin: A Critical Review

Satabdi Biswas, Satiprasad Sahoo, and Anupam Debsarkar

Abstract The most alarming part of inorganic arsenic contamination is its silent killing ability which has an adverse impact on human society. Anthropogenic activities trigger threat from bio-physical to social vulnerability. The Ganga-Meghna-Brahmaputra (GMB) basin has been the worst sufferer for the last four decades. This review paper tries to focus on the impacts and consequences of arsenic calamity, assessment of the risk through Geographical Information System (GIS) and a feasible way-out involving rain water harvesting (RWH) with special reference to India. Arsenic poisoning creates a huge burden for rural people. Identification of various dimensions of arsenic coverage has been a difficult task which made GIS an important tool for the assessment of social vulnerability. However, the rural Indian mass is yet to become fully aware of the severity of the arsenic-related risk. They are still consuming the poison through drinking water for the last four decades without even knowing the treatment protocols. RWH is one of the easy way-outs to combat the situation of the arsenic risk, especially for the poor socio-economic rural households. Thus, to prevent further damages, awareness creation, proper medical care with due endeavours from national and international levels are required.

Keywords Arsenic contamination · Risk assessment · GIS · RWH

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ORIGINAL PAPER

Assessment of adoption potential of rooftop rainwater harvesting to combat water scarcity: a case study of North 24 Parganas district of West Bengal, India

Satabdi Biswas[1] · Satiprasad Sahoo[2] · Anupam Debsarkar[3] · Manoranjan Pal[4]

Received: 22 March 2021 / Accepted: 14 July 2021

Abstract

Rural households of the North 24 Parganas district, West Bengal, India, have been drinking arsenic and iron-contaminated water from shallow tube wells over nearly four decades. In the present study, an attempt is made to establish a relationship between rooftop rainwater harvesting potential and socio-economic status to combat qualitative and quantitative water stress. Multiple linear regression is applied to 923 rural household data collected through a rigorous socio-economic survey. Five variables, i.e., costly asset, less costly asset, monthly savings, use of unsafe drinking water, and less family size, are found statistically significant for the feasibility of rooftop rainwater harvesting after performing multiple linear regression. The Normalized Difference Built-up Index (NDBI) also showed increase in concrete and asphalt surfaces which also emphasizes the necessity of rainwater harvesting (RWH). Results would help local authorities to execute the RWH schemes in contaminated areas and thereby reducing the dependence on groundwater.

Keywords Contaminated drinking water · NDBI · Multiple linear regression · Rooftop rainwater harvesting

Introduction

Population growth with anthropogenic activities makes "water management" more complex. Demands of water for irrigation, industrial, domestic, and drinking and even the aquacultural needs are being met by groundwater in West Bengal, India (Alcamo et al. 2000; Central Ground Water Board or CGWB 2013). Urbanization and its consequent developmental activities have destroyed the traditional sustainable pond-based rainwater harvesting (RWH) agriculture practice and grabbed the peri-urban natural water bodies, drainage channels, or green areas, thereby decreasing the recharge zones of groundwater. Shallow tube well connected with electrified pump aggravated the unethical drafting of groundwater resulting in the development of qualitative water stress. This has pushed millions of lives at risk of an arsenic-related health emergency (Sarkar 2006; Ministry of Water Resources or MWR 2012; Banerjee and Jatav 2017). Contamination of arsenic is predominantly caused by entry of atmospheric oxygen into shallow aquifers, which oxidizes arseno-pyrite substantially (Acharyya 2002). The Ministry of Drinking Water and Sanitation or MDWS (2011) reported that the disaster of arsenic is worsening by adding of untreated sewage, industrial effluent, agricultural fertilizers, and pesticides. However, geologically, the Ganga-Meghna-Brahmaputra plain is contaminated with arsenic and iron in the intermediate aquifers up to the depth of 100 mbgl from the surface (Charlet et al. 2007). As a whole, CGWB had prepared a conceptual plan for artificial recharge in India. Out of the total of 32,87,263 km^2 of

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the country's geographical area, 9,41,541 km^2 was identified as suitable for artificial recharge of groundwater. The total quantity of surplus monsoon runoff to be recharged was worked out as 36.4 billion cubic meter (BCM) (Kumar 2013). Furthermore, CGWB (2013) identified the arsenic hotspots in 79 blocks of eight districts, including North 24 Parganas district of West Bengal. The severity already covers 72% of the country's arsenic suffering population in West Bengal (Public Health Engineering or PHED 2018). According to the Bureau of Indian Standard (BIS) (2012), more than 90% of the rural population rely on hand-based shallow tube wells for drinking purposes. Consuming arsenic-rich water for drinking and cooking purposes for prolonged time has been one of the major pathways of arsenic contamination. Agricultural workers drink arsenic-contaminated water from irrigation wells, thus getting doubly exposed both at home and workplace (Sarkar 2006). In most of the cases, the piped water supply is groundwater-based (MDWS 2011). The poisoning of arsenic is manifested through skin lesions, pigmentation, and bronzing of skin, and under extreme circumstances through cardiovascular diseases, neurological effects, chronic lung-liver-kidney diseases, diabetes mellitus, cancers of the skin, reproductive diseases, hematological disorders, low birth weight, adverse pregnancy outcomes, growth and height disorder among children, etc. (Singh et al. 2007). In West Bengal, observatory wells are being maintained by the State Water Investigation Directorate (SWID) and PHED on regular basis and they used to mark the arsenic-contaminated tube wells with a red cross. Despite knowing the fact, local people are bound to consume this contaminated water as they do not have any other alternatives (MDWS 2011). North 24 Parganas receives an average annual rainfall of 1762 mm, which in absence of proper harvesting generates huge volume of surface runoff which overflows the river banks in almost every monsoon. This extra water can be effectively used in cooking, drinking, kitchen gardening, and cattle feeding.

To date, the government is yet to provide an arsenic-free, low-cost, user-friendly system, while open disposal of arsenic mitigation filters raises the risk in multiple ways due to the ecological impact of highly toxic sludge of the filters thus necessitating the implementation of RWH as an alternative source of safe water (Sarkar 2006; Dhali et al. 2019; Bera and Das Chatterjee 2019; Kar et al. 2020; Rana and Suryanarayana 2020; Sayl et al. 2020). Many researchers used remote sensing and geographical nformation system (RS and GIS) for detecting suitable sites for RWH with artificial recharge after analyzing the status of groundwater (Ramireddy et al. 2015; Matomela et al. 2020). The contaminated water has a cascading effect that excludes the entire family from the society, as arsenicosis patients are being treated as a social stigma. Numerous patients complained of recurrence of symptoms even after completion of treatment due to re-exposure to the arsenic-contaminated water while coming back home (Sarkar 2006). Arsenicosis patients used to lose their economic productivity and their overall quality of life got deteriorated (Bhattacharya et al. 2019).

High-cost arsenic removal plants provided temporary relief but were not recommended as long-term solution (Sarkar 2006). Thus, it was to be substituted by RWH to combat the dreadful effect of arsenic contamination (MDWS 2011; Dey et al. 2014). Few researchers (Rahman et al. 2014; Amos et al. 2016) advocated for the adoption of rooftop rainwater harvesting in small or medium-scale residential units without much waiting for financial and infrastructural assistance from the government. Hence, greater attention is required to overcome the water contamination issue by adopting rooftop rainwater harvesting.

So far, none of the researchers followed *the mixed approach to explore the impact of qualitative and quantitative water stress, rainfall pattern, increase in a built-up area, and socio-economic status of rural households on the adoption of rooftop rainwater harvesting. The present study has attempted to bridge this gap and to address the pertinent socio-economic issues behind the non-adoption of rooftop rainwater harvesting by rural households in arsenic-iron contaminated areas of the district of North 24 Parganas.*

Thus, the main objectives of this work can be summarized as follows:

1. *To assess the risk associated and level of awareness of getting contaminated by polluted groundwater*
2. *To assess the feasibility of rooftop rainwater harvesting by rural households considering household size, monthly savings, use of unsafe water, roof area, costly assets, and less costly assets.*

Government initiatives

Realizing the gravity of the problem, the state government took several initiatives, such as the promulgation of acts which started with "Water Act 1988" published in the Gazette of India (1988) and setting up strategies and plans as part of water governance for control of water pollution. Subsequent initiatives are "West Bengal Groundwater Resources (management control and regulation) Act (2005)" to control the extraction of groundwater, "Municipal (Building) Rules (2007)" for making RWH mandatory in urban areas, and "Conservation and Management Rule (2010)" for protection of wetlands (PHED 2018). Further, the CGWB (2013) of India recommended both traditional and rooftop rainwater harvesting for food grain production. The Government of India developed the National Rural Drinking Water Programme (NRDWP) to serve 70 l per capita per day (lpcd) for rural households by 2022 and set a fixed goal to cover 90% of households by pipe water supply as well as decrease the use of hand pumps to less than 10% (MDWS

2011). The NRDWP promotes the conjunctive use of surface water, groundwater, and RWH. In India, as a part of constitutional provision, "water" is a state matter (http://mowr. Gov.in/water-indian-constitution) and accordingly, the state government gave priority to supply surface-based piped water schemes through "Vision 2020" (BIS 2012). An Arsenic Task Force was formed and they suggested a master plan in 2005–2006 for the entire arsenic-affected areas of West Bengal. In this master plan, they chalked out 338 groundwater-based and 12 surfaces water–based piped water supply schemes for implementation and installation of 165 arsenic removal plants (ARP) on the existing groundwater-based schemes (Bhowmick et al. 2018). The West Bengal Government installed 577 ARPs, out of which 145 (25.1%) were found in defunct condition (Hossain et al. 2006). However, the existing policies on water security do not curb down the adverse effects of using contaminated drinking water due to the following four-fold reasons.

- Firstly, contamination of drinking water was aggravated due to institutional negligence such as uncontrolled installation of private shallow tube well, unreliable supply of public stand posts, poor operation, and maintenance, mushrooming of unsafe packaged drinking water industries that do not maintain BIS level (Banerjee and Jatav 2017).
- Secondly, the ARPs were based on modern technology, which could not be operated and maintained by villagers. The filter materials needed to be changed on regular basis, but due to lack of awareness, several households used the filters for a longer period (Sarkar 2006). PHED carried out a survey at Baduria, North 24 Parganas, in 2016, which showed that people still drink contaminated water on-premises apart from having access to deep public stand-points (PHED 2018).
- Thirdly, the above policies mostly do not involve the local community in the process of water governance (Dey et al. 2014; Roy 2019). Thus, it became unpopular, e.g., arsenic removal plants at the technological park in Baruipur, South 24 Parganas, were found inoperative due to lack of awareness, willingness, and user-friendliness (CGWB 2011) Planning Commission (PC), 2007).
- Fourthly, *the acceptability of rooftop rainwater harvesting is still very low; thus, it has been a big question in water-stressed areas of the state (*UNICEF 2020*).* Furthermore, the government policies on RWH dealt only with structural issues getting confined only in the paper works. *Adoption of a centralized policy implementation system where the federal government had a monopoly over the technological know-how of the RWH further aggravated the problem, because, it certainly did not trickle down to the people living in water-contaminated areas* (Bhowmick et al. 2018).

Study area

The present study was conducted in Amdanga, Barrackpore II, Barasat II, and Basirhat I blocks of the North 24 Parganas district of West Bengal (Fig.1). Geologically the district has a high concentration of arsenic-iron in the shallow depth**.** The area has a flat topography with a gentle slope towards the south-east direction (Charlet et al. 2007). The tropical monsoon has huge reliable rain from 1295 to 1750 mm with a relative humidity of 65% on 97 average rainy days. The average range of temperature varies between 9 and 42 °C. The study area has a dichotomy of water-logging and drinking water scarcity during the rainy and dry seasons, respectively. Farmers grow different crops, i.e., three types of rice, oilseed, sugarcane, pulses, vegetables, jute, fruits, and flowers on fertile soil. According to the 2011 census, the total population of North 24 Parganas was 10,082,852 with a density of 2500 person/km^2, which was more than the district's figure (2445) and nearly 5 times higher than the country average (460 person/km^2). According to the Census of India, the level of urbanization of the district remained high at 57.6% compared to the state and the national average of 31.89 and 31.16%, respectively (https://censusindia.gov.in/pca/cdb_pca_census/houselisting-housing-wb.html). *However, the threat of arsenic covers 99.39% of the population under 253 Mouzas out of 1606 in study district* (Chatterjee et al. 2009). *However, more than 95% of the rural household relies on shallow tube wells for drinking purposes in the district* (Banerjee 2016).

Methodology

The methodologies followed in different phases of the present study are described hereunder.

Selection of study area and data collection

In the first step of the survey, CGWB Report (2013) was consulted to form the basis of the selection of representative sample blocks. CGWB identified four categories based on the "stages of groundwater." Accordingly one representative block was selected from each category of area, i.e., Category I: Safe and arsenic affected, Barasat II block; Category II: Safe and water table declining with arsenic contamination, Basirhat I block; Category III: Safe with water table declining, Amdanga; and Category IV: Semi-critical, Barrackpore II block (Table 1). After identifying blocks and then villages, habitats were selected. Habitats with wells having a high concentration[1] of arsenic and iron were identified from the chosen villages. Initially, households were asked questions to gather

[1] The arsenic and iron maximum permissible limit of 0.01 ppm and 0.3 ppm, respectively (IS 10500: 1991)

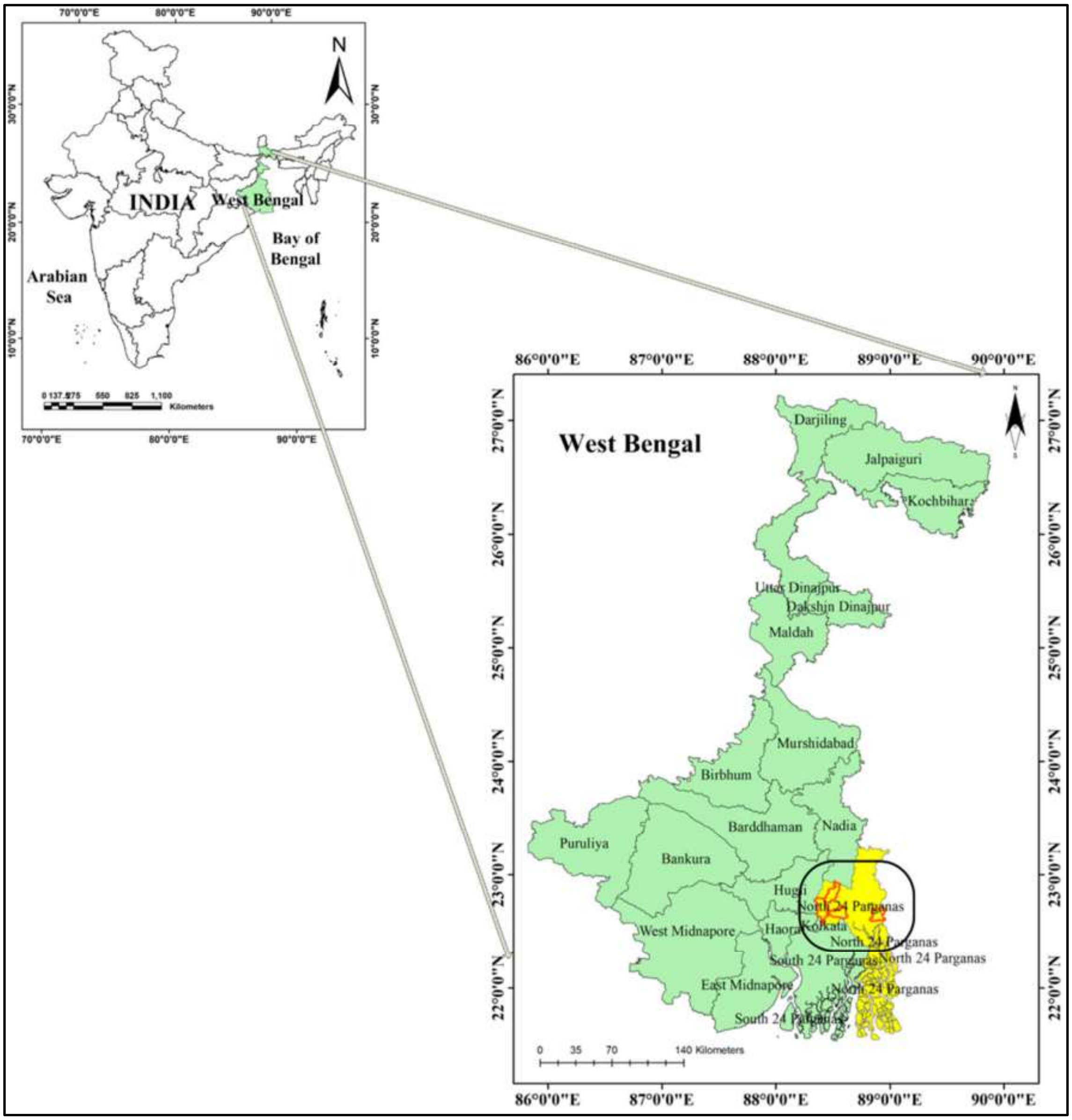

Fig. 1 Study area

Table 1 Characteristics of study area

Block	Surveyed Hhds.	Max. Conc. of As (ppm)	Max. Conc. of Fe (ppm)	Decadal variation	Popn.	Population density/ km^2	Existing water supply schemes	Characteristics
Amdanga	179	3.00	7.42	25881	191,673	1376.17	1	Safe with water table declining
Barasat II	247	2.04	5.5	31820	200,918	1761.82	8	Safe and arsenic affected
Barrackpore II	211	10.01	4.39	58344	217,171	5335.90	3	Semi-critical
Basirhat I	286	5.25	5.25	23872	171,613	1535.00	11	Safe and water table declining with arsenic contamination

Hhds. Households, *Popn.* population size, *Max. Conc.* maximum concentration, *As (ppm)* arsenic (parts per million)

Source: SWID, PHED, CGWB (2011–2017) Kolkata, Census 2011, District Statistical Handbook 2013, and Field survey (2019) information about any previous experience of water harvesting. The rooftop rainwater harvesting potential was assessed from the households' socio-economic status through a well-designed questionnaire survey. However, the first section of the questionnaire was framed to get the general information of the respondents. The water quality, quantity, choice of drinking and domestic water, and household assets were covered in the second part. The three parts of the questionnaire dealt with water-related issues, direct and indirect effects of water, awareness and willingness towards rooftop rainwater harvesting. The respondents comprised both male- and female-headed households in 32 villages of four blocks. The sample size considered for the study was 923 households (Fig. 2), which was reasonably adequate. This is because the statistical tests were carried out only in regression analysis to see the significance of the regression coefficients using the entire set of data. Degree of freedom greater that 40 is considered to be quite sufficient for this purpose.

Calculation of Normalized Difference Built-up Index

In the present study, a built-up index map was developed and multiple linear regression was carried out to explore the feasibility of rooftop rainwater harvesting.

Normalized Difference Built-up Index (NDBI) In the second phase, the Normalized Difference Built-up Index is computed to identify the hotspot areas based on the increase in concrete and asphalt surfaces with the help of the following equation (Zha et al. 2003):

$$NDBI = \frac{MIR - NIR}{MIR + NIR} \tag{1}$$

Here, *MIR* and *NIR* represent the middle infrared band and the near-infrared band, respectively. Here, we used LANDSAT 8 Operational Land Imager (OLI) with the most recent satellite imagery data of 2020. The built-up areas have a unique spectral response that is a higher reflectance in the MIR wavelength range compared to the NIR wavelength range. The NDBI values range from − 1 to + 1. A very low value of NDBI such as 0.1 and below indicates non-urban features, while high values represent impervious surfaces such as asphalt and concrete structures. It is a ratio which helps to classify the results into value-wise different ranges, e.g., high, medium, and low. It has also been profusely used in recent studies (Debusk and Hunt 2012; Choudhury et al. 2019; Malik et al. 2019).

