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Analytic Hierarchy Process (AHP) and Geoinformatics based Site Suitability Analysis for Rainwater Harvesting Structures in West Bengal Dry Land Area

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Abstract

Water is a precious necessity for humanity. Yet due to dynamic climatic conditions, in Bengal dry land areas, water table is showing a receding trend. Keeping in view this dictum, the present study has been carried out. The study is based on data and field check, to identify the most suitable site for the planning of rainwater harvesting structures in the area and its hinterland, mainly to surface water purification and increase the groundwater resources for sustainable development. Determination of Rainwater Harvesting (RWH) potential sites' study uses various GIS inputs which were prepared using satellite images and integrated with weighted overlay techniques in a GIS environment to derive suitable sites for soil and water conservation structures. Analytic Hierarchy Process (AHP) has been applied to normalize the different factors as per their influences. All the factor values were summed up, and the overall site suitability score was computed according to conservation RWH structure suitability. Based on site suitability results, topographic characteristics, and locations for conservation structures, 76 check dams, 12 percolation tanks, 348 ponds, 50 farm ponds, 18 stop dam and 21 reserves were selected for implementation of soil and water conservation structures. They will sustain the productivity of surface water urtication and increase the groundwater resources for future in and around Bengal's dry-land areas. The outcome of this study may be replicated in an identical terrain condition for sustainable development planning.

Key words: Dry-land; RWH; RS; GIS; GNSS; AHP; WIO; Site-Suitability; Superimposed

Introduction

Water plays a vital role in fulfilling the basic human need for life and health and in socio-economic development. Throughout the world does not have access to clean water for domestic use purposes? The biggest challenge of the 21st century is to overcome the growing water shortage. Due to pollution of both groundwater and surface waters and the overall increased demand for water resources as a result of global climate change and population growth, many communities worldwide are approaching the limits of their traditional water resources. Mainly the availability of water is limited during summer due to large fluctuations of precipitation and low capacities to store water, even in areas with high rainfall and low evapotranspiration [1]. As the primary source of water is rain, it becomes necessary for us to harvest it effectively. We can maximize the storage and minimize the wastage of rainwater. Today rainwater harvesting system is crucial for the semi-arid geographical area in the world. But the success of these systems mainly depends on identifying suitable sites and technology. Therefore, researchers are increasingly recommending the collection of rainwater using the vegetation of ecosystems, the establishment of systems for collecting rainwater, and an increase in the output of available water resources [2]. Many methods have been proposed to deal with water shortage so far. However, among different methods, RWH is the best method to combat water shortage in arid regions because rainwater is fresh and can be easily collected [3]. However, selecting appropriate sites for rainwater harvesting potential on a large scale presents a significant challenge. It is necessary for all physiographic and climatic data in the study region. Remote Sensing (RS) and Geographical Information Systems (GIS) help facilitate the task for large areas and permit rapid and cost-effective site surveys. Integration of Remote Sensing [4]. GIS techniques provides reliable, accurate and updated database on land and water resources, which is a prerequisite for an integrated approach in identifying suitable sites for water harvesting structures. Using RS, GIS and AHP, the present study endeavors to locate the site for water harvesting structures in West Bengal dry-land area. The people are practicing the unplanned manner to store the water [5]. This study also provides the suggested sites for water structures planned for conservation and better water utilization [6]. The study aims to identify RWH suitable sites using GIS and AHP integrating model for rainwater harvesting structures and improve groundwater layer for the conservation and better utilization of rainwater in and around the West Bengal dry-land area.

Materials and Methods

Study Area

The dry-lands of the West Bengal were selected to implement this study due to their considerable divergence in topography and climate. The study area is approximately 28,697 sq.km, and geographically extended between 85° 40' E to 88° 15' E longitudes and 21° 45' N to 24° 45' N latitude over six districts Purulia, Bankura, Jhargram, West Birbhum, and West Medinipur (Figure 1).

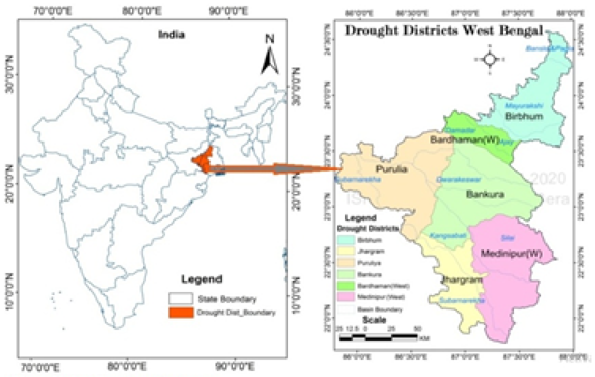

Figure 01, Location Map of Study area

Figure 1: Location Map.

The climate, in general, falls in the dry zone (drought) classification. Rainfall ranges between 1100-1400 mm/year, the average daily maximum temperature is 45℃ in the summer, and the average daily minimum temperature is 10℃ in the winter. The major drainage system comprises of Kangsabati/Kansai, Subarnarekha, Silai, Damodar, Dwarakeswar, Ajoy, Dwarka, Juneurakshi, Bramhine, Bansoli, Pagla and its tributaries. Site selection for RWH structures depends on various spatial data of fine spatial resolution. The selected parameters are considered as per previous studies summarized in Table 1. Several types of RWH exist in the study area to satisfy water requirements for agriculture and groundwater recharge. The criteria for site search analysis are based on an intensive literature review (Table 1), use of indigenous knowledge and expert knowledge [7-14].

Author (s)	Soil (HSG)	Slope	LU/LC	Drainage/ Order	Climate (Rainfall)	Geology Lineamen t	Litho/ GM	Pond	Socio-Economy	GWP
Ibrahim et al. 2019	1	1	1	1				1		
Weerasinghe et al. 2011	1	1	1							
Gavit et al. 2018	1	1	1	1		1				
Adham et al. 2018	1	1	1	1						
Dabiri et al. 2016	1	1	1							
Prasad et al. 2014	1	1	1	1		1	1			
Zheng et al. 2018	1	1	1							
Mishra& Panda. 2015	1	1	1	1		1	1	1		1
Lohar et al. 2018	1	1	1	1		1				
Kumar et al. 2017	1	1	1	1		1				
Singh et al. 2009	1	1	1	1						
Adham et al. 2016	1	1		1	1				1	
Dwiatmojo et al. 2021	1	1	1	1	1					
Mahmoud &Alazba. 2015	1		1		1					
Buraihi&Shariff 2015	1	1	1	1						

Ahmad&Goparaju. 2017	1	1	1	1	1					
Forzieri et al. 2008		1	1		1					1
Mati et al. 2007	1	1	1		1					1
Tsiko and Haile 2011	1	1			1				1	
Tumbo et al. 2013	1	1	1	1	1				1	
Asala. L 2015	1	1	1	1		1	1	1		
	Litho/ GM=Lithology/Geomorphology, GWP= Ground Water Potentiality									

Table 1: Literature review for selection of parameter and potential RWH sites.

Criteria used for identification of potential RWH sites

In this study, ten parameters were considered for identifying suitable surface rainwater harvesting sites that need to be overlaid in a GIS environment to develop a successful suitability model for surface rainwater harvesting. These parameters include; lithology (surface), geology (lineament and fault), slope (topography), soil (hydrological soil group), rainfall (climate), drainage (stream order), pond density (existing surface water body), land use/cover (surface cover) and another factor although indirectly linked to RWH, yet was considered was potential groundwater zone (for future perspective sustainable groundwater use through implementation of RWH in the high potential zone) and socio-economic issues (accessibility, population density, peoples' priority and land-use practices) of the dry-land area under consideration.

Lithology (Surface): Lithology was categorized into five major units, which are: (1) basic lava (2) laterite and lateritic soil (3) mica schist with hornblende schist (4) granite/ gangpur granite&gravel; and (5) sandstone, silt, shale, red&brown clay (Figure. 2a). All these rock types were classified according to the scale of RWH suitability by their properties in Table 2.

RWH Structure	Type	Application
Recharge Structure	Checked dam	Recharge to aquifer and surface storage for dry period demand based supply for live saving irrigation and domestic use
	Percolation tank	
Storage Structure	Pond	For livestock storage and restricted irrigation
	Farm pond	
	Stop dam	Surface storage restricted irrigation
	Reservoir	Surface storage agricultural irrigation and drinking water supply by purification as well as hydro power

Table 2: Specification of proposed RWH Structure's&Application.

Geology (Lineament&Fault): Another important factor like geology control the surface water structures mainly lineaments and Faults are considered. A lineament was extracted from the DEM data (GLCF). The lineaments are shown in Figure 2.b. Lineament density map was generated because it collects the water and where the water is accumulated and stored high volumes of water when it rains). Different classes of lineament density corresponding to their percentages were categorized in Table 2.