Multiple linear regression

In the third phase, an econometric model, i.e., multiple linear regression was applied over the 923 households survey data. Initially, six binary categorical potential variables were selected to identify rainfall harvesting potential estimation from the concrete roof as "RRWH potentiality" (*Y*) among rural households in four study blocks. Six variables were considered, viz., household size, monthly savings, use of unsafe drinking water, concrete roof area, costly asset, and less costly asset. SPSS (version 9) was used for statistical analysis.

Results

Rainfall

The 45 years (1972–2017) historical rainfall data indicated that rainfall in the study area had been high during monsoon and scarce in the dry season. The average rainfall was 1719.91 mm. The average monsoon and post-monsoon rainfall were obtained as 1289.01 mm with a standard deviation of 252.12 and 205.62 mm with a standard deviation of 94.52 mm, respectively. The minimum and maximum rainfall occurring during the monsoon season have been reported as 921.03 mm and 1772.14 mm, while in the post-monsoon season, the same was recorded as 32.9 mm and 466.97, mm respectively. The average recharge by the monsoon rain was recorded at 1251.5 million-hectare meters or M ha m for four selected blocks. The rainfall distribution pattern indicates the occurrence of huge rain over a shorter time signifying a high potential for RWH in the study area. *However, rainwater mostly flows down as surface runoff and thereby gets wasted due to the absence of proper planning and lack of awareness among the study population.*

Groundwater status

All the study blocks have confined aquifer with piezometric surface groundwater level nearer to the ground level, i.e., from 5 to 12 m below ground level or mbgl. The block-wise groundwater profile is shown in Table 2.

On analysis it is found that more than 91% of the groundwater was drafted by shallow tube well and was used for irrigation purposes in Amdanga and Barasat II block. The maximum share of land is used for the cultivation of major crops like boro paddy (6605 ha), jute (3992 ha), aus paddy (1193 ha), potato (370 ha), mustard (2549 ha), and sugarcane (228 ha) in the Amdanga block. In this block, one of the most important livelihoods is pisciculture (cultivation of spawn in shallow pond locally known as "bheri"), which is supported by shallow tube wells in the dry season. This is one of the probable reasons for the decline of the piezometric surface of the water table in Amdanga block. More than 4606 ha m of potential recharge happened during monsoon, which was not enough to control the declining rate of water level. Amdanga and Basirhat I had a steady post-monsoon water decline of

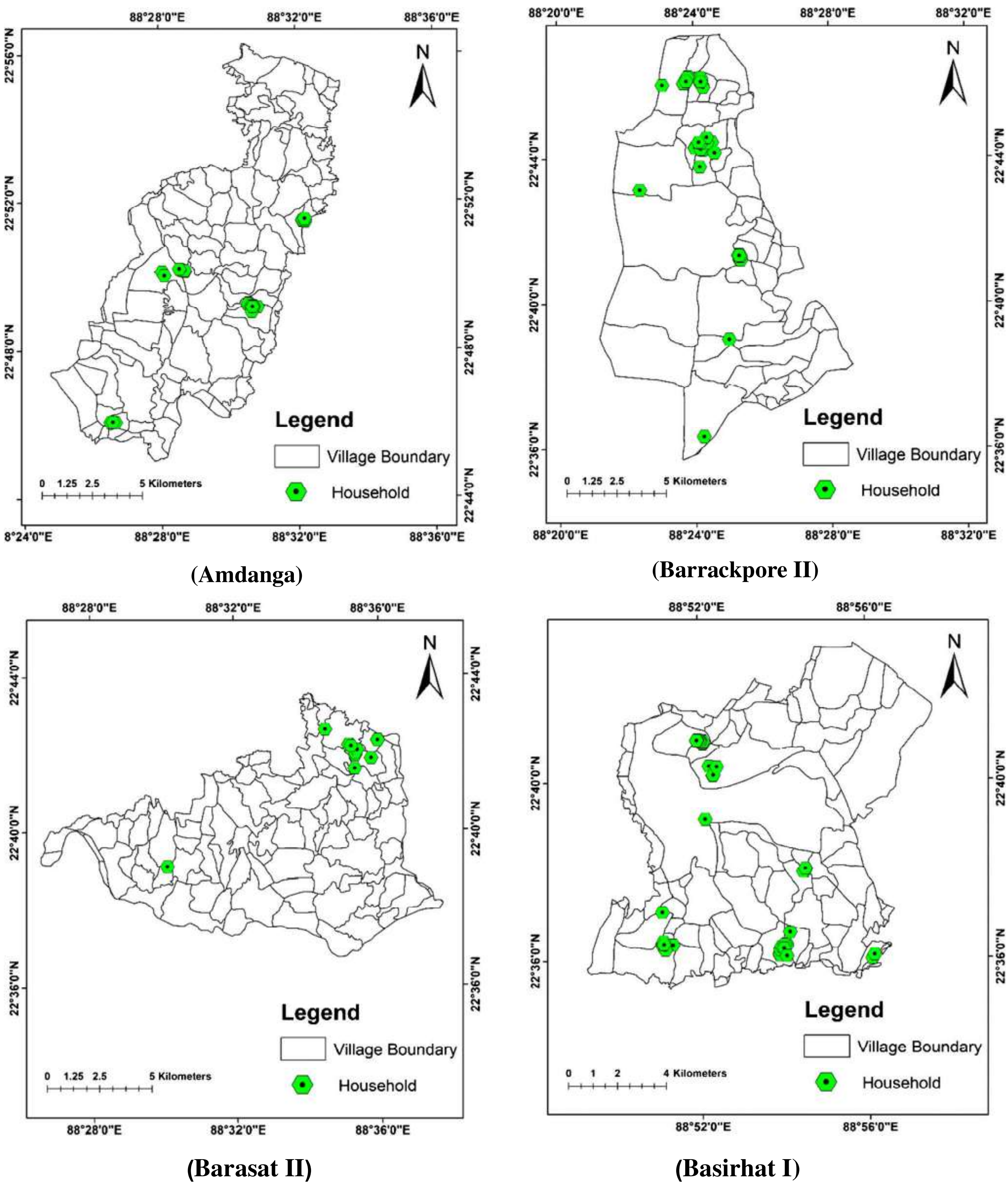

Fig. 2 Location of surveyed households with village boundary for Amdanga, Barrackpore II, Barasat II and Basirhat I blocks

2.38 and 2.14, mbgl respectively. Thus, these two blocks are categorized as “water table declining block” by CGWB. Barasat II and Basirhat I cultivate almost the same types of crops except sugarcane, i.e., aus, boro, wheat, jute, mustard, and potato (14, 2167, 262, 3124, 1437, and 194 hec and 108, 1453, 563, 2972, 741, and 115 for Barasat II and Basirhat I, respectively) with numerous shallow tube wells. Generally, jute, sugarcane (sown in March or May), and “aus” paddy

Table 2 Groundwater profile

Blocks	GW structure for irrigation		Recharge from rainfall (ha m)		Net annual GW availability (ha m)	Existing gross GW draft for (ha m)			Total draft GW (ha m)	Net GW availability for future irrigation (ha.m)	Stage of GW development in %	Net area available pisciculture (hec)
	DTW	STW	Monsoon	Non monsoon		Irrigation	Domestic	Industry				
Amdanga	30	1964	4595.9	1288.3	6393.4	3379.6	196.1	98.1	3673.8	2625.0	57.46	958
Barasat II	27	2318	4016.5	1020.7	5779.0	3813.8	200.1	100.0	4113.9	1568.6	71.19	2898
Barrackpore II	15	24	4043.8	1054.9	4702.6	348.6	2839.7	1419.8	4608.1	− 1275.0	97.99	310
Basirhat I	4	1991	4617.8	1372.0	6364.6	2871.4	308.7	154.3	3334.4	2881.4	52.39	1292

GW groundwater, *ha m* hectare meter, *hec* hectare

Source: District Statistical Handbook 2012–2013, SWID, PHED, CGWB (2011-\–2017) Kolkata

(May to June sowing period) are cultivated largely depending on pre-monsoon cyclones which are essential to grow the crops. Similarly, "boro," the second dominated category of paddy and potato (sown from October to November) depends largely on irrigation of shallow tube well. However, sugarcane takes more than 1 year to mature and thus requires groundwater for more than a year around. Surprisingly, Basirhat I drafted more water for domestic use than Barasat II. However, Barasat II block has the highest users of shallow tube well for drafting of groundwater for agricultural, pisciculture, domestic, and industrial purposes (6711.80 ha m), which became responsible for excessive lowering of groundwater table. The quantity of the net groundwater available was comparatively low for Barasat II. The Barasat II block has a more rural population than Basirhat I (188,294 compared to 150,520). Thus, Barasat II drafted more groundwater concerning the total draft than Basirhat I. The maximum depth of the groundwater level in post-monsoon was gone down by 5.44 mbgl (2017) and 5.34 mbgl (2013) in Barasat II and Amdanga blocks, respectively. The net available groundwater for future usage is estimated as 27.14%, indicating an alarming stage for Barasat II. *This block had become responsible for gradual conversion into "semi-critical stage" in terms of "groundwater development,"* whereas Barrackpore II is a highly urbanized and industrialized block of the district, which extract a major portion of groundwater for domestic (61.62%) and industrial (30.81%) purposes. Exceptionally, this block used 24 shallow tube wells for boro and jute cultivation (514 and 30 hec, respectively). *According to the CGWB report (2011), Barrackpore II was categorized as a "semi-critical" block, demanding a serious need for artificial recharge.*

Figure 3 shows the variation in yearly post-monsoon well water level, which was rapidly declining compared to pre-monsoon level overtime for all four blocks. The average declining rate of well water over the study period (i.e., 2011 to 2017) ranged from 1.99 to 2.98 m though the average monsoon and non-monsoon recharge happened by rain, river, and floodwater. However, as few wells got dry in between, the data pertaining to depth of groundwater table were absent in Fig. 3 which were revived subsequently. It further indicates an increase in the over-drafting of groundwater with time. Except for Barrackpore II, the remaining three blocks were categorized as "safe" from the viewpoint of future drafting in terms of quantity but not in terms of quality of water.

The quality of well water was largely degraded due to the presence of arsenic in the shallow depth (Planning Commission or PC 2007). In terms of the listed standard water quality parameters, arsenic and iron were the matter of real concern for the study area. The pH level of all the wells of four blocks fluctuated marginally over the period 2001–2017 during both pre-monsoon and post-monsoon seasons. It had been within the range specified by IS 10500-2012 (i.e., for pH, it is

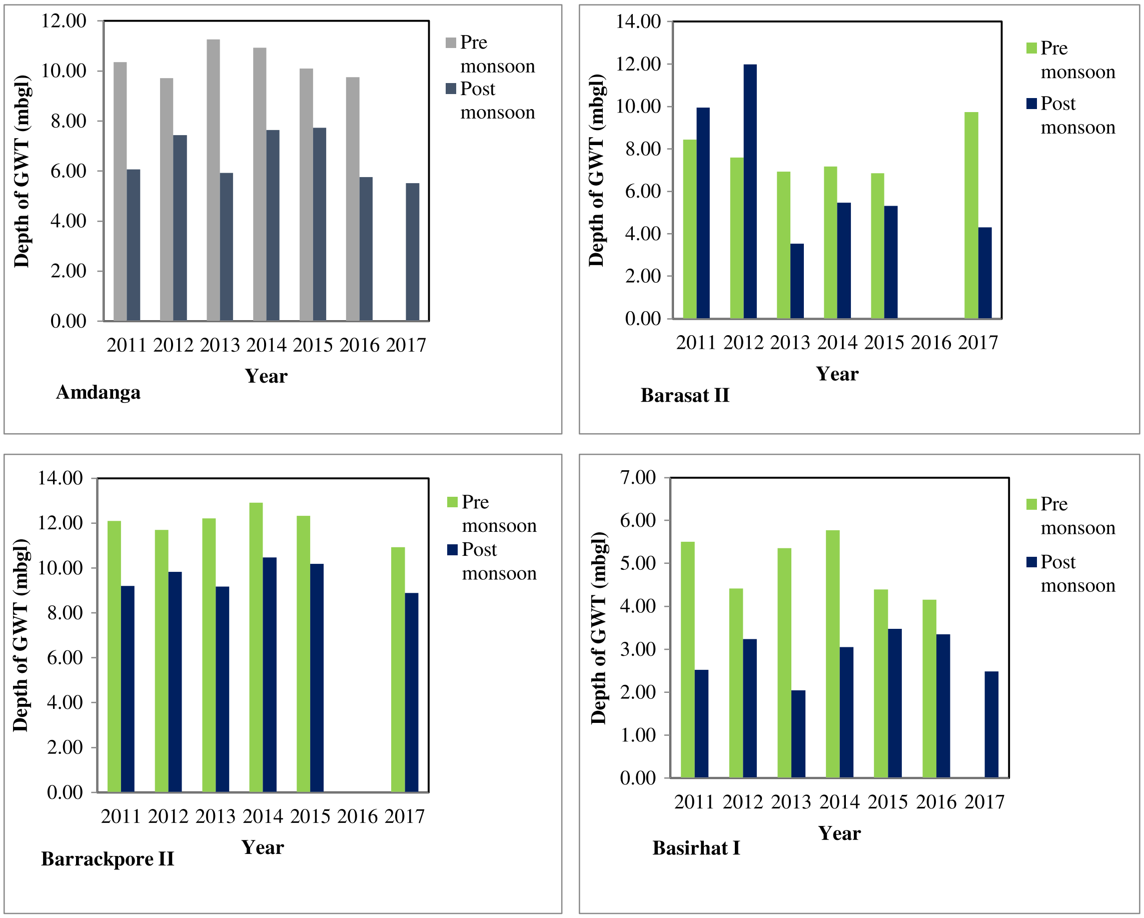

Fig. 3 **Pre- and post-monsoon water level of Amdanga, Barasat II, Barrackpore II, and Basirhat I blocks.** Source: SWID, PHED, CGWB (2011–2017)

between 6.5 and 8.5) but on a higher side especially in post-monsoon samples. In the case of arsenic and iron, all blocks had a high concentration of arsenic (> 0.01 mg/l) and iron (> 0.1 mg/l) as specified in IS 10500-2012, imposing a real threat (Table 3). *Barasat II had the highest concentration of arsenic, i.e., 0.95 mg/l, followed by Basirhat I and Barrackpore II having 0.53 and 0.13 mg/l, respectively*. There was a direct relationship between arsenic and iron in the post-monsoon season. The highest percentage of the arsenic-affected population was found in Amdanga (96.53%), followed by Barasat II (19.32%), Barrackpore II (17.15%), and Basirhat I (6.04%), respectively (Fig. 4). The first shallow aquifer was found arsenic contaminated in the case of all study blocks except the Barrackpore II, which was contaminated in both the 1st and 2nd shallow aquifers. Most of the contaminated shallow tubewells were found in Barrackpore II. Four villages of this block are still at risk. According to PHED, still, no piped water supply schemes is existing in the affected villages of Barrackpore II, Basirhat I, and Barasat II blocks. The CGWB suggested installing 9 tube wells to serve the villagers of Barrackpore II. *However, Amdanga had only 1* piped water supply scheme *whereas 8 and 11* piped water supply schemes

Table 3 Qualitative risk of groundwater

Blocks	Total TWs (PHED)	% of TWs have As in mg/l			Population in risk, 2011	% of affected population
		(> 0.01–< 0.05)	(> 0.05)	> 0.01		
Amdanga	1404	27.78	9.33	37.11	185014	96.53%
Barasat II	1147	26.94	15.87	42.81	38827	19.32%
Barrackpore II	951	65.51	0.42	65.93	37234	17.15%
Basirhat I	1326	12.37	7.62	19.99	10365	6.04%

Source: SWID, PHED, CGWB (2011–2017) Kolkata, Census of India 2011 part XIIA

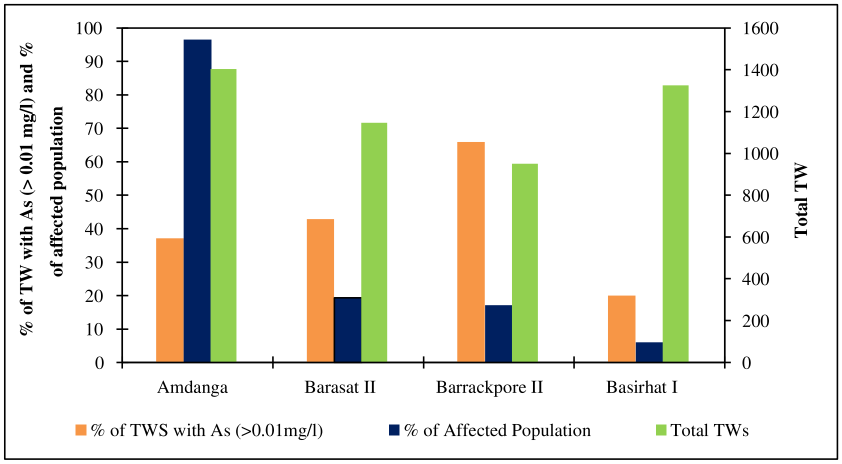

Fig. 4 Percentage of arsenic affected people with tube wells

were in operation for Barasat II and Basirhat I blocks, respectively, to combat the arsenic contamination. PHED mostly caters groundwater to the tank-based, piped water supply schemes in the arsenic-contaminated areas of the study blocks excepting Barrackpore II, which had both surface and groundwater-based supply.

Normalized Difference Built-up Index map

The Normalized Difference Built-up Index map was developed to identify the extent of increase in concrete and asphalt zone (Fig. 5). It included the built-up area in the form of buildings and pavements, which represents the extent of urbanization. The western portion of the district already experienced huge urbanization, i.e., Barrackpore II, Barasat II, and partly Amdanga. *The northern portion of Amdanga, the western part of Barasat II, the north to the eastern stretch of the Barrackpore II, and the entire southern section of Basirhat I block were marked as hotspot zones in terms of increase concrete and asphalt.*

Socio-economic study

Decision on the installation of RRWH gadgets does not only depend on physical characteristics but also on socio-economic features. Table 4 presents the salient socio-economic variables considered to ascertain the feasibility of RRWH from the concrete roof. It was difficult to get exact data about income, savings, availability of homestead land, and roof area at the individual level. Generally, respondents provided necessary data without a satisfactory degree of sanguinity. In the present study, the response of rural households in regard of possession of costly assets (viz., cell phone, television, television with cable connection, refrigerator, computer, car/two-wheeler, and domestic water filter) was sought for to identify the higher income group. The overall economic status of the surveyed households was not good. The average monthly income was $ 77.66 (INR 5500 per month). Out of the surveyed households, 38% was in $ 70.60 (INR 5000) per month slab, 41% was in the $ 70.60 to 141.20 (INR 5,001–10,000), and 20.9% was more than $141.20 (INR 10,000) per month slab. As per the survey, 57% of the households were found educated[2]. However, we excluded 0–6-year-old children from education criteria (Table 4).

However, variables, viz., own tube well, shallow tube well, submersible pump, banned tube well, and private packaged water having very low frequency among households, were indirectly correlated with rooftop rainwater harvesting and were clubbed together as "use of unsafe drinking water" (X_3). Similarly, television with cable connection, car, bike, computer, refrigerator, and modern domestic water filter were clubbed together as costly asset (X_5) and cycle, radio/tape, television, and phone are considered as a less costly asset (X_6). The recent policy of the central and state governments about to provide BPL (below poverty level) households a concrete roof gradually by two schemes, i.e., "Pradhan Mantri Abas Yojana" and "Nijo Griho Nijo Abas," respectively. Thus, we considered concrete roofs for our study (X_4). Only 19.4% had livestock among which 55.3% required almost 25 l water per day (lpcd). More than 40% of households temporarily harvested rainwater in small pots but not on regular basis.

Multiple linear regression analysis

In the multiple linear regression, basically, we tried to assess a single response of predicted variable (*Y*), which depends linearly on six important key predictor variables.

The equation of multiple linear regression is

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon \quad (1)$$

[2] Any person who studied at least up to Class V standard considered as literate.