Slope (Topography): The slope map (Figure. 2.c was prepared from a Digital Elevation Model (DEM) with 30-m resolution to maintain the continuity of water flow to the catchment outlet In the study area, slope has been categorized into five classes, *i.e.* very low, low, medium, high and very high. The lower slope values indicate the flatter terrain (gentle slope), and higher slope values correspond to the steeper slope of the terrain. In surface rainwater harvesting assessment, it is an essential factor, combined with other factors for site location and implementation of all ground-based rainwater harvesting technologies since it depicts areas with preferable high proportion of surface runoff. The different classes of slopes corresponding to their percentages were categorized in Table 3.

Parameters	Sub Classes	Suitability	RWH Structures Remarks
Lithology	Basic Lava	High	Check Dam, Reservoir
	Laterite and Lateritic soil	Low	Restricted
	Mica schist with Hornblende Schist	Medium	Percolation Tank, Pond
	Granite/Gangpur Granite&Gravel	High	Check Dam, Reservoir
	Sandstone, silt, shale, Clay (R&B)	High	Percolation Tank, Farm Pond
Geology (Lineament & Fault)	>8	Very High	Check Dam, Reservoir
	8-16	Medium High	Percolation Tank, Farm Pond
	16-24		
	24-32	High	Pond, Farm Pond
	<32		
Slope	Flat	High to Very High	Check Dam, Reservoir, Percolation Tank
	Undulating/gently sloping		
	Sloping	High	Farm Pond, Ponds
	Hilly	Medium	
	Steep	Low	Restricted
Hydrological Soil	Group A	Moderate	Check Dam, Reservoir, Percolation Tank
	Group B		
	Group C	Medium High	Pond, Farm Pond
	Group D	High	
Rainfall Weekly (mm)	130.42 to 154.72	Medium to High	Pond, Farm Pond
	154.73 to 162.97		
	162.98 to 165.78	High	Check Dam, Reservoir, Percolation Tank
	165.79 to 174.04	Very High	
Drainage (Stream order)	1st&2nd order	Medium High	Pond, Farm Pond, Check Dam
	3rd&4th order		
	5th&6th order	High	Reservoir, Percolation Tank
Pond	High Density	High	Pond, Farm Pond
	Moderate Density	Medium	Percolation Tank
	Low Density	Medium to High	Check Dam, Reservoir
	Very low Density		
Land use/ Cover	Crop land	Medium	Check Dam, Percolation Tank
	Water bodies	High	
	Built-up land	Low	Pond, Farm Pond
	Forest land	High	Check Dam, Reservoir

	Shrub land	Medium	Check Dam
	Fallow land		Percolation Tank, Pond
Potential Groundwater Zone	High	High	Pond, Farm Pond
	Moderate	High	Check Dam, Reservoir, Percolation Tank
	Low		
Socio Economy Criteria (Activity)	Class 1	Medium High	Check Dam, Reservoir
	Class 2	Medium	Percolation Tank, Pond, Farm Pond
	Class 3	High	

Table 3: General Criteria of each Thematic Layer and Constraints for RWH Suitability.

Soil (Hydrological Soil Group): The partials containing soil are categorized into four Hydrologic Soil Group [HSG] groups A,B,C&D followed by USDA Natural Resources Conservation Services (NRCS) guideline. An HSG group A and B is suitable for water harvesting structures that allow retention of water. On the other hand, HSG C and D are good in infiltrating runoff into the underground to recharge the aquifers. The Soil data has been procured from the National Bureau of Soil Survey&Land Use Planning, Nagpur. The same is converted to digital format. The various characteristics of HSG are shown in Table 2 and the spatial extent of these soil groups is demonstrated with the help of Figure.2.d.

Rainfall (Precipitation): RWH systems can only function where sufficient rainfall occurs by any structures. Average daily rainfall for the period 1980–2019 was collected from NASA (NASA/POWER SRB/FL ASHFlux/MERRA2/G EOS 5.12.4 Grid 0.50x0.50) database. The weekly rainfall amount in the study area was determined by applying the Inverse Distance Weight (IDW) function to interpolate the data from forty-two stations. This IDW method is commonly used to estimate values at unmeasured locations and to get the rainfall's spatial variability across an area or a catchment. The rainfall depth data was then reclassified and scored, as shown in Table 2. Areas with high annual rainfall are ranked as highly suitable (Figure 2e).