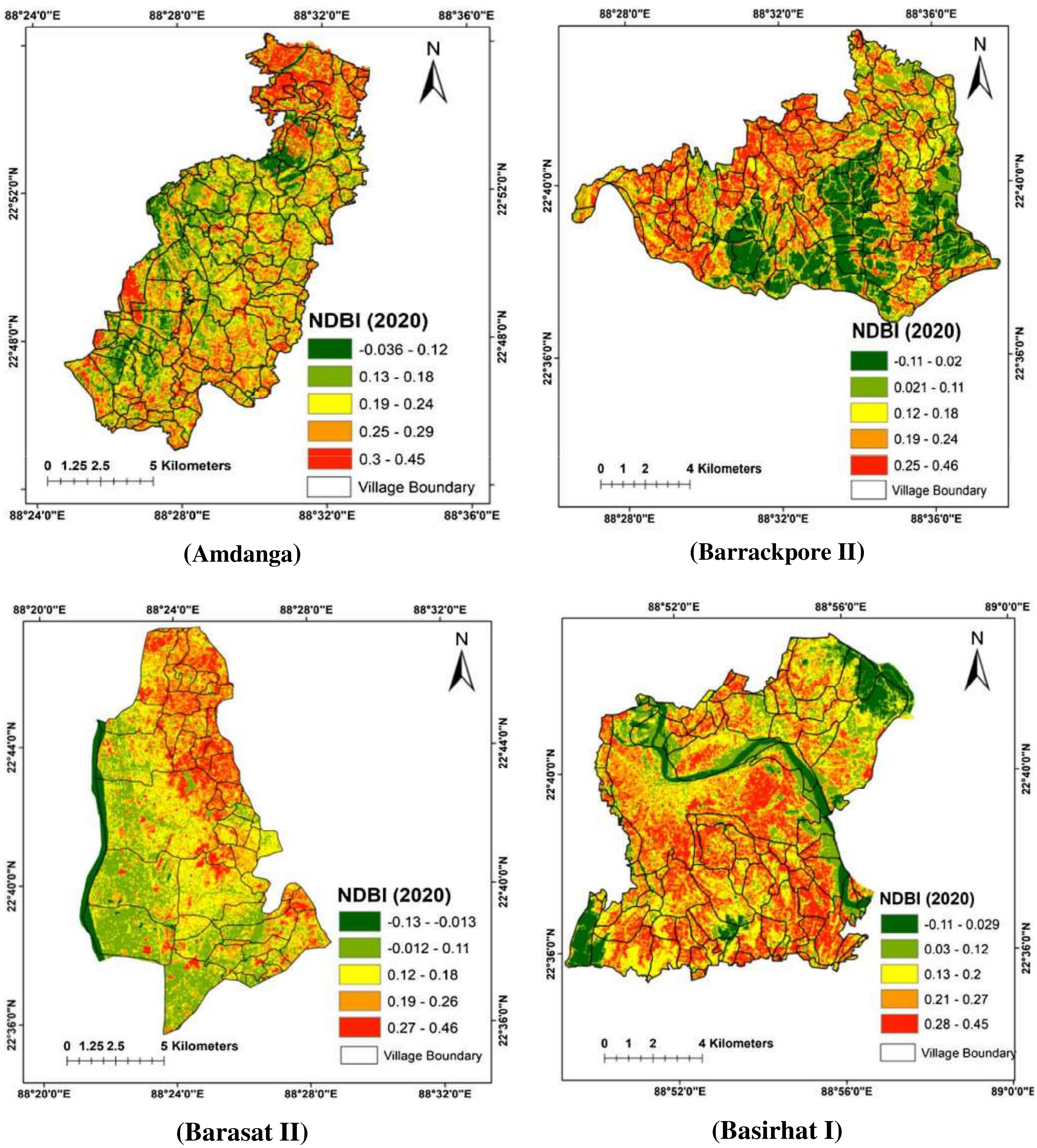

Fig. 5 Normalized Difference Built-up Index map: Amdanga, Barasat II, Barrackpore II, and Basirhat I

where,

Predicted variable, Y = "RRWH potentiality"

X_1 = family size, X_2 = monthly savings, X_3 = use of unsafe drinking water, X_4 = concrete roof area, X_5 = costly asset, X_6 = less costly asset, ϵ = error term, and β_i = slope coefficient associated with the predictor X_i for i = 1, 2, …, 6.

As shown in the above formulation, all the six regressors have been used to arrive at the result. Other variables depicted in Table 4 were not taken in the regression analysis as these variables did not have any significant contribution. The multiple linear regression was carried out to see the effect of the explanatory variables on the "RRWH potentiality." RRWH

Table 4 Key variables of socio-economic study

Variables	Category	Percentage
Use of unsafe drinking water	Yes	43
Adequacy of supplied water	Yes	82.8
Education level of the respondent	Up to class V	57.0
Previous experience of water harvesting	Yes	40
Family size	1 to 4	53.5
	5 to 10	43.9
	11 and more	2.6
Monthly income	Up to 5000	38
	5001 to 10000	41
	10001 and more	21
Monthly saving	Yes	24
Ownership of house	Yes	94.9
Homestead land	Yes	97.4
Concrete roof area up to 37.16 m^2 (400 ft^2)	Yes	91.2
Water collecting time	More than 20 min	71.3
Livestock water demand	Up to 25 l	55.3
Costly asset	Television with cable connection, car, bike, computer, refrigerator, and modern domestic water filter	76.3
Less costly asset	Cycle, radio/tape, television, phone, etc.	70.5

Source: Primary data (2019)

potentiality was calculated by a standard formula adopted by the Central Public Works Department (CPWD2002) to predict "RRWH potentiality" per annum (Y).

RRH potentiality = Roof area x annual rainfall (mm) x coefficient of the concrete roof.

= household roof area (m^2) x 1.6m (i.e., 1600 mm) x 0.85.

The roof area was taken as household-wise individual roof, annual rainfall taken into consideration with an average rainfall of North 24 Parganas, and coefficient of concrete roof taken 0.85 as standard.

Dependent variable (Y)= "RRH potentiality", * Significant at 5% and ** significant at 1%

Family size (X_1): up to 4 members = 0, more = 1; savings (X_2): up to Rs. 10,000 = 0, more = 1; sources of unsafe water (X_3): yes = 1, no = 0; roof area (X_4): up to 400 m^2 = 1401 to 1500 m^2 = 2; costly asset (X_5): high = 0, low = 1; cheap asset (X_6): low asset = 0, high asset = 1

The result of the multiple linear regression (Table 5) shows that all variables, except roof area, have a significant effect on "RRWH potentiality." Also, all the variables, except family size, have a positive effect. *Thus, the effects are in the expected directions. Family size, monthly savings, and costly assets have significance at 1% level. The use of unsafe drinking water and less costly asset have a significant effect at 5% level.* The rooftop rainwater harvesting potentiality, as

Table 5 Result of multiple linear regression of RRH potentiality on the related independent socio-economic variables of the households

	Coefficients	Std. error	t	Sig.
Family size (X_1)	− 66381.6	17287.5	− 3.840	0.000**
Monthly savings (X_2)	251173.5	30161.5	8.328	0.000**
Use of unsafe drinking water (X_3)	37873.0	17651.4	2.146	0.032*
Roof area (X_4)	14827.1	31001.7	0.478	0.633
Costly asset (X_5)	92227.5	17269.1	5.341	0.000**
Less costly asset (X_6)	42128.6	17718.1	2.378	0.018*
R^2 = 0.135, F = 23.77				

expected, was less acceptable to the households whose family size was bigger. One of the key reasons behind this was that most of the residents were poor and per capita income decreased as family size increased. Naturally, with the increased family size, respondents were not interested to adopt rooftop rainwater harvesting. Most of them used tube well water, submersible pump water, or well water (89.1%) as a source of unsafe drinking water. However, irrespective of their economic standing, they consumed contaminated groundwater with the assumption that groundwater was safer than surface water or roof water.

The respondents were not aware of the adverse impact of drinking contaminated water and hence could not relate skin disorders with arsenic contamination. Though 72.7% of the respondents were found aware of arsenic contamination, they were reluctant towards adopting RRWH. Another key variable, i.e., "unsafe drinking water" indicated the positive inclination towards the RRWH. It implied the higher the risk of drinking unsafe water, the higher would be the probability of an increase in potential harvested rainfall from the concrete roof. Of the surveyed households of Amdanga and Basirhat I blocks, 11.2% reported that broken tube wells were not repaired even for more than 1 year. Some existing ponds had been turned into dumping grounds. Nearly 14% of the surveyed households had ponds (129 out of 923 households), whereas 15.9% of them used the pond for domestic purposes. Of the respondents, 20.3% knew that they had been suffering from arsenic-related skin disorders. Sometimes they were well aware of the contamination of arsenic, but *few of them kept on consuming unsafe water even from tube wells which were marked as banned*.

The section of the households, who can afford, are expected to opt for the adoption of rooftop rainwater harvesting. Wealthy households had adequate roof area, i.e., above 400 m^2, for harvesting rainwater, and 53.6% of these wealthy households had sufficient infrastructural facility, i.e., homestead land, own house, and water tank. Also, despite having previous experiences of collecting rainwater, they did not practice on a regular basis. Above 97% of households had 500-m^2 homestead land. Surprisingly, the roof area did not have significant impact on the potential of rooftop rainwater harvesting. *The households that had large roof areas were not so much interested in rooftop rainwater harvesting probably because they were not adversely affected by arsenic.* Of the respondents, 82.8% complained about the inadequacy of water during summer as the water level went down. Thus, they felt arsenic contamination was not at all a serious issue to reckon with. Some households did not think that so-called skin diseases are associated with contaminated water. About 55% of households installed private shallow tube wells in their residential areas and were considered as "safe." Another 4.4% installed a motor pump for extracting groundwater for domestic purposes. When the respondents were asked about their perception of drinking harvested water, the majority of the responses were not in the favor of harvested drinking water because of social and mental taboos. As a whole, the model was very much successful in predicting the "RRWH potentiality."

Water-borne diseases are widespread in the area (Table 6). *Unsafe drinking water, possibly contaminated by arsenic and iron, are thought to be the prime reason for these diseases*. At the same time, consuming contaminated water implied an issue of governmental negligence. The water-related expenses depend on sources of water, and family size, irrespective of the income of the household.

As an example, 11.43% of households bought private packaged water *at the rate of 20 rupees for a 20-l water jar and these bottled waters did not maintain the standard guideline*. Among them, 6.02% belonged to the lower economic class. Almost 98.2% of the surveyed population complained that mosquito biting and water logging were regular phenomena. The one-time individual expenditure for the installation of rooftop rainwater harvesting was $ 1049.41 (INR 74,320) for approximately 37.16 m^2 of roof area. It was reasonably affordable for above poverty level (APL) section considering the one-time investment for the installation of rooftop rainwater harvesting and its associated long-time benefit, as the chances of having water risk and diseases would get largely minimized.

Discussion

Arsenic problem is a very complex developmental issue (Sarkar 2006). MDWS (2011) found 32% of rich households had a pipeline connection for drinking water in their own premises from PHED, whereas only 1% of the poorest households availed this facility. Groundwater has been a community resource but still seemed to be an individual property and thus exploited disproportionately (MWR 2012). The increasing trend was found in the case of boro, jute, potato, pulses, and oilseed cultivation for the district except for aus paddy from 2014 to 2015 at the cost of deeper drilling for groundwater which increased the arsenic level in the topsoil region (Rahman and Hasegawa 2011; Biswas 2020). There had been an exceptional 22.59% increase in the built-up area for the western part of the district due to the rapid mushrooming of small-scale industries.

Charlet et al. *(2007)* conducted a study in Chakdaha, North 24 Parganas, and found that the high level of arsenic vertically transferred from STW to 150 m DTW, which was previously marked as "arsenic-free" wells. These deep tube wells were extensively used for supply of drinking water to the respective communities and thus became sources of widespread poisoning for the local population. Furthermore, the portion of affected population with a poor socio-economic background

Table 6 Water-related diseases of households

Diseases	% of the surveyed population in last 3 years
Arsenic-related diseases	20.3
Frequent diarrhea and dysentery	16.5
Frequent jaundice and typhoid	14.5
Gastrointestinal problems	49.2
Vector-borne diseases	7.48

Source: field data (2019)

could not afford taking food rich in protein, folate, and vitamin B. Thus, arsenic is not excreted from the human body and causes oxidative damage, increased skin lesions, and other malignant diseases (Singh et al. 2007; PHED 2018; Roy 2019). Sarkar (2018) mentioned that the supply of safe and adequate water to the people is the primary responsibility of the government as households had been paying requisite tax.

Thus, the problem demands a well-planned solution by incorporating policy guidelines integrating the combined effort of government and non-governmental agencies. Strategies are to be developed involving multiple steps like promoting household filter, community-based filter, slow sand filter, construction of dug wells, introducing rainwater harvesting, and supplying river water and deep well water after filtration. Immediate need is to restrict unsustainable agricultural policy, inequity, and top-down approach in framing to mitigate arsenic-iron pollution (Sarkar 2006). Sarkar (2006) suggested following remedial measures which were feasible and ecologically appropriate for arsenic affected rural households: (i) introduction of river water supply schemes through pipeline to the villages adjacent to the river after treating microbiological and chemical contaminants. But it needed high capital investment and political willingness; (ii) excavation of deep bore well to supply arsenic-free water but there was a possibility of leaching of arsenic from higher arsenic-contaminated layer to safer layer lying below; (iii) supply of arsenic-safe dug well water as it is located above the arsenic contaminated aquifers. However, sometimes it has bad odor and chances of occurrence of water borne diseases due to seepage of sewage or contaminated surface water; (iv) promotion of RWH, as a viable alternative solution for arsenic-affected areas belonging to potential rainfall zone. A major technical disadvantage of RWH in rural Bengal was the roof materials (straw, asbestos, roof tiles other than concrete) which could not yield sufficient quantity of harvested water. Dhere and Dhere (2016) estimated that if half of the India's average rainfall (1170 mm) would be captured by each village (having nearly average 1.12 hectare of land), then near about 6.57 million liters of rainwater could be harvested. As an example, 1.86 million liters of potential rooftop rain water could be harvested from 46 equipped houses in the Revengaon village, Maharashtra. This harvested rainwater could mitigate the water demand of 1199 persons for 78 days or 255 persons for 1 year at rate of 22.4 lpcd.

In our study, we found, irrespective of economic class and educational status, the respondents had a serious dearth of knowledge about rooftop rainwater harvesting yet to be implemented successfully by rural households. Dave (2016) stated common people did not understand the issue of "safe water"; thus, they did not fight for safe water as a right. It was worthy to mention that there was a wide difference between the data catered by the government and non-governmental agencies regarding arsenic and iron contamination and number of private shallow tube wells (Bhattacharya et al. 2019).

Kar et al. (2020) found that the relationship between rWH and socio-economy was more complex as it depended on the mindset of the locals. Therefore, special attention is needed to combat the arsenic contamination by transferring traditional knowledge to the rural households as mitigation cannot be effectively achieved by mere enactment of laws. The villagers needed to be convinced with scientific reality about manifold adverse effects of unsafe water and to revive the traditional RWH to prevent arsenic exposure (Sarkar 2006). Getting people to participate in any social development program is not an easy task. Public participation means their overall involvement in the processes such as fixing up priorities, taking initiatives, carrying out the contribution, taking ideas, labor, and time. The harvested water satisfies not only the domestic water demand but also for agriculture purposes (Dhere and Dhere 2016). Good governance should include intensive participation of communities, transparency of water quality, and accountability to the society for the sustainability of water for all. Thus, there was a need to give continuous professional support to the Gram Panchayat (MDWS 2011). Few researchers suggested public investment, good education, and social and agricultural capital as some effective means of improving the adoption of RWH (Below et al. 2012; Chhetri et al. 2017). MWR (2012) emphasized on the need to introduce improved technologies of water use, increase in the number of artificial recharging projects, and granting incentives for the community to encourage conservation of the local aquifers. Hossain et al. (2006) conducted a comparative study about ARPs in two different blocks (Domkol in Murshidabad district, Swarupnagar and Deganga in North 24 Parganas), which showed that 39 (80%), 38 (95%), and 14 (87.5%) ARPs were not useful. After a field survey, it was found that 44.2% of the ARP-treated water turned into yellow/red/reddish-brown color and 5.8% produced bad odor making treated water unacceptable to the villagers. The results showed that 95% and 80% of the tube wells connected with ARPs in Swarupnagar and Domkol were found to have arsenic concentration above 50 μg/l. The problem of arsenic was yet to be addressed with due importance especially for the rural areas with low-cost technology (Singh et al. 2007). RWH has been made mandatory in urban areas by the state government.[3]

Authorities might expect that in rural areas, primarily due to the availability of ample space for pond and other water bodies to collect rainwater naturally, it would be relatively easier to popularize RWH. In our study, we find land acquisition for the construction of water bodies and engineering structures for recharge have been big challenges for the achievement of the stated objective. Also, if the implementation of rooftop rainwater harvesting schemes was not made mandatory in a true sense, it would depend a lot on an individual household decision and the purpose would not be served. Thus, supply of safe water became a choice-specific decision of common people. Instead of this, water has been treated as a public good without any kind of imposition of water tax in West Bengal. Hence, water management practices were given less importance and people were coping with water shortage both in terms of quality and quantity. Thus, there was a serious need for RWH in Barrackpore II, Barasat II, Basirhat I, and Amdanga blocks.

Policy and recommendation

Realizing the severity of the problem, 100 billion INR has been allocated to be spent for the "National Rural Drinking Water Programme" by the Government of India in the 2019 budget and 6.15 billion INR has been allocated by the West Bengal Government for the same (Kanadje 2019). In other words, 0.29% and 0.25% of the financial budget have been allocated for arsenic-free safe water by central and state governments, respectively. Also, the Ministry of Housing and Urban Affairs allocated 417.65 billion INR in the FY 2018–2019 for the building of houses for people (PSR 2018).

Our recommendation lies in the development of a *package essential for coalescing the existing schemes like "Jal Dharo Jal Bharo" (water conservation scheme) and "Pradhan Mantri Abas Yojana" into a single scheme to offer incentives towards development of rooftop rainwater harvesting schemes for the households*. Existing acts might have to be modified accordingly (MWR 2012). Re-excavation and development of new ponds for RWH under the NREGA[4] scheme would help for the financial empowerment of rural people in the long run. These three projects have been at present running side by side by the state and the central governments, respectively. Finally, along with these schemes, conduction of the social awareness program along with technological know-how of rooftop rainwater harvesting on the importance of water conservation from grass root level is required. Therefore, water should be preferably managed as a community resource under the public trust doctrine of state government.

[3] Installation of RRWH system has been made mandatory for the Municipal area as per Rule 71 of the West Bengal Municipal (Building) Rules, (GWB. 2007)

[4] (NREGA) National Rural Employment Guarantee Act, 2005. This is a social security scheme of the Government of India and it provides employment of the rural people of India.

Conclusion

Despite plenty of rainfall, the water table has been gradually declining. Also, the Normalized Difference Built-up Index map indicated an increase in the share of concrete and asphalt surface, liable for offering blockage to the natural recharge process. Despite the prevalence of water contamination, rural people have not been adopting rooftop rainwater harvesting and the reasons behind this reluctance in adopting rooftop rainwater harvesting have been investigated. We further estimated the rainfall harvesting potential to combat qualitative water stress by multiple linear regression. The result found five variables, i.e., unsafe drinking water, monthly savings, costly asset, less costly asset, and household size, are statistically significant. The use of unsafe contaminated water is found to be the key variable. Hence, it might be one key inclination towards rooftop rainwater harvesting. The cumulative effect of unsafe drinking water on households has been neglected continuously. Thus, the results of multiple linear regression analysis showed that the selected socio-economic variables were reasonably effective to explain the feasibility of rooftop rainwater harvesting. *Arsenic is difficult to be removed overnight, but it depends much on the social attitude and acceptability of RWH. It is expected that the findings of the paper would help in designing sustainable planning and its necessary modifications in the management of RWH policies by the local authorities.*

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Supervision and overall guidance: Dr. Anupam Debsarkar
Statistical application: Dr. Manoranjan Pal

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication All the authors give consent for the publication.

Conflicts of interest The authors declare that there is no conflict of interest.

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Advances in Water Resources Management for Sustainable Use

Springer

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Chapter 7
Socio-economic Assessment of Arsenic and Iron Contamination of Groundwater and Feasibility of Rainwater Harvesting (RWH): A Case Study of Amdanga Block, North 24 Parganas, West Bengal, India

Satabdi Biswas and Anupam Debsarkar

Introduction

'Water' is defined as a colourless, odourless and tasteless fugitive resource. This flowing agent passes through space, time and landscape to society and the economy of a nation [1]. Uncontrolled population pressure on continuously changing land-use patterns further changes the environment. Water is not the only measure of development; it also helps indirectly to reduce poverty. Our lifestyle has become water-centric and sometimes water is treated as a luxury good. The human footprint on the water creates some issues like water crises, water tensions, conflict and ultimately water scarcity. In developing countries increasing the trend of water demand makes the situation more complicated. Worldwide, 780 million peoples are deprived of accessing improved drinking water [2]. As per this report, worldwide 525,000 child deaths happen each year due to diarrhoea and another 443 million school day losses happen only due to water-related illness. Thus, the quality of water is a matter of safety of life. Water contamination due to Arsenic (As), Fluoride (F) and Iron (Fe) is a very common inorganic threat to humans in the present world. Arsenic contamination is found in both developed and developing countries like Argentina, Bangladesh, Cambodia, Chile, China, Hungary, India, Mexico, Nepal, Pakistan, Romania, the United States of America, Vietnam, etc. Acute health hazards took place for all types of contamination. Life and livelihood

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Ayad M. Fadhil Al-Quraishi
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Environmental Degradation in Asia

Land Degradation, Environmental Contamination, and Human Activities

Springer

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Preface

This volume came into the mind of the editors to help Asian countries in taking the necessary steps to protect the environment against human-induced degradation. As a result, the book titled "Environmental Degradation in Asia: Land Degradation, Environmental Contamination, and Human Activities" will assist Asian countries in meeting the SDGs connected to the environment. The volume consists of four parts and 29 chapters written by more than 70 authors from different Asian countries. The four parts cover (i) Land Degradation in eight chapters, (ii) Part II: Soil Degradation and Environmental Contamination in eight, (iii) Part III: Climate Change and Human Activities in nine chapters, and (iv) Part IV: Drought, Vegetation Degradation in four chapters.

Chapter 1 is titled "Land Use Land Cover Mapping in Support of Land Degradation Mapping Using Tree-Based Classifiers". The authors developed land cover mapping of the study area of Shiraz using Landsat-8 and Sentinel-2A satellite images based on several supervised machine learning classifiers, including a complex tree, a medium tree, a simple tree, and a fine gaussian SVM, developed in the MATLAB programming language. The OA and KI statistical indices are used to evaluate the obtained classification results. Additionally, the results are compared with the previously mentioned supervised methods of tree-based algorithms against the fine Gaussian SVM method for Landsat-8 and Sentinel-2A satellite image classification.

Chapter 2 is titled "Detection of Anthropogenic and Environmental Degradation in Mongolia Using Multi-Sources Remotely Sensed Time Series Data and Machine Learning Techniques". The chapter presents the detected environmental change and land degradation of Mongolia for the period 1990-2019 using multi-sources RS time-series data. The impacts of several factors are investigated including (1) climate factor impact on land degradation and environmental change, (2) impact of land cover change on land degradation and environmental change, (3) impact of vegetation index on land degradation and environmental change, and (4) impact of drought on land degradation and environmental change.

Chapter 3 is titled "Assessment of Land Degradation Vulnerability Using GIS-Based Multicriteria Decision Analysis in Zakho District, Kurdistan Region of Iraq". The authors evaluate land degradation vulnerability and identify vulnerable zones in the Zakho district in the Kurdistan Region of Iraq using GIS, RS, and a multicriteria decision analysis approach. They analyze the susceptibility of land degradation in the study area using a variety of physical and socio-economic criteria.

Chapter 4 is titled "Evaluation of Geo-hazard Induced by Zarand Earthquake in Central Iran Using Thermal Remote Sensing Data and GIS". In this chapter, the geo-hazard evaluation of the Zarand Earthquake in central Iran, which occurred February 10th–28th, 2005, is analyzed, and the land surface temperature (LST) variation for the years 2004, 2005, and 2007 is mapped. Finally, the in-situ air temperature variation for the entire month of February 2005 (1st–28th February) is analyzed and compared with data from the ten years before (1994–2004) and six years (2006–2011) after the earthquake. The authors use the satellite data of the MODIS daytime LST product (MOD11A1) from the thermal band during the period from February 10th to 28th, 2005.

Chapter 5 is titled "Environmental Control of the Sand Dunes in Iraq". The authors use three methods to detect the changes in the shape, size, and area of the different studied dunes. The three approaches are (a) field work, (b) Iraqi geological maps, and (c) GIS technique.

Chapter 6 is titled "Amu Darya Dynamics in Afghanistan Using Remote Sensing Data". This chapter applies remote sensing data and geo-information techniques to understand the temporal and spatial channel changes and dynamics of the Amu Darya river along Afghanistan's border. Also, mapping and analyzing the land cover changes of four classes over the study area are being investigated. Moreover, determining land conversion from 1990– 2020 between the investigated classes has been conducted. Also, seasonal land degradation is being investigated. The authors used four Landsat images (1990, 2000, 2011, and 2020) from the same period (May–July) to avoid seasonal changes. The seasonal changes are investigated in 2020, in all four seasons. Their analysis has been made on the Google Earth Engine platform.

Chapter 7 is titled "A New Method for Land Degradation Assessment in the Arid Zone of Republic of Kazakhstan". The authors use the following major processes altogether to characterize the land degradation phenomenon: decreasing productivity, i.e., changes in vegetation; soil degradation (erosion); desertification (increasing of bare land area); and salinization of the soil. These processes are well recognizable using satellite data in the form of direct observation, band ratio computations, or other more or less sophisticated approaches.

Chapter 8 is titled "Land Degradation Issues in Uzbekistan". The chapter focuses on showing that existing soil degradation problems are under the effects of climate change and suggests different ways of solving them.

Chapter 9 is titled "Soil Erosion Catastrophe in Iraq-Preview, Causes, and Study Cases". In this chapter, the authors review most of the available research articles and reports that are interested in and involved in estimating and managing soil erosion in Iraq.

Chapter 10 is titled "Assessment of Aircraft Noise Pollution on Students' Performance". Here, the authors explore the effects of aircraft noise on students' learning performance and teachers' teaching performance at selected schools near Abu Dhabi International Airport.

Chapter 11 is titled "Role of Effective Factors on Soil Erosion and Land Degradation: A Review". The authors conducted a comprehensive review and discussed the main factors affecting land degradation, with a major focus on soil erosion. Land degradation sources fall into two main categories: natural and anthropogenic sources affecting land degradation. The main anthropogenic sources, including the role of agriculture, soil salinity, building and urbanity, culture, people's outcomes, environmental pollution, and war, are presented and discussed.

Chapter 12 is titled "Cadmium Fractionation Technique as a Chemical Degradation Indicator for Some Soils Near Diyala River in Iraqi Center". The authors, in this chapter, investigate pollution with cadmium as a chemical degradation indicator for some soils irrigated by the Diyala River (southern part) in the Iraqi center.

Chapter 13 is titled "Land Degradation Due to MSW Dumping and Sanitary Landfilling: Iraq as a Case Study". The chapter focuses on finding out the rate of land degradation due to open dumping and landfilling of solid waste in the short and long term. The social and environmental impacts and the measures to stop this tragedy and land rehabilitation in the long term are presented.

Chapter 14 is titled "RUSLE Model in the Northwest Part of the Zagros Mountain Belt". Investigation of this topic is essential to suggest mitigations and extend the life of the Mosul Dam. The Mosul Dam, which impounds the Tigris River, suffers from different problems, one of which is siltation. This kind of investigation helps in understanding the nature and type of land erosion processes. Also, many sectors of society in a concerned region will benefit from this investigation. The authors estimate the mean annual loss of soil in the Al-Khabur River Basin (KhRB) on the northwest side of the western Zagros Range (Kurdistan Region/Iraq).

Chapter 15 is titled "Changes in the Water Quality of Large Rivers in the Asian Part of Russia from the Standpoint of Achieving Sustainable Development Goals". The authors studied the interim tendencies in water quality in the large rivers of the Asian part of Russia applying Indicator SDG 6.3.2 methodology. The primary objective was to choose the so-called target values characterizing good water quality. In Level 1 evaluation, they used national water quality standards, those recommended by UNEP, and individual target values for each region under discussion.

Chapter 16 is titled "A Sustainable Way for Fish Health Management by Replacement of Chemical and Drugs by Earthworm". The authors investigated the need for a sustainable method for fish health management. They also found that earthworms play a key role in this approach.

Chapter 17 is titled "Integration of Field Investigation and Geoinformatics for Urban Environmental Quality Appraisal of Bankura Town, West Bengal, India". This chapter endeavor thus attempts to look into all the parameters required for a sustainable Bankura town and assess the environmental quality to address policy initiatives.

Chapter 18 is titled "Urban Heat Island Under the Background of Urbanization: A Case Study in Nan Jing City, China". The authors attempt to look into all the parameters required for a sustainable Bankura town and assess the environmental quality to address policy initiatives.

Chapter 19 is titled "Optimization of Ecological Environment Sensor Network Sites with Multiple Monitoring Targets". In this chapter, the authors elaborated on a sampling optimization methodology for multi-objective factors. In addition to considering spatial coverage, they also consider the need for information redundancy and economic efficiency. They planned a two-stage site design and layout plan. The goal of the first phase is to show the spatial relationship between precipitation, land surface temperature, soil moisture, and environmental covariates and to obtain their spatial trends. The goal of the second phase is to reflect the relationship between precipitation, surface temperature, soil moisture, and other constraints.

Chapter 20 is titled "The Influence of Large Scales of Reservoir Construction in the Upper Yangtze River Basin on Regional Precipitation". The study work provides a first reference for understanding the relationship between regional reservoir planning and precipitation changes. Therefore, this chapter focuses on revealing the total and local impact of the existing reservoirs on precipitation change in the UYRB using multi-source precipitation data for the first time. To accomplish this, the suitability of satellite precipitation products on each sub-basin and time scales of day, month, and year was assessed in order to use them to find and analyze temporal and spatial changes in precipitation and extreme precipitation in the UYRB.

Chapter 21 is titled "Impact of Climate Changes and Landuse/Land Cover Changes on Water Resources in Malaysia". This chapter presents a comprehensive review on climate and anthropogenic activities to incorporate the major findings of the previous studies to help policymakers identify specific basins that need to be improved and prioritized. The review highlights the most recent trends and potential impacts of land use change, climate change, and combined land use and climate change impacts on water quantity and quality in various parts of Malaysia and identifies the major sources of water resource degradation. The authors suggest mitigation and adaptation strategies for managing water resources, i.e. sources in Malaysia based on the conducted review.

Chapter 22 is titled "Impact of Land Use—Land Cover and Socio-economic Changes on Groundwater Availability: A Case Study of Barrackpore-II Block, West Bengal, India". This chapter is intended to find out the extent of groundwater scarcity, identify the change in LULC and hotspots of water, and access the water insufficiency and awareness of rooftop RWH (RRWH) by rural households.

Chapter 23 is titled "Unplanned Urban Sprawl Impact on Cultivable Soil Degradation". It aims to determine the extent of cultivatable soil degradation caused by changing the type of soil use from agricultural to urban (slums). The Normalized Difference Building Index (NDBI) and the Built-up Index (UI) are used to assess the decline of cultivable soils as soil use changes.

Chapter 24 is titled "Variability Analysis of Local Climate Change and Its Association with Urbanization in the Beijing-Tianjin-Hebei Region, China". In this chapter, the authors selected four contiguous cities in China's Beijing-Tianjin-Hebei region as the study area. The meteorological, socio-economic, and LUCC data are synthetically used to explore the correlation and variability between urbanization and local climate change. The authors constructed urbanization indicators based on population size, population density, GDP, built-up area, and socio-economic data. Several data analysis methods, including Pearson's moment correlation, Spearman's rank correlation, and EOF were selected to achieve the goals.

Chapter 25 is titled "Spatial-Environmental Assessment of the Transport System in the Northern Emirates, UAE: Toward Policies and Practices". The chapter examines the relationship between economic growth, environmental degradation, and infrastructure development in the UAE. The authors bring into focus the development of the transport system in the northern emirates, an emerging economic region in the UAE, and the effects this has had on environmental degradation. The authors assess and devise a variety of proposed policies and practices that curb the inevitable environmental degradation associated with the development of the transport system.

Chapter 26 is titled "Influence of Cryogenic Processes and Phenomena on Minimum Runoff in Russia". The main purpose of this chapter is to assess the cumulative impact on the groundwater recharge of Russian rivers, including those located in the Asian part of the country, of many cryogenic phenomena and processes occurring in riverbeds, catchments, swamps, wetlands, soils, and fissured and loose rocks. The chapter presents the authors' reflections on the evolution of stable and unstable structures in «water flow-ice-channel sediments» system (in annual and multiyear cycles) as air temperature decreases. Also, according to the authors, it lists the main problems arising in the assessment of minimum runoff and groundwater recharge of rivers under climate change.

Chapter 27 is titled "Forest Successional Change and Its Effect on Plant Species Diversity: A Case Study for Euxine Forests, NE Turkey". The chapter focuses on four main objectives. They are (1) to determine the variation of plant species diversity in the stages of forest succession; (2) to evaluate how the succession stages in tree, shrub, and herbaceous layers affect plant species replacement; (3) to determine the distribution of abundance according to the seral stages of succession; and (4) to explore the distribution of endemic and rare taxa in the succession stages.

Chapter 28 is titled "Desertification in China: Role of Natural Succession in the Sustainable Revegetation of Drylands". This chapter reviews relevant studies that identify the factors leading to successful and long-term sustainable revegetation of degraded semi-arid and arid drylands. The authors compare ecological methods of revegetation, focusing on the process of natural succession and its implementation in China's drylands during the last 15 years. Furthermore, the authors discuss the actual value of large-scale restoration with sustainable vegetation for the agronomy and reversal of desertification trends and as a potential tool to directly mitigate climate warming and aridity on a local, regional, and maybe even country level.

Chapter 29 is titled "Estimation of Satellite-Based Regional-Scale Evapotranspiration for Agriculture Water Management Using Penman-Monteith Method". In this chapter, the authors estimate the monthly reference evapotranspiration (ET0) based on the FAO Penman-Monteith method using the Landsat-7 ETM+ and Landsat-8 OLI seasonal data of 2014, 2015, and 2016 over the Dwarakeswar-Gandheswari river basin. The model input parameters are emissivity, land surface temperature (LST), net radiation, soil heat flux (G), air temperature, actual and saturation vapor pressure, and wind speed. Correlation analyses have been performed of ET and field-based soil moisture data in the proposed command area. Additionally, results are validated by using MODIS LST for estimated LST and MODIS ET for estimated ET. Moreover, the assessment of regional-scale-based evapotranspiration is a challenge to the agricultural and hydrological frame. This analysis demonstrates the potential applicability of this methodology.

Special thanks are due to all the authors who contributed to this volume. Without their efforts and patience, it would not have been possible to produce this unique volume on Environmental Degradation in Asia. Also, thanks should be extended to include the Springer team, particularly the publishing editor: Alexis Vizcaino, who largely supported the authors and editors during the production of this volume.

Erbil, Kurdistan Region, Iraq — Ayad M. Fadhil Al-Quraishi
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Zagazig, Egypt — Abdelazim M. Negm
April 2022

Contents

Impact of Land Use—Land Cover and Socio-economic Changes on Groundwater Availability: A Case Study of Barrackpore-II Block, West Bengal, India

Satabdi Biswas, Satiprasad Sahoo, and Anupam Debsarkar

Abstract Limited access to safe water is a growing crisis for rural areas. Various socio-economic activities are responsible for changing land use and land cover (LULC) and hotspots for water. The present study has been undertaken to unveil the crisis of groundwater scarcity and seek a way out through mixed methods, including recent changes to LULC (2010–2020) and a socio-economic survey carried out for 211 rural households in Barrackpore II block, West Bengal, India. The amalgamation of GIS and statistical techniques showed a drastic increase in the built-up area at the cost of water bodies and vegetation. The LULC study showed the maximum share of the land (73.79%) used for built-up purposes, with the share of existing water bodies being only 4.63%. The study was focused on how water scarcity got influenced by some socio-economic variables of the households. A binary logistic regression of the water scarcity index (WSI) was carried out to explain the level of awareness of rooftop rainwater harvesting (RRWH). The result confirmed 85.4% of the predictability of WSI. Anthropogenic activities are mostly responsible for climate degradation which ultimately has led to environmental degradation and contamination of precious water resources. Finally, the study emphasized regular monitoring of the present trend of diminishing water bodies and other green areas and the relevance of the adoption of urgent planning for RRWH as a safe sustainable water management practice for areas with contaminated groundwater.

Keyword LULC change · Rainwater harvesting · GIS · Binary logistic regression · Socio-economic study

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1 Introduction

Water is one of the key resources safeguarding food security and the ecosystem. It underpins economic and human productivity. Many underlying human-induced factors related to water make the local environment more complex [1]. Major water demand is met from groundwater, including different irrigation systems of deep tube well (DTW), shallow tube well (STW), aquaculture, urbanization, industrialization, drinking, and domestic water. Even the surface water supply is also based on pumped groundwater [2]. India has been struggling to manage its water resources effectively. Depleting the water table coupled with the instability of access to clean water, food security, and health ultimately led to social and political unrest [3].

Easy access to groundwater, cheaper boring cost, availability of loans from a bank, subsidized electricity and compelling to need boost 'Boro cultivation' (winter rice) along with other crops are responsible for unethical major share drafting of groundwater common in West Bengal [4]. High drafting causes the gradual appearance of arsenic on the surface as shallow aquifer (20–80 m bgl) is affected by the geological source of arsenic and high level of iron contamination [5].

The arsenic contamination in drinking water has gradually become a worldwide overuse over the last four decades [6, 7]. However, from 2004 villages had experienced a huge growth of STW coming up with the National Policy of Arsenic Mitigation (NPAM) [4]. The arsenic toxicity covers 34,000 km^2 with 42.4 million people at risk in 37 blocks of West Bengal. The highly affected nine districts are North 24 Parganas, South 24 Parganas, Malda, Murshidabad, Nadia, Kolkata, Howrah, Hoogly, and Bardhaman. Surprisingly, most blocks are situated on the eastern side of the river Bhagirathi [8]. Nearly 98% of water samples of public tube wells of the state were reported to have an arsenic concentration above 0.01 mg/l. Even in some cases, it was noticed as high as 0.135 mg/l [9].

In the district of North 24 Parganas, the level of arsenic was reported in the range of 0.06–2.28 mg/l, causing the suffering of 21,96,158 populations in 2699 affected habitats, which is the worst situation in the state [10, 11]. The rural habitations of the district mostly depend on groundwater with only 4.9% being catered by surface water systems and alternative sources. Thus, groundwater is the only significant source for the piped water supply schemes (PWSS). Out of groundwater-based PWSS, 64% are covered by different small-scale PWSS, each covering nearly 10 habitations. However, this groundwater-based scheme is typically fitted with a bore well and pumps, supplying water to households after disinfection through chlorination [5]. More precisely, 53.4% arsenic contaminated tube wells were found in the North 24 Parganas among which 3.4% had above the level of 300 μg/l. Consuming arsenic-contaminated water over a prolonged period in the form of cooking, drinking, and irrigation, the poison of arsenic has entered the food chain [5]. It is worth mentioning that the BIS level for arsenic is 0.01 mg/l since 2003 [12]. The severity of arsenic calamity causes many health-related sufferings such as skin lesions, diarrhoea, gastrointestinal problems, anemia, renal defect, neurological defects, etc. Arsenic also causes oxidative damage and alters the regulation of DNA repair [7, 8]. The level of urbanization of the district remained high at 57.6% compared to state and the national average of 31.89 and 31.16%, respectively (Census of India 2011).