Drainage (Stream order): The drainage line was extracted from the DEM image with a spatial resolution of 30 m. Drainage lines are divided per their order, followed by the hierarchical connection proposed by the Strahler stream order. The drainage flow and pattern is controlled by initial slope and topography. There was a total of 13270 streamlets found in the dry-land area, out of which 2865 streamlets are of 1st order, 6616 of 8451894 m are of 2nd order, 3155 of 4135586 m, 3rd order 1704 of 1988908 m, 4th order 977 of 1063376 m, 5th order 425 of 523837 m and 6th order 393 of 399058 m. The total length of the streams was found to be 2819.54 km. The stream order existing in this study area is marked in Figure 2.f, where different potential RWH sites are classified in Table 2.

Pond (Surface Water): Ponds are mapped from the MSS satellite image and updated from Google Earth. 466 total ponds were identified; IDW method was applied for categorization and suitability analysis (Table 3) of pond density (Figure.2.g).

Land Use/Cover: The land use of an area influences runoff and is also an important indicator for selecting suitable sites for harvesting rainwater. The cloud-free geocoded digital data of Landsat ETM+ data was downloaded from the GLCF. Band 1, 3 and 4 of the Landsat ETM + images were used to create the land-use/land-cover map, supervised classification approach using the maximum likelihood method Different land use classes obtained after classification (accuracy level 90.17%) are given in Figure 2h.

Potential groundwater zone: Artificial groundwater recharge is, therefore, a solution to this challenge since it complements the natural recharge. Thus, in this study, groundwater potential zones (Figure 2i) were considered over the RWH suitability site (Table 3). Therefore, the groundwater potential zone in the study area has been classified into three zones, namely, low (8,625 sqkm), medium (10,989 sqkm) and high (9,082 sqkm), respectively.

Socio economy criteria (Activity): The socio-economic parameters ((Figure 2j) influence how suitable the intervention is for the main stakeholders. Identifying good indicators for socio-economic conditions concerning the functioning of these RWH systems (Table 3) is much more complex than the biophysical ones. In this study, based on the primary activity link, people give more importance than other activity link people, primarily focusing on the socially backward population.

On the basis of IMSD&FAO guidelines, the following parameters (Figure 2) were selected as requirements for suitable site. The methodology adopted in this study for finding the RWH suitable site of the structure is given in Figure 3.

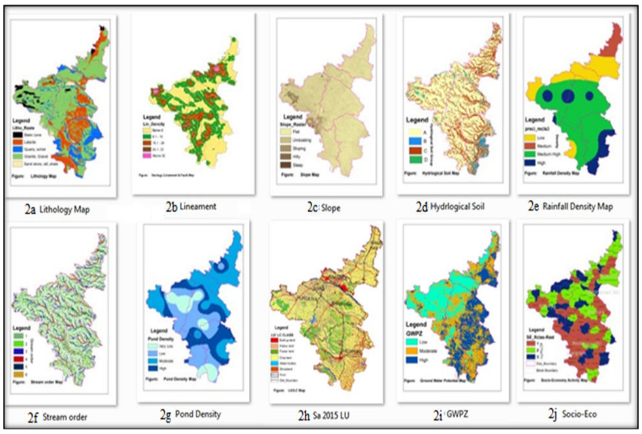

Figure 2: Reclassified Parameter Maps.

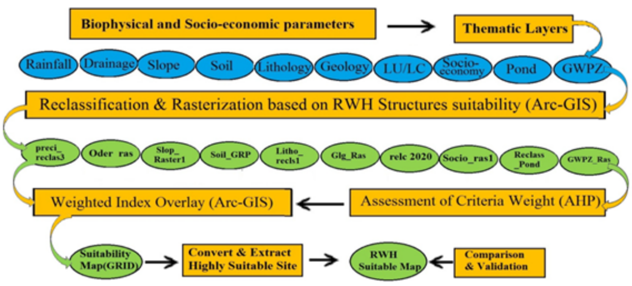

Figure 3: Conceptual methodology for generation of RWH structures site suitability mapping.

Specification of proposed RWH Structures:

Specific guidelines from IMSD&FAO were also taken into consideration regarding some of the conditions that must be followed to sustainably implement surface rainwater harvesting study. Selected RWH Structure's&application are summarized in Table 2.