Under such circumstances, arsenic contamination puts a huge burden on rural households. It happens in three ways: unpopular Government programs, lack of proper institutional efforts, and ignorance about the socioeconomic and cultural background. To unfold in brief, most government policies are by and large associated with the dependency on a single source, i.e. groundwater for all uses, even for real estate development business, especially in adjoining areas of Kolkata [4]. Arsenicosis is aggravated by malnutrition, poor socioeconomic status, illiteracy, food habit, and regular consumption of contaminated water [5]. The poor socio-economic condition has become a threat for nearly 20% of the state population affected by arsenic contamination [7]. In the technological park at Baruipur, West Bengal, most of the arsenic removal plants were found inoperative because of a lack of awareness of arsenic-related hazards among the affected population, poor sense of belonging, and willingness, user-unfriendliness, etc. [5].

The lack of participation of the highly affected and marginal community in the government's water policy decision-making platform was another reason behind the failure [5, 6]. There are several underlying socio-economic and anthropogenic factors such as poverty, population growth, unawareness of water resources, unscientific and primitive method of groundwater withdrawals, etc. All play a significant role in aggravating water scarcity [11].

To date, the government is yet to provide enough technical support to encounter arsenic calamity in a cost-effective and user-friendly way, while presently available and widely used arsenic mitigation filter systems further damage soil, surface water, and the local ecosystem due to unplanned open disposal [8]. It is necessary to change the present behavior of water use and tap new sources like Rainwater harvesting (RWH) to avoid deadly diseases [8]. However, RWH has been widely practiced in dry areas of Bankura, Birbhum, Darjeeling, Jalpaiguri, and Purulia by different agencies. Artificial recharge plants were developed in some of the arsenic-affected areas like Swarupnagar and Gaighata Blocks, North 24-Parganas, West Bengal [13]. RWH plays a vital role in combatting water scarcity by individuals or governments at a reasonable cost [14].

There have been several studies on analyzing the land use and landcover (LULC) to select a suitable site of RWH [15–17]. No such research has so far been made to combine LULC with the socio-economic aspect. The present study attempts to provide a mixed approach to assess the extent of water scarcity and the feasibility of RWH to overcome the adverse effects of declining groundwater levels. Incorporating the recent (2010–2020) LULC change, we identify the water hotspot, and finally, water scarcity is judged by rural households, which was so far unnoticed, especially in the semi-critical block like Barrackpore II, North 24 Parganas District of West Bengal. Heavy drafting of groundwater by rampant use of shallow, medium capacity, and deep tube wells are very common in the study area to support winter paddy and other crops as well as industrial and domestic purposes. This indiscriminate overdrafting of groundwater is one of the main causes of land degradation, water pollution, and associated environmental problems. A gradual decline of groundwater table with increasing arsenic-iron contamination caused by various anthropogenic activities is influencing all dimensions of the environment. It is necessary to adopt adequate measures to combat groundwater-related land degradation for the sustainability of the environment. Thus, the present paper helps formulate a potential action plan for augmenting groundwater by the local authority to extract the maximum benefit of RWH. Thus, the objectives of this study can be summarized as:

1. To find out the extent of groundwater scarcity,
2. To identify the change of LULC and hotspots of water,
3. To access the water insufficiency and awareness of rooftop RWH (RRWH) by rural households.

2 Study Area

The present study area is Barrackpore II, North 24 Parganas, West Bengal, India (see Fig. 1). Topographically, this block is a part of the Gangetic delta having an average elevation of 25 m. Geologically it has an alternate layer of sand, silt, dark gray clay of middle and upper Holocene age (http://wbwridd.gov.in/). Having deltaic plain with silt types of fertile soil, agriculture is done involving a huge number of DTW and STW mainly for Boro (winter paddy) cultivation. Most of the agricultural lands are used for multi-crop cultivation throughout the year. The clay surface gets poorly drained, thus, facing a flood in every rainy season. The average rainfall is more than 1600 mm, mostly happening during the rainy season.

The questionnaire survey was based on 11 selected villages like Chhota Kanthalia, Bara Kanthaliya, Surjyapur, Iswaripur, Dopere, Bilkanda I, Bilkanda II, Patulia, Sewli, Mohanpur, and Bandipur that covered 7.56% of total households as per the 2011 census (see Table 1). However, the total villages of the block are 15, having 51,874 rural populations with the highest decadal growth rate of 36.73%.

The surveyed area has a historical background that after partition with Bangladesh, many refugees settled here. The proximity of Kolkata and the river Hooghly influenced the urbanization process. Simultaneously, industries like jute, petrochemical, electronics, iron and steel factories, food processing, and information sector have pulled a large section of the rural people of the adjacent blocks. However, at present, though many industries are closed, better amenities attract people from rural areas [18]. Gradually, the agricultural landscape started changing in 2004 mainly in two ways. Firstly, with rapid mushrooming of small-scale dye, textile, glycerine factories abstracting excessive groundwater and secondly, due to disposal of untreated industrial waste degrading the agricultural land, surface water bodies, and shallow aquifer [4]. These industries made huge shifts in labor from agriculture. Our study area is facing quantitative and qualitative water scarcity, which puts underprivileged rural households in a critical situation.

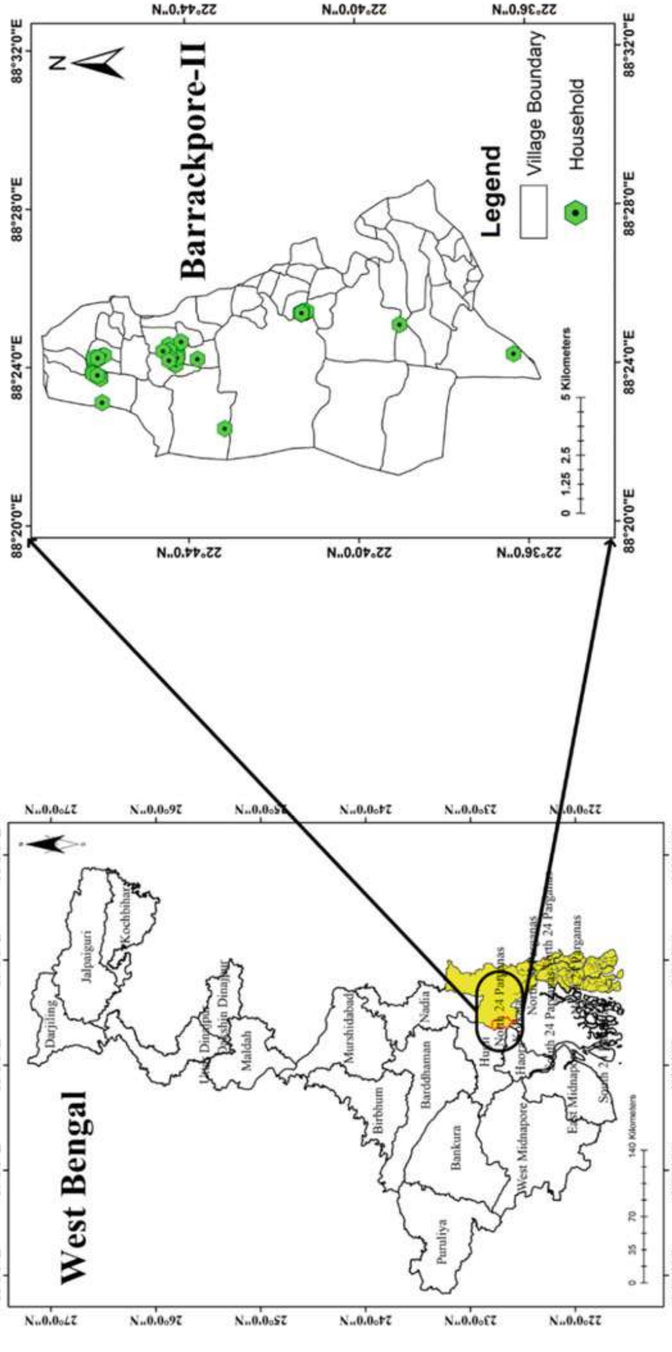

Fig. 1 Study area and location of the households survey

Table 1 Details of the study area: Barrackpore II block

Stage of groundwater development	Surveyed village	Surveyed households	% Samples with Arsenic > 10 ppb	Average rainfall in mm	Average rainy days in monsoon	Driest month with rainfall	Wettest month with rainfall
Semi-critical	11	211(22.9%)	0.32	1570	81	December, 3 mm	August, 306 mm

Source SWID 2018, Census of India 2011 part XIIA, PHED 2018, Primary data 2019

3 Material and Methodology

The methodology consists of three parts viz., data collection, data analysis, and assessment of the significance of RRWH through statistical analysis represented in Fig. 2.

3.1 Data Collection

Satellite images from Landsat 7 ETM+ (Enhanced Thematic Mapper Plus) and American Earth Observation Satellite Landsat 8 OLI/TIRS (Operational Land Imager

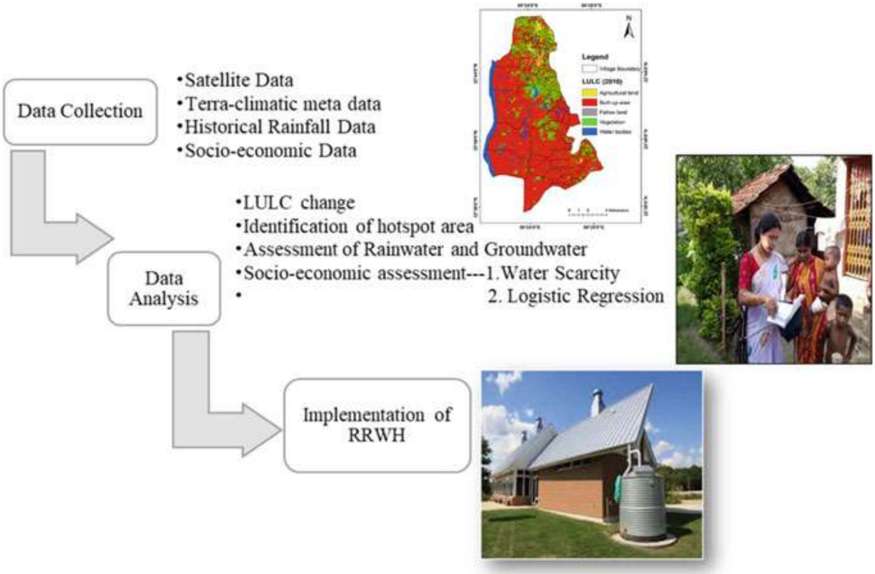

Fig. 2 Graphical representation of methodology

Table 2 Details of satellite data

Satellite data	Path/row	Time	Spatial resolution (m)	Map projection	UTM zone	Datum	No. of bands
Landsat 7 ETM+	138/44	2010/01/29	30	UTM	45° N	WGS84	8
Landsat 8 OLI/TIRS	138/44	2020/01/01	30	UTM	45° N	WGS84	11

(OLI) and Thermal Infrared Sensor (TIRS) were used for preparing LULC. The Terra-climatic metadata having monthly 0.5° × 0.5° grid-wise resolution was collected from (https://climate.northwestknowledge.net) to develop a water deficit map. Forty-five years of historical rainfall data (1971–2015) were collected from IMD (Pune). To enquire about the key information of water scarcity and awareness of water, a questionnaire survey was carried out in the rural areas of Barrackpore II block through personal interviews of 211 households during 2018–2019. The questionnaire consisted of three sections: (1) socio-economic characteristics including income of the household, (2) household's perceptions on the water scarcity (3) household awareness about RRWH.

3.2 Methodology of LULC

The LULC was developed in remote sensing (RS) and geographical information system (GIS) platform to predict the changes during 2010–2020 in the study area (Table 2). The field visit was done to verify the latitude and longitude of specific LULC categories by taking an average of 10° latitude and longitude points. Cross-checking was made based on the pixel color tone of the Landsat image using GIS. Layer stacking and haze reduction were done to improve the quality of satellite images for LULC using ERDAS Imagine and Arc GIS software. The LULC changes were analyzed with the 'K-means Clustering unsupervised classification method'. The Google Earth Images were used for selecting and validating the LULC classes. The key categories of the LULC were agricultural land, built-up area, fallow land, vegetation, and water bodies. Among water bodies, we considered a wetland, ponds, other surface water bodies (locally known bills or jhils), etc.

3.3 Calculation of Index with Statistical Analysis

The water scarcity index was calculated based on the responses of the rural households. However, the responses were perception-based judgments made from socio-economic aspects. For this index, we considered a set of 5 questions. However, the response of each question was converted to an indicator of the index with two values ‘0’and ‘1’. ‘1’ was given as the positive contributor of the index and ‘0’ was taken otherwise. The index was obtained by adding the binary values to the related questions, namely the ‘water scarcity index’ (WSI). Thus, each household had five answers. Suppose the answers to these questions were 0, 0, 1, 1, 1, then we took some of the values of a particular household, and the sum was 3. So, we had a number between 0 to 5 for each household. We took two values as a cut-off value and then considered each household having the sum of the answers to these five questions. Then less than or equal to ‘2’ was given ‘0’ and the households having the sum of more than 2 were given ‘1’. All five variables showed significant dependency within the index by bivariate tables. All the independent variables were strongly associated with dependent variables in the chi-square test (χ^2). In the second stage, we considered logistic regression to assess the combined effect of some socio-economic variables on the ‘water scarcity index’ (WSI). The questionnaire was coded with the help of SPSS software.

4 Results

4.1 Assessment of Rainwater and Groundwater

The average rainfall of 45 years for the study area was 1719.91 mm. The average monsoon and post-monsoon rainfalls were 1289.01 mm and 205.62 mm, respectively. The range of monsoon rainfall varied from 921.03 to 1772.14 mm. It indicates a greater scope of natural recharge when soil and other factors are favorable. The results showed huge potentialities for RRWH. The study area was categorized as ‘semi-critical’ based on the stage of groundwater development and it already has 97.99% development (Table 3). Net groundwater available for future uses showed a negative value (−12,744.99 ham), which implies the urgent necessity for artificial recharge and stringent restrictions over further drafting. However, according to the Central Ground Water Board (2017), more than 70% to equal or more than 100% drafting of groundwater was categorized as ‘semi-critical. The aquifer is very near to the surface and thus, a lion’s share of groundwater was extracted from the shallow aquifer for all purposes very easily.

The quality of the water is intricately associated with the drafting of groundwater. The falling water level trend was found in both the wells with an average of 0.351 and 0.616 m/years from 2007 to 2017. Barrackpore-II block is one of the highly urbanized blocks of North 24 Parganas. It has the highest negative growth (−25.42%) during 1991–2001 due to the formation of new municipalities (Development and Planning Department 2010). The decadal variation of the population for the block was 58,344 as per the present census. Due to intensive urbanization, the population density and water demand are expected to reach respective values of 9976.14 person/km^2 and

Table 3 Groundwater profile of Barrackpore II Block*

Block	Net groundwater availability (ha.m)	Existing gross groundwater draft for all uses (ha.m)	Stage of groundwater development in %	Gross groundwater for irrigation (ha.m)	Rainfall recharge in monsoon (ha.m)	Net groundwater available for future (ha.m)	Depth of GWL (m) bgl	Aquifer thickness (m)
Barrackpore II	4702.55	4608.11	97.99	348.60	4043.75	−12,744.99	12.9	35

ha.m = hectare metre, (m) bgl = metre below ground level
**Source* State CGWB 2017 and PHED 2017

Table 4 Percentage of change in the LULC

	Barrackpore-II (%)	
Year	2010	2020
Agricultural land	2.00	1.89
Built-up area	72.1	73.79
Fallow land	1.87	1.47
Vegetation	18.5	18.22
Water bodies	5.53	4.63

2233 m^3/day by the year 2031. The water demand of urban North 24 Parganas is expected to be 111.48 MLD (million liters per day) in 2021 [10].

4.2 LULC Change

In our study, rural settlement and impermeable surfaces, including roads, were categorized as 'built-up area' while bare land, seasonal bare land, and brick kiln came under 'fallow land'. Another LULC class was 'vegetation', consisting of open fields, grass, forest patch, roadside trees, shrub, scattered trees, kitchen gardens, etc. Areas coming under the river, pond, bills, wetland, and other surface water bodies were classified as 'water bodies' and agricultural land. These are the five categories of LULC. The percentage of LULC changes is presented in Table 4. As appears in Fig. 3, the major land use for the study area in 2010 was built-up areas (72.1%) followed by vegetation, water bodies, agricultural land, and fallow land, and the same trend will be observed in 2020.

The built-up area has increased from 72.1 to 73.79%, i.e. by 1.69% over a span of 10 years'. However, in this block, the percentage share of water bodies, vegetation, agricultural land, and fallow land was reduced marginally to the extent of 0.9%, 0.28%, 0.11%, and 1.05%, respectively, over the decade (2010–2020).

4.3 Identification of Hotspot

The water deficit zoning map was developed to identify hotspot zones of water (see Fig. 4). The terra-climatic data included temperature, precipitation, evaporation, vapor pressure, runoff, soil moisture, etc. The water balance model was calculated based on the Thornthwaite-Mather climatic method. As the Barrckpore II block has already been highly urbanized with the less rural area, more than 50% area was under high (45.83–46.14 mm) to very high (46.14–46.64 mm) water deficit, mostly in the east to the south-eastern part of the block. On the contrary very small area was found under low (45.30–45.59 mm) to very low (45.01–45.30 mm) water deficit categories, scattered mostly over the north and western parts of the block.

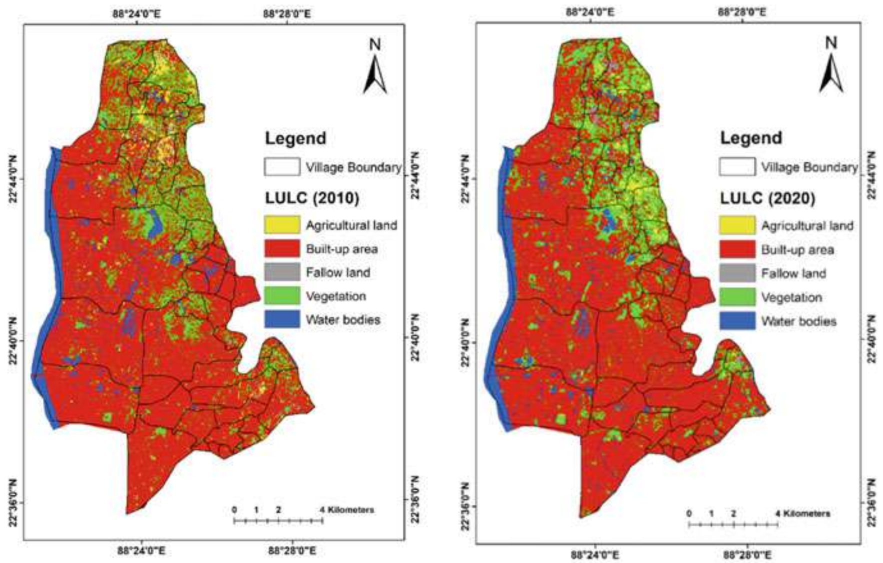

Fig. 3 LULC of Barrackpore-II from 2010 to 2020

4.4 Socio-economic Assessments of Water Scarcity and RRWH

4.4.1 Socio-economic Characteristics of the Households

Water is tied in a complex relationship with the socio-economy and surrounding environment [1]. In the present study, we tried to unfold the water scarcity situation faced by rural households in their daily lives. They were found to be well aware of RRWH to combat the situation.

(a) ***General Information about the Households***

Among the respondents, males and females were 51.2% and 48.8%, respectively. Each household had an average of 4 members (73.5%). Among the households, 18.0% were engaged in agricultural activity. Almost 47% of the household's monthly income was Rs. 10,000. Most of the respondents had attained class X level education (51.7%) and 31.3% of families had at least one educated member in the family. About 27.5% had more than Rs. 10,001 monthly incomes. The rural household used to fetch water from groundwater-based shallow hand tubes as the principal source of water.