Selected important parameters for determining appropriate areas of RWH systems evaluated by several experts 'selection criteria (Table 1) and then all parameters and their sub classes wise suitability categorized in Table 3.

Each criterion's relative importance weight is vital for decision-makers since each factor has a varying significance. Therefore, decisions made on multi-criteria analysis are based on each criterion's relative importance weight (parameter) [15]. A pairwise comparison method, commonly known as Analytic Hierarchy Process (AHP), is mainly used and has been adopted for this study. It involves the evaluation of each criterion against each other criteria, which is done in pairs to decide which criterion is more significant than the other for a given aim. Table 4 shows the rating used to compare the two criteria on a 9 point continuous scale proposed by Saaty [16].

Intensity of significance	Description
1	Equally importance
2	Equally to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance
Reciprocals of above	If an activity i has one of the above non zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.

Table 4: The Scale of Pair wise Comparison.

RWH related parameters pairwise comparison has been made according to their influence in the study area [16]. To fill a table matrix (Table 5), the values are written on the diagonal top right box. Then, the lower diagonal left box cells are the inverse values of the top diagonal box. This is done to convert the qualitative terms to what extent a factor is more significant than the other into quantitative terms, thus giving it the rating weights. Table 8 represent the quantitative terms of how each factor affect the selection of site search analysis.

Parameters	Rainfall	Drainage	Slope	Soil	Lithology	Geology	Pond Den	LU/C	Socio-eco	PGW
Rainfall	1	2	3	4	5	6	7	8	9	10
Drainage	0.5	1	2	3	4	5	6	7	8	9
Slope	0.33	0.5	1	2	3	4	5	6	7	8
Soil	0.25	0.33	0.5	1	2	3	4	5	6	7
Lithology	0.2	0.25	0.33	0.5	1	2	3	4	5	6
Geology	0.17	0.2	0.25	0.33	0.5	1	2	3	4	5
Pond	0.14	0.17	0.2	0.25	0.33	0.5	1	2	3	4
LU/C	0.13	0.14	0.17	0.2	0.25	0.3	0.5	1	2	3

Socio-eco	0.11	0.13	0.14	0.17	0.2	0.25	0.33	0.5	1	2
GWP	0.1	0.11	0.13	0.14	0.17	0.2	0.25	0.33	0.5	1
∑	2.93	4.83	7.72	11.59	16.45	22.25	29.08	36.83	45.5	55

Table 5: Pair wise comparison of parameters.

Weights are calculated by normalizing the eigenvector associated with the maximum eigenvalue of the matrix [17]. Then the Consistency Ratio (CR) is computed to check the consistency of comparisons by using the following formulas:

CR=(Consistancy Index (CI))/(Random Inconsistency Index (RI))

CI=(λ max-n)/(n-1)

Where: λ max-Principal Eigen-value=sum of products between each elements of the priority vector and column total, n=number of comparisons/criteria

According to Saaty, if the consistency ratio (CR)>0.10, then some pair-wise values need to be reconsidered and the process is repeated till the desired value of C<0.10 is reached (Table 6).

N	RI
1	0
2	0
3	0.58
4	0.9
5	1.01
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51

Table 6: Random Indices (RI).

AHP is particularly useful in multi-index evaluation and consists in our RWH evaluation tool of the following steps:

i. Selection of RWH structure's (Table 2) and parameters (Table 3).

ii. Classification of suitability for each parameter and their sub-classes (Table 3).

iii. Parameters pair wise comparison (Table 4) for their influences calculation (Table 5).

iv. Normalized the matrix (Table 7) for weightage calculation.

v. Statistical and GIS analysis for generation of suitability maps through weighted overlay index model.

vi. Most RWH suitable site identification (Figures 4-8).

Parameters	Rainfall	Drainage	Slope	Soil	Lithology	Geology	Pond Den	LU/C	Socio-eco	PGW	Priority vector
Rainfall	0.341	0.414	0.39	0.35	0.303	0.269	0.24	0.217	0.197	0.182	0.29
Drainage	0.17	0.207	0.26	0.26	0.243	0.224	0.21	0.19	0.175	0.164	0.209
Slope	0.112	0.103	0.13	0.17	0.182	0.179	0.17	0.162	0.153	0.145	0.151
Soil	0.085	0.068	0.06	0.09	0.121	0.134	0.14	0.135	0.131	0.127	0.109
Lithology	0.068	0.051	0.04	0.04	0.06	0.089	0.1	0.108	0.109	0.109	0.078
Geology	0.058	0.041	0.03	0.03	0.03	0.044	0.07	0.081	0.087	0.091	0.056
Pond	0.047	0.035	0.03	0.02	0.02	0.022	0.03	0.054	0.065	0.073	0.04

LU/C	0.044	0.028	0.02	0.02	0.015	0.013	0.02	0.027	0.043	0.055	0.028
Socio-eco	0.037	0.026	0.02	0.01	0.012	0.011	0.01	0.013	0.021	0.036	0.02
GWP	0.034	0.022	0.02	0.01	0.01	0.008	0.01	0.008	0.01	0.018	0.015
ג Max	0.849	1.013	1.17	1.27	1.295	1.256	1.16	1.046	0.927	0.835	
CL	(10.825-10) /(10-1) = 0.091	_									
CR	0.061	_									

Table 7: Normalized Matrix with results.

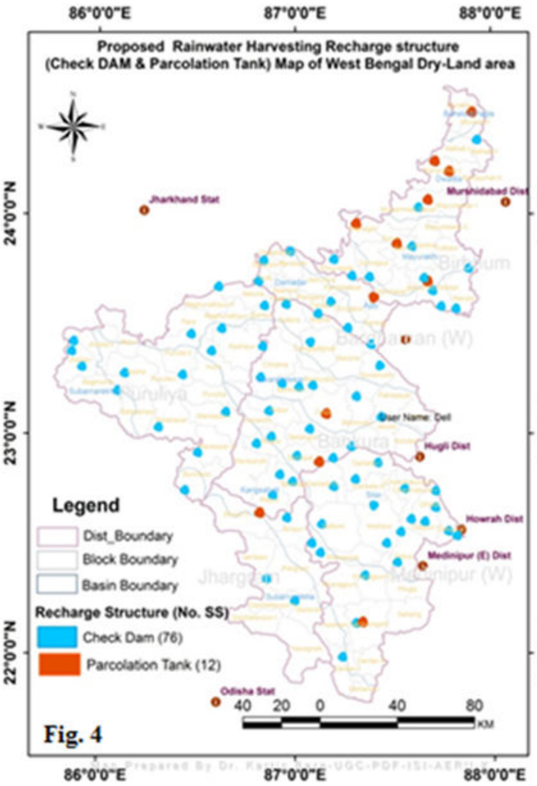

Figure 4: RWH check Dam and Percolation tank suitable site.

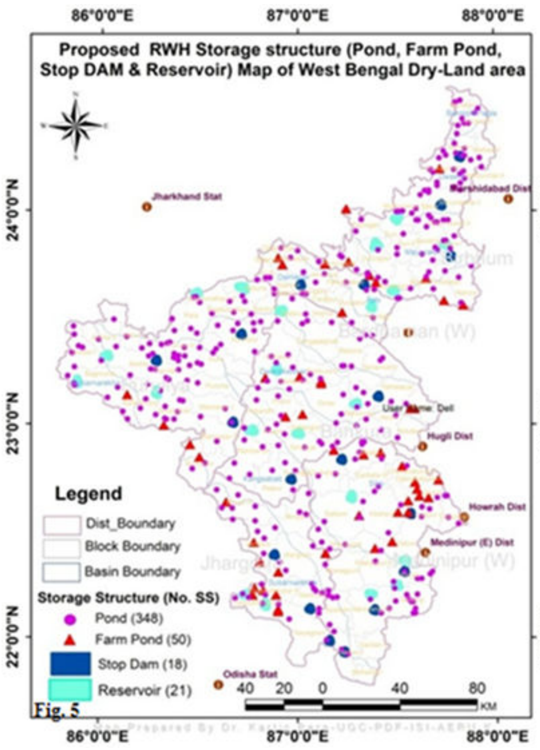

Figure 5: RWH Stop Dam and Reservoir suitable site.