(b) ***Perception of Households about Water Scarcity***

As judged by households in the water scarcity index, we found that 52.6% of households complained about acute water shortage in summer. When asked about drinking water sources, 89.1% admitted their dependency on PHE/own shallow tube well

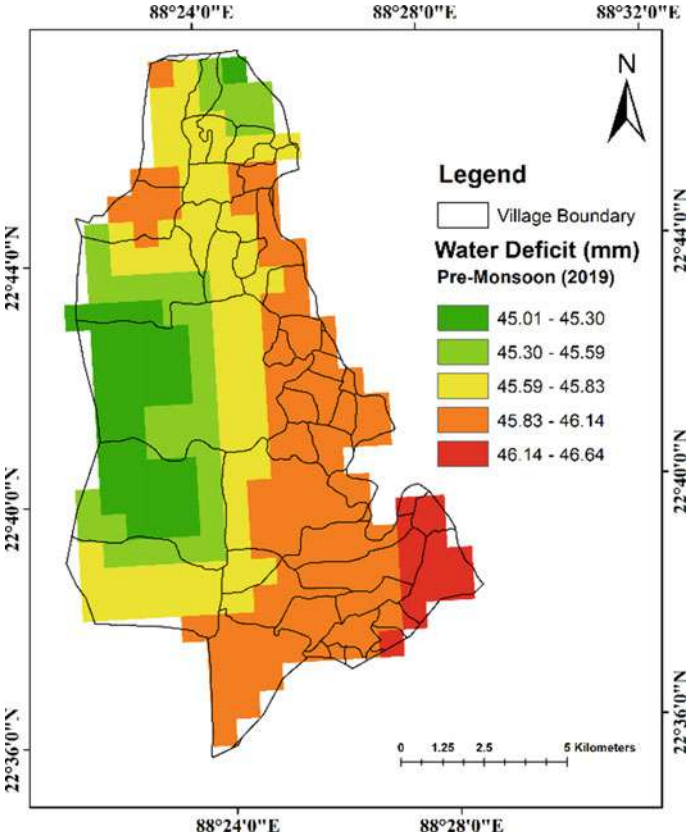

Fig. 4 Water deficit map of Barrackpore-II, 2019

water. Regarding the taste of water, 75.4% of households expressed their water as having 'good taste'. According to the households, sweet water meant 'good' and salty or odorous water 'not good'. Almost cent percent of households expressed a dislike for water due to its reddish color. The first shallow aquifer of the study block was contaminated with arsenic and iron, having 7.14 ppb and 1.01 ppm, respectively [19]. Thus, rural households suffered a lot from the single dependency on the groundwater.

(c) ***Water-related Diseases***

During the field survey, the percentage of households frequently suffering from waterborne diseases, i.e. dysentery, diarrhea, jaundice, typhoid, was 66.4%. All these five variables were included in WSI. A significant portion of the households (70.1%) had frequently been suffering from combined water and vector-related diseases. Near about 6.6% of the households were suffering from skin lesions, whereas 10.4% were suffering from constipation which implied the quality of supplied water was a matter of concern. The share of pucca houses and land around the household for constructing a water reservoir was found 93.8% and 86.7%, respectively. However, 24.2% of the households already had their water tank.

4.4.2 Binary Logistic Regression Analysis

The present study intended to find out whether rural households were aware of RRWH as an alternative way of countering groundwater scarcity. The logistic regression was carried out by taking the log-odd ratio of WSI on nine independent socio-economic variables (See Table 5). WSI was taken as a dependent variable (y) given values '0' for low water scarcity and '1', for acute water scarcity. Each of the nine variables was taken as binary with '0' for low and '1' for high.

Data were analyzed with binary logistic regression to assess the extent of water scarcity and awareness of RRWH as judged by the households.

In logistic regression, six variables i.e. 'male member', 'female member', 'large roof area', 'gastrointestinal problem', 'willingness to direct use of RRWH water' and 'other known families to use rainwater' were found to have a statistically significant effect on WSI. The suffering from the gastrointestinal problem, other known families to use rainwater had a positive effect on WSI while roof area and willingness to direct use of RRWH had a negative effect. The reason behind this can be explained that having more male and female members in the family implied a large family size, which further implied increased water demand. We also tried to find out whether

Table 5 Result of Logistic Regression of water scarcity index (WSI) on the Related Independent Variables

	B	S.E	Sig	Exp (B)
Male member	2.343	0.472	0.000***	10.418
Female member	2.060	0.463	0.000***	7.848
Roof area	−1.064	0.442	0.016**	0.345
Known iron	−0.042	0.619	0.946	0.959
Known arsenic	−0.855	0.875	0.329	0.425
Gastro-intestinal problem	1.325	0.478	0.006**	3.762
Collect rain	−0.580	0.671	0.387	0.560
Willingness to direct use of RRWH water	−1.049	0.559	0.060*	0.350
Other known families using rainwater	2.294	0.797	0.004**	9.910

−2 Log likelihood = 167.919, percentage of correct 85.8%,
Dependent Variable (Y) = 'Water Scarcity Index (WSI)',
*: Significant at 10%, **: Significant at 5% & ***: Significant at 1%.
Male member: up to 2 = 0, 3 and more = 1, Female member: up to 2 = 0, 3 and more = 1, Roof area: large = 0, small = 1, Known iron: Yes = 1, No = 0, Known Arsenic: Yes = 1, No = 0, Gastro-intestinal problem: Yes = 1, No = 0, Collect rain: Yes = 1, No = 0, Willing to direct use; Yes = 1, No = 0, Know other families use rainwater: Yes = 1, No = 0.

the water requirement of male and female members was significantly different, and consequently, they were considered separately.

The more male and female members in a family were found to be 26.5 and 25.1% of households respectively. More than 57% of households had been suffering from gastrointestinal problems which implied poor water quality. Thus, 15.2% of sizable households were found to buy water as they felt private packaged bottled water was a reliable source of drinking water. In comparison, only 8.5% of households preferred to treat drinking water by domestic water filter or boiling. This private packaged water might be one possible reason for positive significance. However, bottled water did not maintain the standard of the BIS level. Only 8.1% of households were aware of the fact that their neighbors used to collect rainwater for domestic purposes in the rainy season. Whereas only 38.4% of households had a large roof (more than 400 m^2). Nearly 22% of respondents expressed their willingness to use the harvested water for drinking purposes in the future, while 62.6% of respondents were found conditionally willing i.e. expecting incentives.

Surprisingly, 27 and 17.5% of respondents were well aware of iron and arsenic problems. More than 89% of households used the shallow tube well as drinking water without having any alternatives. The Public Health Engineering Department (PHED) is the sole authority for the installation and supply of drinking/domestic water while the local government (Gram Panchayat) has been responsible for its maintenance. DTW and private STW were untreated drinking water sources, and the respondents were compelled to consume the same having no alternative. Thus, these two variables harmed WSI. However, only 19.9% of households occasionally collected rainwater whatever they could collect in their home but none of them used it for drinking purposes but mostly for other domestic purposes.

However, 'households had large family sizes', 'a large roof area', 'suffering from gastrointestinal problems' and 'knowing neighbors collecting rainwater in the locality' had significant influence in the order of at least at 5% level of significance. Only willingness to direct use of RRWH had a 10% level of significance. Overall, the logistic regression could explain 85.8% of the dependent variable.

5 Discussion

The supply of unsafe drinking water in rural North 24 Parganas has a cumulative effect on the households and consequently, they face an enormous amount of risk related to arsenic toxicity. Sometimes skin lesions due to arsenic contamination are mistaken by people as leprosy due to a lack of social awareness. Rural people took it as a curse of God and socially boycott the families suffering from arsenicosis [20].

Agriculture, infrastructure, and other anthropogenic expansions are primarily responsible for the negative impacts of LULC [21]. Thus, groundwater is nearly the source of all critical consumption and has made a tremendous adverse impact in peri-urban villages of North 24 Parganas [4]. Banerjee and Jatav [4] pointed out that institutional negligence and Governmental failure were responsible for water insufficiency in many ways. Firstly, infrastructural lacuna, erratic supply, poor operation and maintenance, unreliable supply of public stand posts were responsible for water scarcity. This scarcity is supplemented by rampant private informal tube wells and private packaged drinking water. Secondly, private packaged drinking water does not maintain the BIS standard. Thirdly, untreated industrial wastes go into low-lying paddy land or surface watercourses and contaminate them along with shallow aquifers. Over time, those lands become fallow and are being sold to the factories. Thus, agricultural land and water bodies are converted by powerful industrial lobbies. This further aggravates the situation by illegal extraction of groundwater for industries and 'Boro cultivation'. Lastly, the policy of real estate development ruins the groundwater and natural recharge process. The hydro-geochemistry of groundwater is dependent on several factors like soil, lithology of rock, percolations of rainwater, climate, the role of microorganisms, topography and the role of human activities, etc. [22].

Another study [2] identifies the hotspot areas based on LULC change (1990–2017) in North 24 Parganas. Their result showed that the western and northwestern parts of the district experienced huge urbanization with a 22.59% increase in the built-up area due to the development of cities like Rajarhat Newtown-Gopalpur, Barrackpore, Barasat, Bidhannagar. However, this transformation was gained from the agriculture and vegetation area. But over time, a huge number of brick kilns were identified in the surrounding low-lying agricultural land for getting more benefits. Population growth was one of the significant factors directly affecting the existing LULC. According to [23], it was found that the forest land was degraded or fragmented by the pressure population after assessing LULC. Pristine [24] developed a district-wise Spatio-temporal surface model from 2000 to 2014 to assess the groundwater storage changes and stress zones by the GIS platform in West Bengal, India. The result found that the negative attitude of humans towards urbanization blocks infiltration and surface retention. Banerjee and Jatav [4] found that 20% of households complained about the acute water crisis for some reason in the Bodai village under Barrackpore II.

The findings of the Planning Commission of India (2007) recommended RWH as a local solution for providing safe drinking water through ponds with proper planning and motivation of local people. But in this district ponds are heavily used for pisciculture. Kar and Mukherjee [1] suggested introducing RWH with low-cost water treatment technology to ensure water for all including underprivileged rural people in the project. However, the cement factory situated in Sujapur, Barrackpore II estimated annually 2780 m^3 or 20% potential harvested storage capacity by RWH [22] but [4] argued and stated that re-cycling wastewater and RWH were hardly taken up in Barrackpore II. However, Das and Angadi [18] suggested that rooftop RWH necessary for Barrackpore II.

Addressing water scarcity calls for integration across different multi-disciplinary approaches among all water-related resources, economic and social welfare, and sustainability of ecosystems without compromise. Simultaneously, it is necessary to overcome the existing wastage of water in agriculture, restore the lack of trust in governmental activities, minimize corruption, adopt scientific attitudes with traditional producers, and promote such technologies to improve society's quality of life [14].

Rana and Suryanarayana [17] found socio-economic criteria extremely crucial, thus, making the field study necessary to select sites for RWH to avoid land conflict. An increase in awareness levels and education helps stop the consumption of arsenic-contaminated water and introduce RWH [8]. Sarkar [25] found that educated people are more aware of water contamination and related health implications. It was also mentioned that it was the responsibility of the government to supply safe and sufficient water to people as they have been paying taxes. It was suggested [18, 26] to make people aware of the negative impact of the transformation of natural land into the built-up area.

Unlike these studies, the present study found rural households quite educated, had enough roof area, pucca house, homestead land, and had their own water tank but suffering from water-related health hazards and faced water insufficiency in summer. Buying unsafe water puts households in a critical situation. Only 6.2% demanded proper training of RRWH. It was found from the survey that the households did not know the proper know-how of RRWH. It implied households were not aware of RRWH as an alternative water source. But few households occasionally crudely collected rainwater. Thus, unconsciously rainwater was being considered as an alternative source of safe water. However, 33.2% of households suffered from acute water scarcity, which is established by logistic regression.

This study noticed that the built-up area is the giant feature increasing at the cost of vegetation cover, water bodies, fallow land, and agricultural land LULC categories from the year 2010 to 2020. Additionally, the steep water demand would be very challenging to cater safe water to future generations. However, more than 52% of respondents complained about water shortage to lower the water table. In our study, the water deficit zoning maps identified the hot spots in the study area where RWH needs to be introduced with an artificial recharge structure like an injection well.

6 Policy Implication and Recommendations

The need of the hour to have a more effective institutional regulatory work restricts the drafting of groundwater and establishes a balance between development and environment conservation centering socio-economy. First of all, the government should restrict population growth which is the key factor in controlling the negative change of land use. Water, particularly the groundwater needs to be managed as a community resource by the state under public trust doctrine to achieve food, better standard of life, and livelihood security of rural households. Following measures would be suggested for considering the magnitude and extent of the water situation.

- It is necessary to introduce appropriate land use to restrict and penalize illegal construction and landfilling. A region-wise micro-level aquifer mapping, arsenic-iron-based vulnerability maps, and LULC maps should be published in the public domain to make people aware of the quantity-quality status of the aquifer and drastic changes in land use and to share a periodical update.
- The over-withdrawal of groundwater should be minimized by regulating the use of STW and DTW for pumping groundwater for all use.
- The local authority should arrange a water safety plan of RWH to introduce simple technical know-how of rooftop RWH by frequent meetings, training, workshop, increasing the social awareness program among the affected community for social acceptance of scheme and rescue their aquifers for the future generation.
- It is imperative to arrest the decline of groundwater levels in over-exploited areas by improved technologies of artificial recharge. The main focus will be to shift from the construction of a high-cost arsenic treatment plant to RWH. RWH helps to dilute the arsenic-iron concentration of aquifers and plays the role of an alternative source of drinking water.
- An increase in the number of parks with water bodies, provision of injection wells and rooftop RWH with recharge wells for all built-up areas, and re-excavation of the existing wells or ponds may be adopted to avoid valuable land acquisition.

7 Conclusions

Significant reduction in water bodies, fallow land, and vegetation cover indicates the consequences of an indiscriminate increase in built-up areas over the last decade in Barrackpore II block. Inadequate awareness regarding the importance of groundwater among the various stakeholders viz. different governmental agencies, policymakers, households, etc. is to be duly addressed as a part of water conservation. However, the socio-demographic status of rural households plays a significant role in changing the LULC, which so far has been neglected repeatedly. Unsafe drinking water has a collapsing effect in terms of arsenic toxicity, sometimes even to the extent of social exclusion. Arsenic is difficult to be removed overnight but the judicious adoption of RRWH as an alternative safe water supply scheme may combat the age-old problem of water scarcity.

Thus, the proposed mixed approach incorporating assessment of LULC change, identification of water hotspot zone, evaluation of the statistical significance of water scarcity perceived by the rural households, and the implementation of RRWH can be considered as a simple yet effective strategy for addressing the issue of combined qualitative and quantitative water stress for semi-critical, arsenic-iron contaminated areas. This method needs less time and more effective to extract the full advantage of RWH. Thus, an attempt was made to identify the root socio-economic factors associated with groundwater depletion by combining GIS and statistical approaches, which would help the local authority combat the water scarcity for other semi-critical blocks with identical socio-economic and physical conditions. The introduction of RWH should cater safe water to the affected community and also enhance the groundwater resource.

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Estimation of Satellite-Based Regional-Scale Evapotranspiration for Agriculture Water Management Using Penman–Monteith Method

Satiprasad Sahoo, Tanushree Basu Roy, Anirban Dhar, and Anupam Debsarkar

Abstract Evapotranspiration (ET) is one of the important parameters in the hydrological cycle affecting water resource availability. Estimating surface evapotranspiration is essential for water resources evaluation, drought monitoring, crops production simulation, and providing guidance for crop water needs in irrigated lands. Reference evapotranspiration (ET0), is a representation of efficient water management for environmental demand. Environmental degradation is crucial for humankind over the past few decades. Thus, hydro-environmental management is required for future sustainable planning purposes. The present study estimates the monthly reference evapotranspiration (ET0) based on the FAO Penman–Monteith method using the Landsat 7 ETM + and Landsat 8 OLI seasonal data of 2014, 2015, and 2016 over the Dwarakeswar—Gandheswari river basin. Required model input parameters are emissivity, land surface temperature (LST), net radiation, soil heat flux (G), air temperature, actual & saturation vapor pressure, and wind speed. Correlation analyses have been performed of ET and field-based soil moisture data in the proposed command area. Finally, results are validated by using MODIS LST for estimated LST and MODIS ET for estimated ET. Moreover, assessment of regional-scale based evapotranspiration is a challenge to the agricultural and hydrological frame. This analysis demonstrates the potential applicability of this methodology.

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1 Introduction

Estimation of ET is essential to know how much water is required during the growing season, to improve crop water management and hydrological applications. ET is the process that accounts for a large portion of the hydrological water budget. On the land surface, an average of about 60% of the precipitation received is returned to the atmosphere through ET.

Moderate numbers of studies are available for the estimation of ET using remote sensing techniques. Calculation of reference crop ET based on Penman evaporation equation using available weather data [1]. Tsouni et al. [2] estimated daily ET for all the 21 days of the study period using the FAO Penman–Monteith, Carlson-Buffum, and Granger method in the Thessaly plain, Greece. Spatiotemporal distribution of ET estimation based on SEBAL model in South –Central Nebraska [3]. Simulation of ET estimation using empirical methods from groundwater under different soil conditions is available in [4]. Evaluation of ET of an oasis-desert transition zone using the Penman–Monteith model in the middle stream of Heihe River, China [5]. Quantification of predicting ET using remote sensing techniques in the mixed vegetation surface areas [6]. Ficklin et al. [7] estimate Palmer Drought Severity Index (PDSI) using Penman–Monteith PET method for current and future drought projections.

Li et al. [8] studied the assessment of ecosystem ET dynamics using the Priestley-Taylor parameter in eastern Inner Mongolia, China. Wang et al. [9] estimated ET under multi-scale conditions using “thermal infrared remote sensing and three-temperature model” in the Zhangye oasis and adjacent Gobi and desert, northwest China. Estimation of ET based on the Simplified Surface Energy Balance (SSEBoP) model for the spatial distribution of water mapping in the Colorado River Basin [10]. Yao et al. [11] reported that the evaporative drought index (EDI) had been used to monitor China’s surface dryness conditions based on the ET model and Hargreaves equation from JAXA-MODIS Insolation products, GEWEX, NCEP-2, and MODIS NDVI data. Groundwater ET estimation is based on empirical equations from irrigated cropland areas [9]. ET’s future scenarios use the Hadley Centre Coupled Model version 3 data for crop production and water balance framework [12]. The Impact of ET formulations for various elevations for various climatic conditions of meteorological drought assessment [13]. Raoufi and Beighley [14] studied daily global ET estimation based on the Penman–Monteith method using land surface temperature (LST) for the period 2000–2013.

The relationship between the surface resistance and remotely sensed stress index based on modified Penman–Monteith in the semi-arid region of Tensift Al Haouz (Morocco) for optimizing irrigation management is available in [15]. Assessments of global and regional scale surface fluxes based on the Penman–Monteith model, Priestley-Taylor Jet Propulsion Laboratory model (PTJPL), and the Global Land

Evaporation Amsterdam Model (GLEAM) is available in [16]. Rozenstein et al. [17] studied cotton ET estimation based on eddy covariance, surface renewal, and heat pulse using Sentinel-2 satellite imagery in the cotton field near Gedera, in the Shfela region in Israel.

Jahanfar et al. [18] performed refined water budget analysis using a modified FAO ET model for Green Roof systems. Fernandes et al. [19] studied the estimation of water use efficiency (WUE) from Moderate Resolution Imaging Spectroradiometer (MODIS) data in the Cerrado of Minas Gerais State (western part of Minas Gerais). Wu et al. [20] identified crop drought index through the Two-Source Energy Balance (TSEB) model for monitoring and assessing winter wheat drought disasters. In a more recent paper, evapotranspiration estimation based on surface energy balance models using satellite data for sustainable agriculture water management [21–26].

However, the middle to upper portions of the river basin is high water stress areas. A Command area is proposed for agricultural water management in the middle portion of the river basin. Moderate-resolution satellite data are used for accurate ET estimations for these different years at a regional scale. Moreover, the estimated seasonal ET is very needful for regional-scale hydro-environmental (e.g., drought) planning and management framework. The proposed methodology is applied to Dwarakeswar—Gandheswari river basin, West Bengal, India.

2 Study Area

Dwarakeswar River is a major river in the western part of West Bengal in India (Fig. 1). The detailed information on the Dwarakeswar- Gandheswari river basin is available in [27]. Penman–Monteith is the best method for ET calculation compared to other methods [28]. Using satellite data, seasonal ET estimation has been performed in the small river basin.