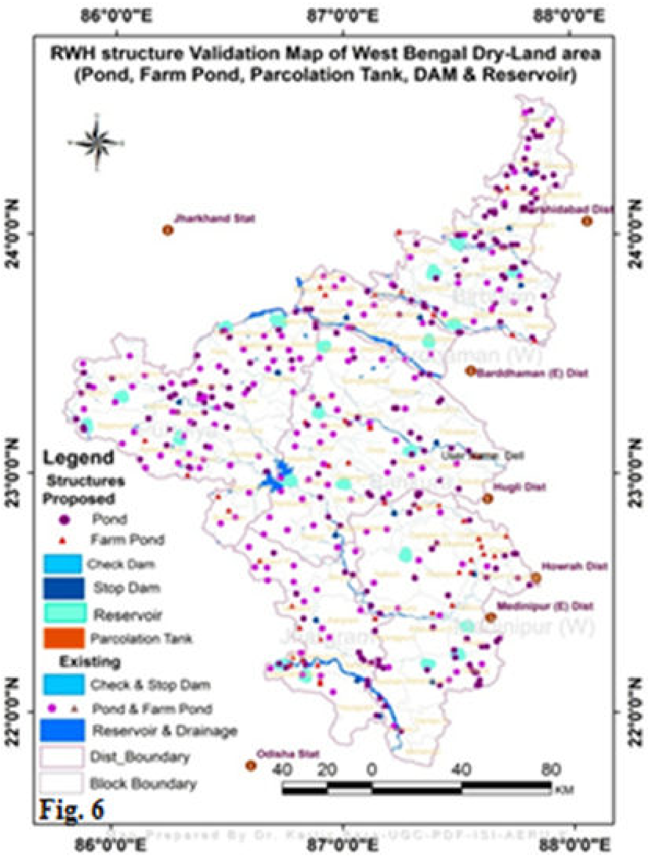

Figure 6: RWH and validation suitable site.

Raster	% Influance	Field	Scale Value
Socio_rasl	1	VALUE	
GWPZ_Ras	2	VALUE	
LU2020	3	NAME	
reclass_Pon	4	VALUE	
Oder_ra	21	VALUE	
preci_recls	29	VALUE	
Soil_CR	11	HSG	
Slope_Raster	15	VALUE	
Glgy_Ras	6	NAME	
Litho_recls1	8	NAME	

Figure 7: Weight valu(Arc GIS).

Raster	% Influence	Field	Scale Value
socio_ras1	1	VALUE	
		1	3
		2	2
		3	Restricted
		NODATA	NODATA
GWPZ_Ras	2	VALUE	
		1	Restricted
		2	2
		3	3
		NODATA	NODATA
relc 2020	3	NAME	
		Crop land	4
		Built-up Land	Restricted
		Fallow land	6
		Water bodies	9
		Forests	8
		Shrubland	3
		NODATA	NODATA
reclass_Pond	4	VALUE	
		1	4
		2	3
		3	2
		4	Restricted
		NODATA	NODATA
Oder_ras	21	VALUE	
		1	6
		2	5
		3	Restricted
		NODATA	NODATA
preci_recls3	29	VALUE	
		1	Restricted
		2	2
		3	4
		4	3
		NODATA	NODATA
Soil_GRP	11	HSG	
		B	2
		D	3
		C	4
		A	Restricted
		NODATA	NODATA
Slope_Raster1	15	VALUE	
		1	2
		2	3
		3	4
		4	5
		5	Restricted
		NODATA	NODATA
Glgy_Ras	6	NAME	
		1 Jurassic metam	Restricted
		2 Undivided Preca	Restricted
		3 Quaternary sedi	2
		4 Lower Triassic t	4
		NODATA	NODATA
Litho_recls1	8	NAME	
		LATERITIC SOIL	Restricted
		STONE,GRAVEL,G	3
		SAND, SHALE, CL	4
		BASIC LAVA	Restricted
		QUARTZ SCHIST,	3
		NODATA	NODATA

Figure 8: Weight determination of different parameters(Arc GIS).

Result&Discussion

Analysis of weighted index Model

Potential sites of RWH used in suitability analysis of recharge and storage rainwater harvesting structures can include the location of dams, tanks, ponds and reservoirs. Site selection analysis can be performed with vector or raster data, but one of the most widely used types of site selections is weighted overlay site selection using raster data. Weighted overlay site selection analysis allows users to rank raster cells and assign a relative importance value to each layer [18]. The result is a suitability surface that ranks potential sites from 1 to 9. Sites with a value of 1 are least suitable, and those with a value of 9 are most suitable.

Weighted Index Model

Weighted Index Model represents weighting the multiple parameters. In this study, a weighted index model was used for data integration. All thematic layers prepared for Bengals dry-land are classified about the site suitability for water harvesting structures. In this study, the most crucial aspect is to assess the area of the high suitable site of water as it would help prepare a plan for sustainable development of soil and water resources. This is carried out keeping in view that all the parameters depend on each other regarding the study.