3 Materials and Methods

Figure 2 presents the methodology adopted in the chapter in more detail in the following subsections.

3.1 Data Sources

Landsat 8 OLI (2014–2016 and Path:139–140, Row: 044) and MODIS (MODIS/Terra and MOD16) data were collected from the Earth Explorer, United

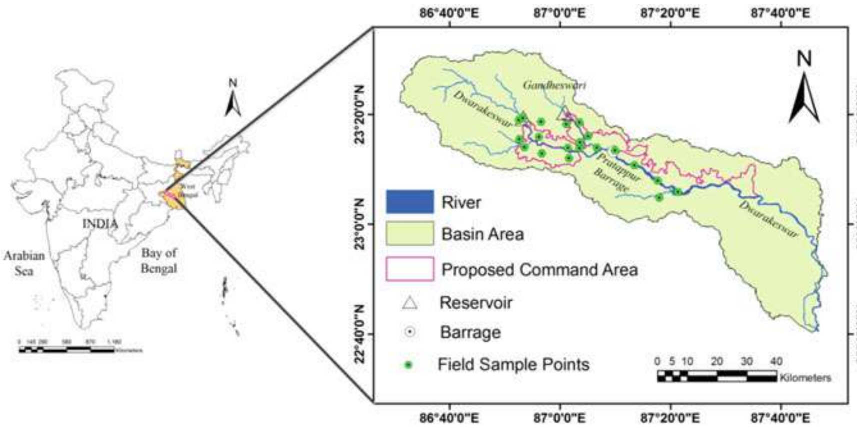

Fig. 1 Location map of the study area

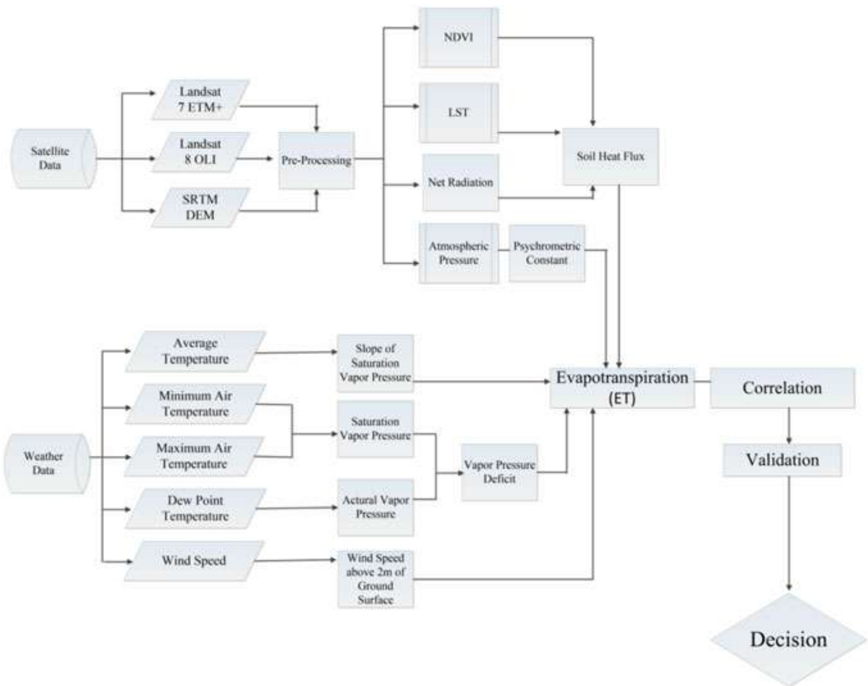

Fig. 2 Overall Methodology

States Geological Survey (USGS) (http://glovis.usgs.gov/). Weather data are collected from the NASA Prediction of Worldwide Energy Resources power.larc.nasa.gov site.

3.2 Methodology

3.2.1 Image Pre-processing

The images were collected in different time periods under different solar illumination, so the Sun angle correction was necessary. After Sun angle correction, the DN values of the images were converted to radiance.

Estimation of Evapotranspiration (ET)

An updated equation is recommended by FAO [28] with the FAO-56 Penman–Monteith Equation. Simplify the equation by using assumed constant parameters for a clipped grass reference crop. It was assumed that the definition for the reference crop is a hypothetical reference crop with a crop height of 0.12 m, a fixed surface resistance of, $70sm^{-1}$ and an albedo value of 0.23 [29].

The new equation is:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

where ET_0 is the reference evapotranspiration ($mm\ day^{-1}$); R_n is the net radiation ($MJ\ \ m^{-2}d^{-1}$); G is the soil heat flux ($MJ\ \ m^{-2}d^{-1}$); T is the mean daily air temperature at 2 m height ($\circ C$); u_2 is the wind speed at 2 m height (m s^{-1}); e_s is the saturation vapor pressure (kPa); e_a is the actual vapor pressure (kPa); $e_z - e_a$ is the saturation vapor pressure deficit (kPa); Δ is the slope of the vapor pressure curve ($kPa\ \ \circ C$); γ is the psychrometric constant ($kPa\ \ \circ C$).

4 Results and Discussion

4.1 Spatiotemporal Variations of Evapotranspiration

Based on the distribution of ET values in January 2014, 2015, and 2016, ET was very high in the higher elevated area of the basin, over Susanna hill, Tilaboni hill, Futiyari dam, Saheb Bandh lake and in the Jangalmahal, Beliatore forest area (Fig. 3). The ET values are also high in the West Midnapore, Hooghly, Purulia, and Bankura district over the study area. ET values are very low in the sandy region and the Burdwan district over the area. This value has gradually increased from 2014 to 2016. The minimum value of ET was found in the Purulia district and in the sandy region. In March, Higher ET value (>120 mm) was found in the Hooghly, West Midnapore, Burdwan and western part of the Bankura district over the study area, and as usual in the higher elevated area of the basin. The maximum portion of the study area is occupied by a medium ET value. In May 2014, the highest ET value was found in the Jangalmahal area, a little bit portion of the Hooghly, West Midnapore and Bankura district. However, in 2016, some portion of the Purulia is also showing a higher ET value.

In June 2014, the lower part of the river basin showed higher ET values, and in the Jangalmagal area, some portions of the Purulia district's ET values are high. In August 2014, the higher ET value was found in the upper part of the river basin, which includes the Purulia district over the study area and the Beliatore forest, Jangalmahal, Joypur jungle area. In September 2015, ET was very high (>152 mm) in the monsoonal flood zone, which includes the western part of Bankura, West Midnapore, Burdwan, and Hooghly district over the study area and also in the Susunia hill. In October 2014, 2015, 2016, higher ET value was found almost every portion of the study area. Susunia hill is showing the highest value as well as the lake, dam,

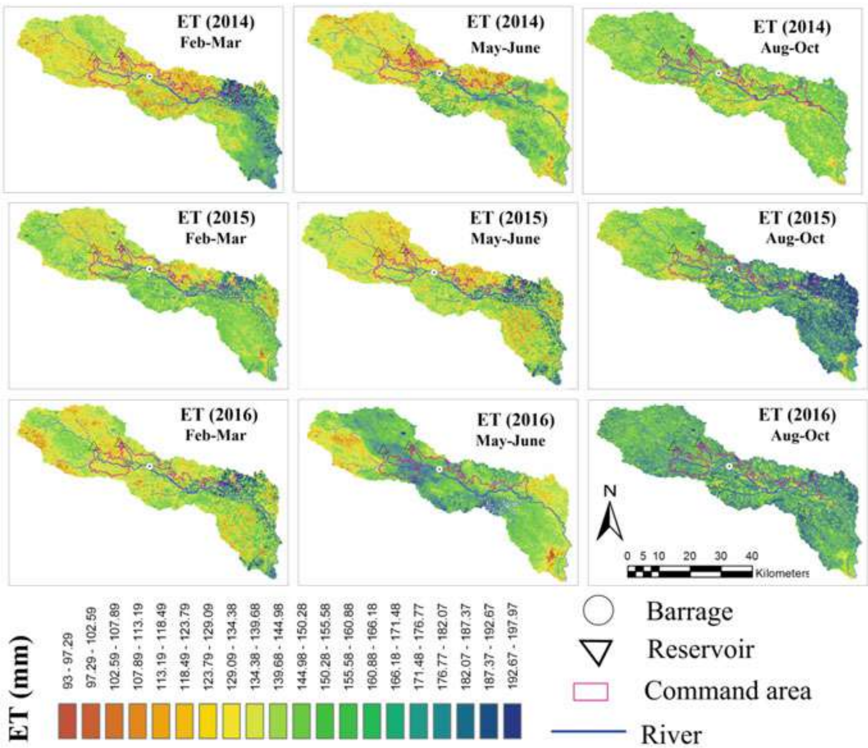

Fig. 3 Satellite-based ET mapping for Dwarakeswar-Gandheswari river basin

and forest areas. ET value was low in the sandy region. The result of ET values for October month in these three years does not vary very much.

Moreover, it could be said that the ET variation in this study area is closely related to crop growth (Fig. 4). The Hilly area and the water body like the dam and lake always show a high ET value. ET values are always lower in the sandy region and the settlement area.

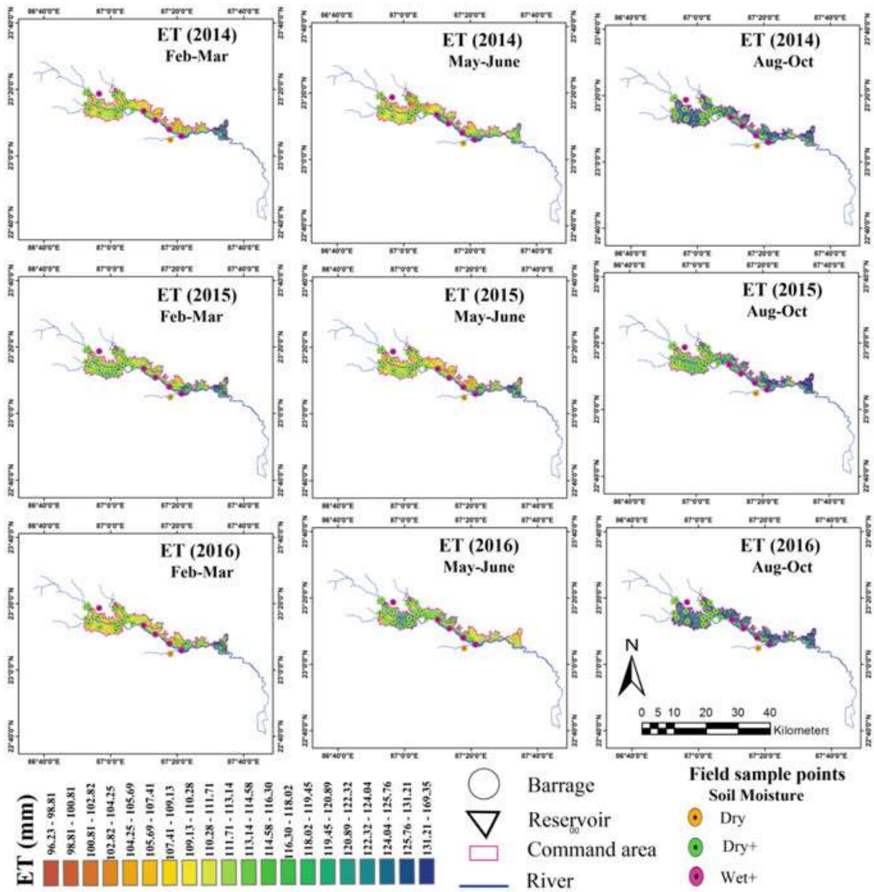

Fig. 4 Estimation of ET for proposed command area with field-based validation points

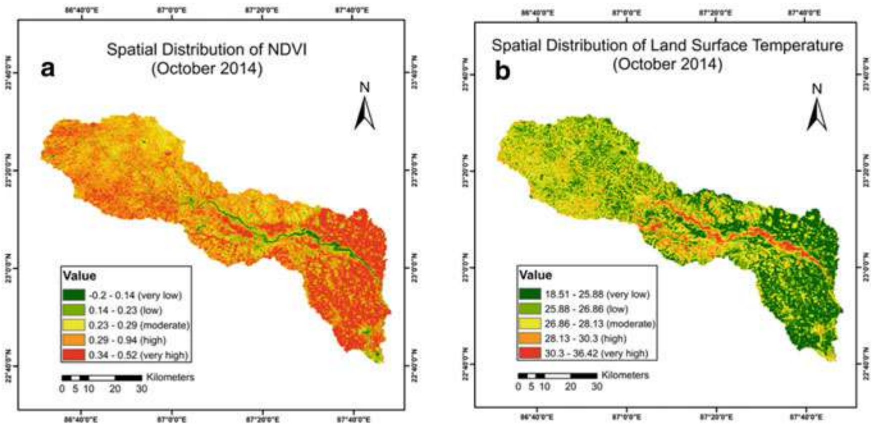

Fig. 5 **a** Spatial distribution of NDVI & **b** LST in October 2014

4.2 Correlation Analysis

4.2.1 NDVI and LST

The NDVI has been widely used for determining temporal LST changes. These images show that where NDVI values are high, LST values are low due to vegetation cover. Thus NDVI and LST represent a strong negative correlation. The water body is a special case, where both NDVI and LST values tended to be the lowest value (Fig. 5).

4.2.2 LST and Soil Heat Flux

The soil heat flux (G) is the energy that is heating the soil. Soil heat flux is positive when the soil is warming and negative when the soil is cooling. Thus Soil heat flux depends on Surface temperature and represents a positive correlation (Fig. 6).

4.2.3 NDVI and ET

Evapotranspiration is strongly related to vegetation. It is an essential component for assessing vegetation dynamics. Thus NDVI is an important variable for evapotranspiration, representing a significant positive relationship with ET (Fig. 7).

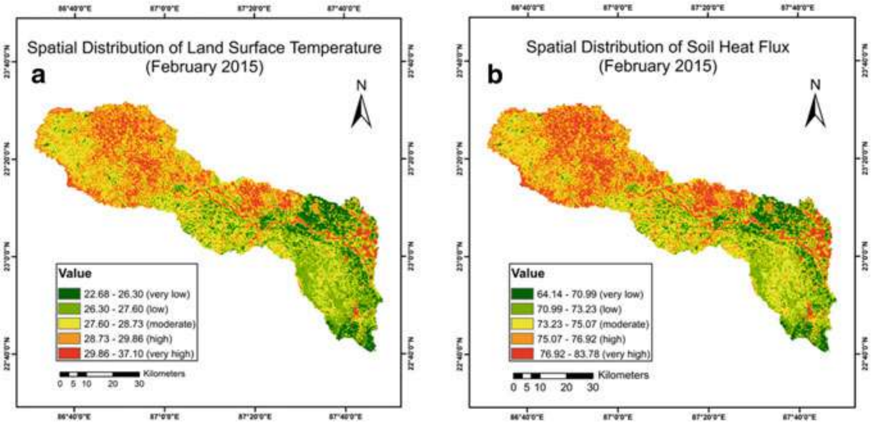

Fig. 6 **a** Spatial distribution of LST and **b** Soil heat flux in february 2015

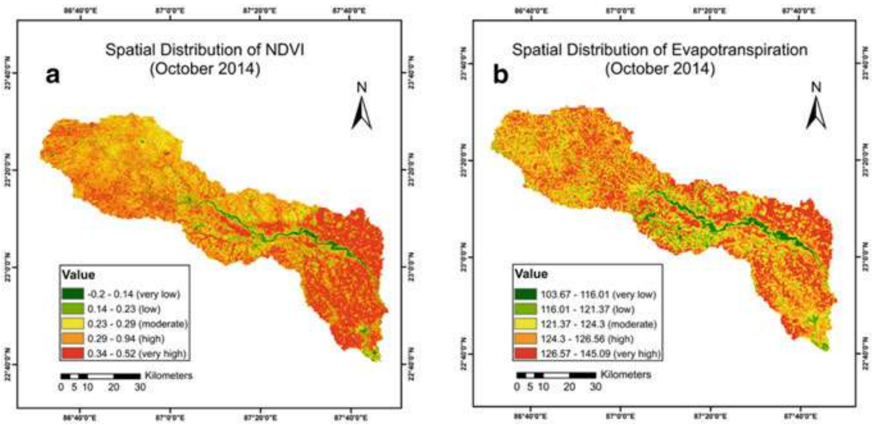

Fig. 7 **a** Spatial distribution of NDVI and **b** ET in October 2014

4.2.4 LST and ET

Evapotranspiration and LST maintain a negative relationship. Land surfaces with larger ET have lower LST. At the same time, air temperature, air humidity, wind speed, and solar radiation remain homogeneous over the land surfaces of interest (Fig. 8).

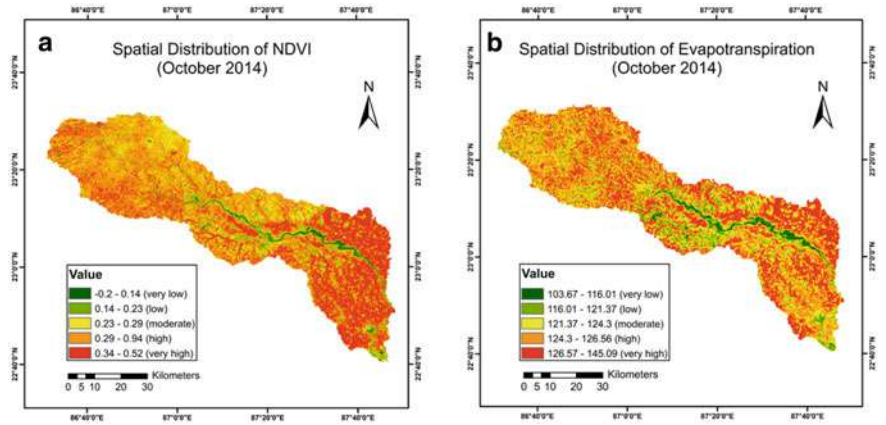

Fig. 8 **a** Spatial distribution of LST and **b** ET in October 2014

4.2.5 *Net Radiation (R_n) and ET*

Net radiation is the total energy that is available to influence the climate. The net radiation of the surface consists of the direct and diffused radiation and the atmospheric emission absorbed and retained by the surface. Therefore, evapotranspiration is strongly dependent on net radiation and represents a positive correlation (Fig. 9).

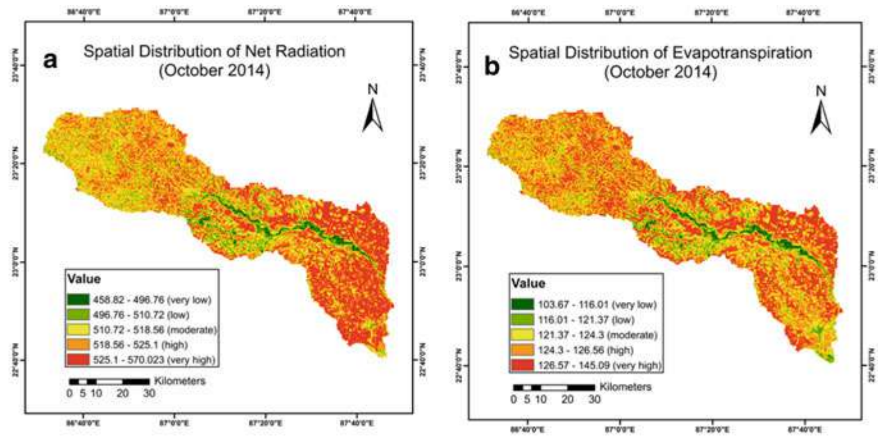

Fig. 9 (**A**) Spatial distribution of Net Radiation and (**B**) ET in October 2014

Table 1 Comparison between the estimated and the observed results of LST in 2015

	Minimum LST (°C)				Maximum LST (°C)			
Months	Estimated value	Observed value	Absolute error	Relative error (%)	Estimated value	Observed value	Absolute error	Relative error (%)
Feb-Mar	24.03	26.75	2.72	11.31918	36.57	37.07	0.5	1.367240
May-Jun	24.16	27.87	3.71	15.35596	31.21	37.45	6.24	19.99359
Aug-Oct	25.51	29.29	3.78	14.81771	36.23	36.59	0.36	0.993651

Table 2 The estimated and the observed results of ET in 2015

	Minimum ET (°C)				Maximum ET (°C)			
Month	Estimated value	Observed value	Absolute error	Relative error (%)	Estimated value	Observed value	Absolute error	Relative error (%)
Feb-Mar	100.399	94.2	6.199	6.1743	114.12	106.3	7.82	6.8524

4.3 Validation

4.3.1 Validation of Land Surface Temperature with MODIS LST

To validate the result of LST Table 1 was made to estimate the absolute and relative error between observed LST values collected from the C6 MODIS LST product (MOD11_L2) and estimated LST values using the above equations.

For minimum LST values, the maximum and absolute minimum errors are respectively 5.05 °C (relative error 26.5%) and 2 °C (relative error 10.9%). The maximum and absolute minimum error for maximum LST values are respectively 4.18 °C (relative error 14.8%) and 0 °C (relative error 0%). These results indicate that this LST estimation method has a small error that may be due to cloud cover, haze, or noise.

4.3.2 Validation of Evapotranspiration with MODIS ET

The estimated ET image of February 2015 was compared to the MODIS ET product in the same month and year (Table 2). For minimum ET values, the absolute error is 6.12 (relative error of 6.17%) and for maximum ET values, the absolute error is 7.82 (relative error of 6.85%).

5 Discussion

The ET estimation is very important for regional scale (e.g. River basin) using satellite-derived data. Penman–Monteith method is used for seasonal/monthly ET estimation purposes using a GIS environment. All utilized parameters are derived through meteorological and satellite data. Four satellite data (SRTM, Landsat ETM + , Landsat OLI, and MODIS) are used for ET calculation. Seven MODIS/Terra LST/Emissivity 8-Day L3 Global 1 km SIN Grid products (MOD11_A1) are utilized for LST [30]. The MODerate Resolution Imaging Spectrometer (MOD16) global ET (MOD16A2) dataset is used for validation purposes [31]. The results show inconsistent comparisons with MOD16 ET. Seasonal time periods (Feb-Mar, May–June, and Aug-Oct) are considered for 2014, 2015, and 2016. The limitation of the research is that rainy season images could not be used due to high clouds, haze, and noise. The collected data used in the model directly affects the accuracy of the ET. The model involves many parameters, and errors in each parameter can affect the calculated results. Further, it is required high spatial resolution satellite data and a denser network of meteorological stations to improve the model. Sensitivity analyses are needed to level of agreement between input and output errors in the study area.

6 Conclusions

This study aims to estimate ET based on Landsat satellite dataset, and the SRTM DEM for Dwarakeswar -Gandheswari river basin based on the FAO-56 Penman–Monteith method. A comparison of the estimated results of ET with the NDVI indicates a good relationship over the study area. ET and NDVI distribution in the study area are strongly correlated. Susunia hill, Tilaboni hill, and the lower part of the river basin, including Burdwan, Hooghly, West Midnapore, and western parts of Bankura district over the study area have higher NDVI, typically have greater ET. Some portions of the Purulia district with sparse vegetation coverage normally have very low ET. ET values for the forests and vegetated areas, where the distribution of vegetation is highly variable, are relatively heterogeneous. ET change in the river basin is closely related to crop growth. The maximum monthly ET values in the entire study area were observed in irrigated cropland and the mountain areas. During the harvesting periods, ET is notably lower than in other months.

In the summer season, some portions of this area are clearly dependent on the irrigation applied. Spatial differences in yield were caused by differences in irrigation scheduling, especially during the dry season when the irrigation schedules were not able to meet the full crop requirements, the yield was reduced. Overall, the ET estimates depend on several factors, including climatic conditions and irrigation from a groundwater well, vegetation rate, and cropping pattern in these areas. High ET rates from water bodies were an indication of very high evaporative water. Moreover, ET results indicate the crop water stress scenarios and the need to differentiate between irrigated and non-irrigated areas. The present analysis is helpful for planning a water resources project with hydraulic structure(s).

7 Recommendations

A few recommendations have been proposed for a sustainable agriculture water management framework under changing climatic conditions using remote sensing & GIS techniques.

i. High-resolution satellite data can be used for ET estimation purposes.
ii. Different hydrological models can be used for long-term evapotranspiration estimations purposes.
iii. Climate data can be correlated with evapotranspiration for drought assessment purposes.
iv. The generated output can be used for future planning of agriculture water management purposes.

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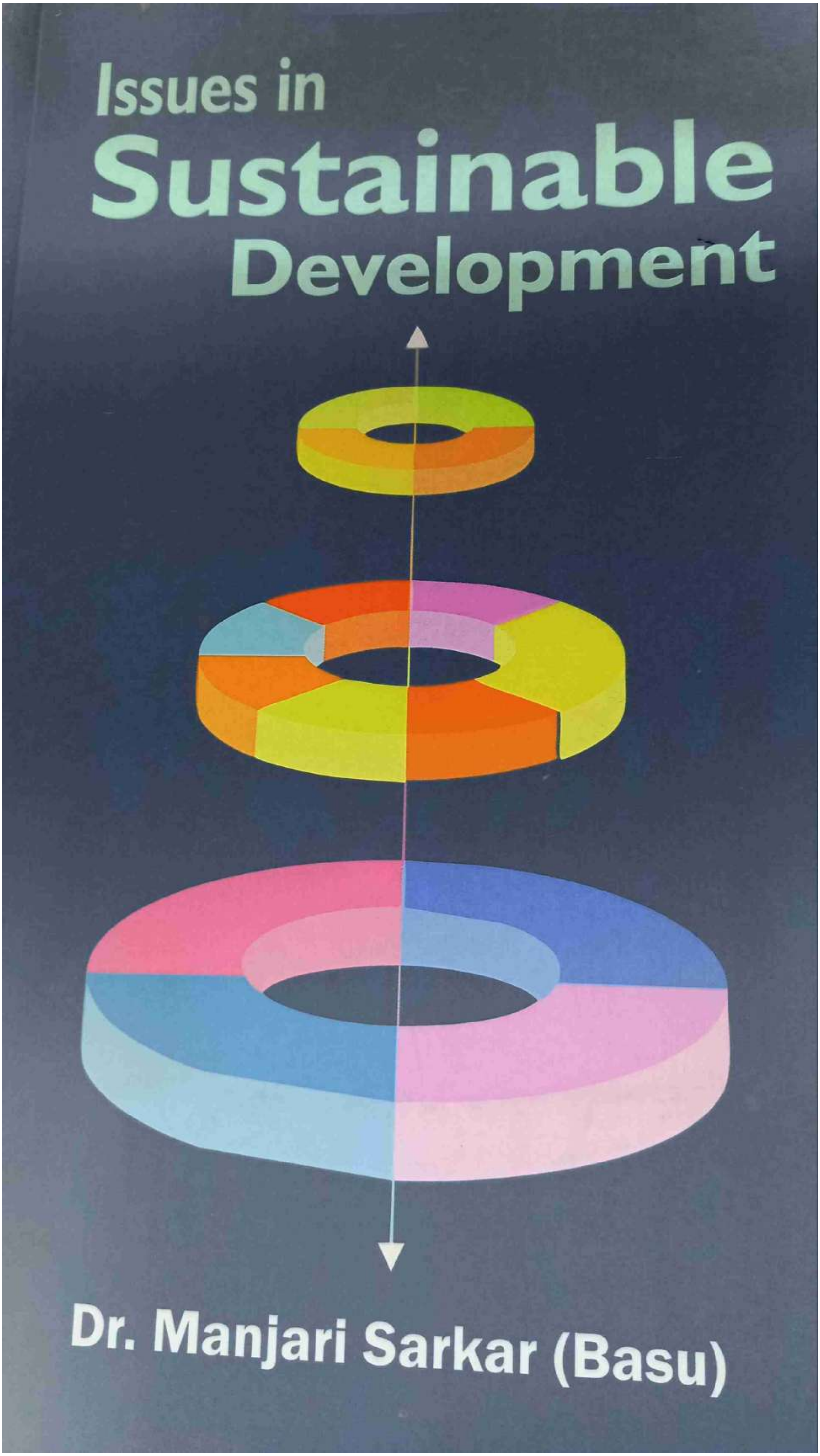
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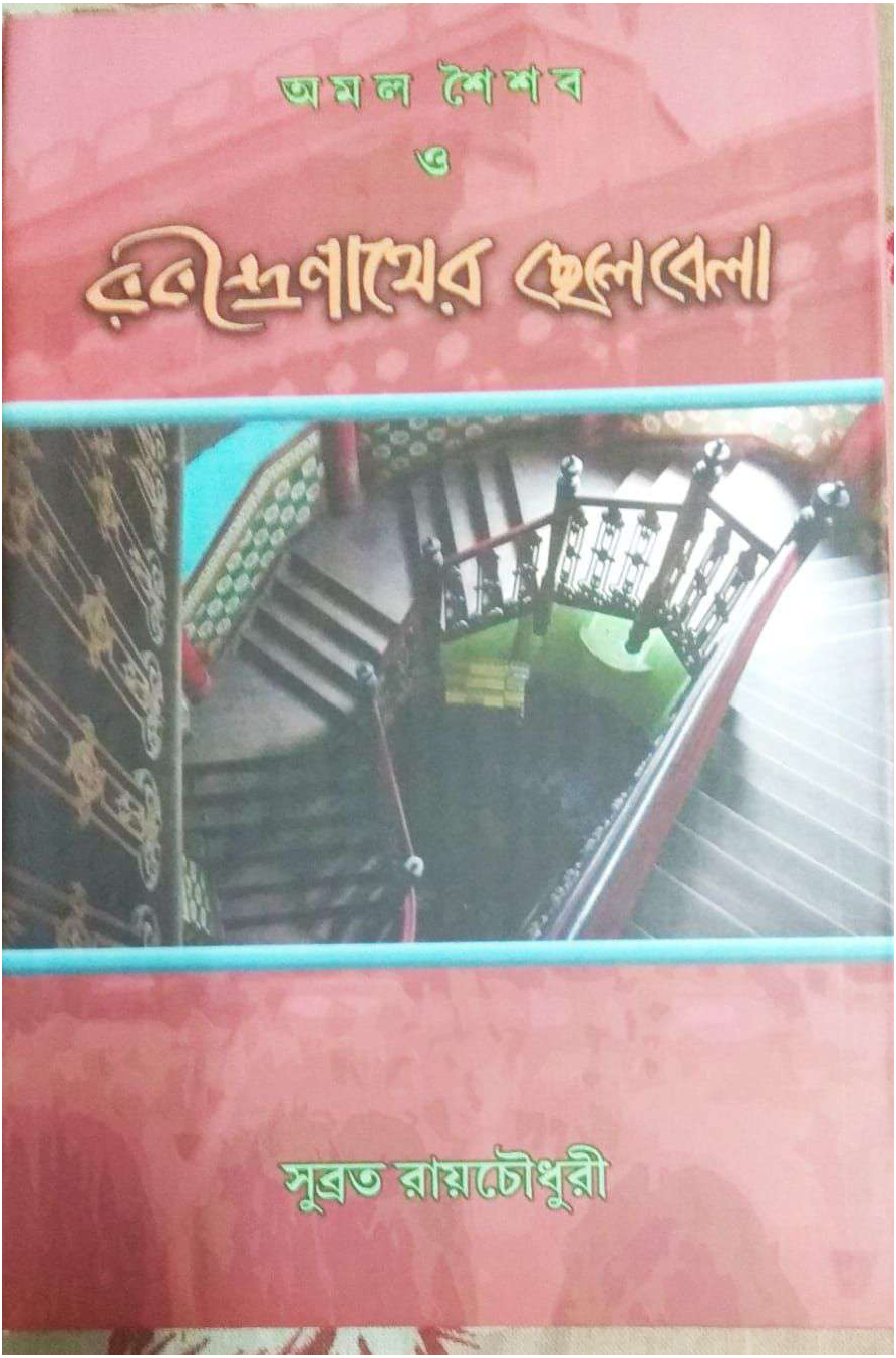


১২৫ বর্ষে বঙ্গীয়-সাহিত্য-পরিষৎ

সম্পাদনা

বারিদবরণ ঘোষ   রতনকুমার নন্দী

বঙ্গীয়-সাহিত্য-পরিষৎ

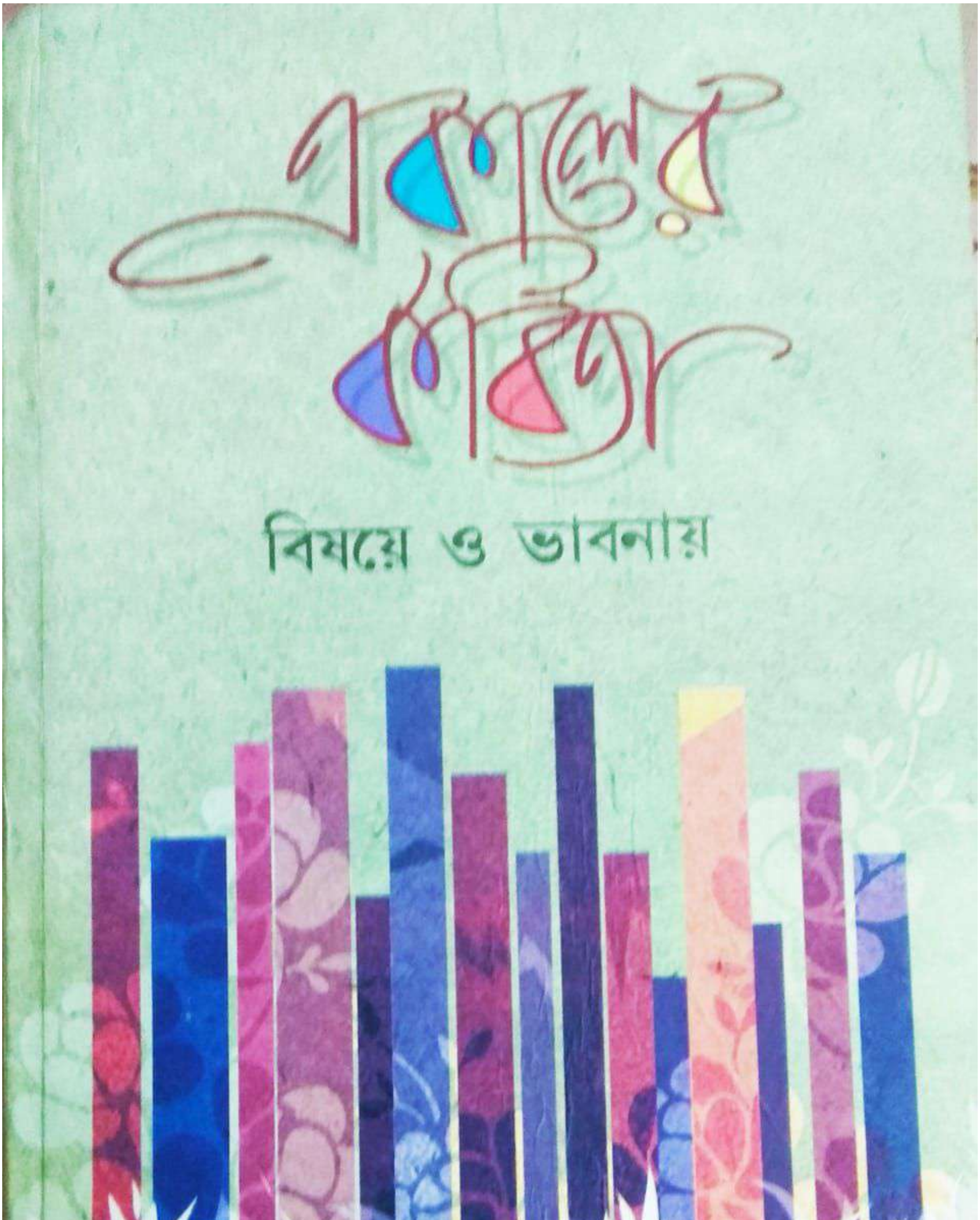
ভাষা বিতর্কে বঙ্গীয়-সাহিত্য-পরিষৎ

সুব্রত রায়চৌধুরী

বাঙালি জীবনে আত্মজাগরণের সাড়া পড়ে গিয়েছিল উনিশ শতকের দ্বিতীয় অর্ধে। শিক্ষিত মধ্যবিত্ত বাঙালি তরুণ শুধু রাজনীতিতে নয়, শিক্ষায় সংস্কৃতিতে ইউরোপীয়দের প্রতিস্পর্ধী একটি মননভূমি তৈরি করে নিতে চাইছিলেন। তবে এই ঝোঁক অনেক ক্ষেত্রেই হয়ে উঠেছিল দেশীয় সংস্কৃতির সঙ্গে সামঞ্জস্যহীন ইংরেজি ভাষা-সাহিত্য ও সংস্কৃতির একটি বিলাসী অনুকরণ। অথচ জাতীয় জাগরণের জন্য প্রয়োজন জাতীয় সাহিত্য, জাতীয় ভাষানীতি। ইংরেজি শিক্ষিত উচ্চ মধ্যবিত্ত তরুণের উদাসীনতায় জাতিসত্তার এই বিকাশ সম্ভব ছিল না। তা অনুভব করতে পেরেছিলেন ইউরোপীয়রাই। যাঁদের রবীন্দ্রনাথ 'বড়ো ইংরেজ' বলেছেন তাঁদেরই অন্যতম জন বিম্‌স্ (১৮৩৭-১৯০২) ১৮৭২-এ নবজাগ্রত বাঙালিকে শোনালেন বাংলা ভাষা-সাহিত্যের অনুশীলন ও উন্নতির জন্য একটি 'বঙ্গীয় সাহিত্য সমাজ' বা 'বঙ্গ একাডেমি' (Academy of Literature for Bengal) প্রতিষ্ঠা করা প্রয়োজন। তিনি লিখেছেন—

> In 1872 I published at Calcutta a small pamphlet in which I advocated the formation of an Academy of Literature for Bengal[১]

আসলে বিম্‌স্ ভারতীয় ভাষাগুলির মধ্যে সর্বাধিক সমৃদ্ধিশালী এবং সম্ভাবনাপূর্ণ বাংলা ভাষা-চর্চায় একটি বিপরীতমুখী প্রক্রিয়া লক্ষ করেছিলেন। একদল সংস্কৃতপ্রেমী পণ্ডিত এ ভাষাকে ক্রমশই আরবি-ফারসির ছোঁয়া বাঁচিয়ে সংস্কৃতগন্ধী তৎসম শব্দের বহুল ব্যবহারের মধ্যে দিয়ে সাধারণের বোধাতীত করে তুলছিলেন। বিপরীতক্রমে সাধুভাষা বর্জিত রূঢ়, কর্কশ অশ্লীল শব্দের সমাবেশে কেউ কেউ ভাষা ব্যবহারে স্বেচ্ছাচারীর ভূমিকাও নিচ্ছিলেন। ভাষাচর্চায় এই বিশৃঙ্খলা থেকে ভাষাকে মুক্ত করার জন্য বিম্‌সের পরামর্শ মেনেই ২১ বছর পরে প্রতিষ্ঠিত হল 'The Bengal Academy of Literature'; দিনটা ছিল রবিবার, ৮ শ্রাবণ, ১৩০০ বঙ্গাব্দ (২৩ জুলাই ১৮৯৩)। কলকাতার ২/২ নবকৃষ্ণ স্ট্রিটের শোভাবাজার রাজবাড়িতে সুপণ্ডিত লুই লিওটার্ড, ইংরেজি ভাষা ও দর্শন শাস্ত্রে সুপণ্ডিত হীরেন্দ্রনাথ দত্ত, কবি ও সমালোচক ক্ষেত্রপাল চক্রবর্তী, বিনয়কৃষ্ণ দেব প্রমুখ ১৭জন বাংলাভাষাপ্রেমী মানুষের প্রচেষ্টায় সেদিন স্থাপিত হয়েছিল বাংলা ভাষাচর্চার এই প্রথম প্রতিষ্ঠানটি।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