Site suitability analysis: Identification of suitable sites for water conservation structures are based on precipitation (Rainfall), drainage, slopes, lithology, geology (lineaments), soil (HSG), land use/land cover, socio-economy activity and potential groundwater zone. All the layers were generated in the ArcGIS-10.6 software were in the vector format. In weighted overlay analysis, the rasterization of each physiographic unit was performed by using the conversion tools in the Arc GIS window. So, the first step of data conversion is rasterization for converting all thematic maps into a raster data format. After this, reclassification of all the raster files was performed using the scale values of each unit. Then, all the layers were ranked based on their influence following the normalized matrix result (Table 5). For the site selection of water conservation structures in the study area, the weightage overlay analysis was used. Depending upon the influencing factors, weights were assigned from rank 1 to 9 in. The lower value`1 represents the low or low suitable sites, whereas the high value 9 represents the highly suitable site over the area.

Further, the weighted overlay function has been processed using the Spatial Analyst Tool, and suitability sites are identified. Then, the resulted values are recalculated according to the suitability of the structure. From the suitability map, only a highly suitableness grid are considered for the implementation.

Water Conservation structures: The multi-layer integration through land use/cover, slope, flow direction, drainage density and rainfall depth gave the suitability units for identifying two main RWH sites (Table 2):

i) Check dams, Percolation Tank under recharge structure

ii) Pond, Farm Pond, Stop Dams and Reservoirs under storage structure.

Factor layers were incorporated in Arc Map, using the weighted overlay function in the ArcGIS analyst and providing the final suitability site. This map was used to identify potential sites (Figures 4,5) for different water harvesting structures in the study area. Technical guidelines suggested by IMSD (1995) and Ziadat et al. were used for selecting suitable sites for conservation structures. These guidelines are used as a knowledge base for identifying site. The decision rules used in the present study to identify suitable zones for water conservation structures are shown in the figure.

Recharge Structure: Two types of rainwater harvesting structures are selected under the RWH recharge structure: Check Dam and Percolation Tank (Figure. 4).

Check Dam: Check dams are a prevalent type of rainwater harvesting structure and recharge structure in the dry-land area and have greater importance since they have a complimentary benefit of controlling soil erosion (IMSD 1995). Check dams are structures constructed of rock, sediment retention fibre rolls, gravel bags, sandbags, or other proprietary products placed across a natural or manufactured channel or drainage ditch (CGWB 2011). In the study area, medium or gentle slope and 3rd and 4th orders streams are considered suitable sites for constructing check dams. There are 76 suitable sites identified for the construction of the check dam. These sites are fulfilling all the necessary conditions needed for the construction of check dams.

Percolation Tanks: Percolation Tanks are another recharge structure for recharging groundwater. These are generally constructed across streams and more extensive gullies to impound a part of the run-off water (IMSD 1995). With moderate slope and proximity to lineaments (<100) are considered as suitable for percolation tank. There are 12 sites identified as highly appropriate for the construction of percolation tanks.

ii **Storage Structure:** Pond, Farm Pond, Stop Dam and Reservoir are selected as RWH storage structures (Figure. 5)

Pond: Ponds are small freshwater bodies with shallow and still water, marsh, and aquatic plants. Ponds June be freshwater or brackish. Ponds are frequently manufactured or expanded beyond their original depths and bounds by anthropogenic causes. Most of the ponds in dry-land area anthropogenic causes are useless due to physiographic setup [19]. But in dry-land areas, ponds play an essential role in domestic and vegetable cultivation in the dry period. Based on pond suitability parameter's identified 348 pond sites are in the Bengal dry-land area.

Farm Ponds: Farm ponds are made by either constructing an embankment across a water source or by excavating pits or combining both. These are the low-cost structures constructed in agricultural land located on higher reaches. The farm ponds are used for protective irrigation in a prolonged dry spell in the monsoon season. Most of the study area is moderately suitable for the construction of farm ponds. However, only fifty highly suitable sites were identified for the construction of farm ponds based on parameters.

Stop Dams: Stop Dam is constructed across the direction of water flow on shallow rivers and streams for water harvesting for irrigation and domestic and animal use. In the study area, deciduous forest, high to low run-off gentle slope and 3rd, 4th or 5th stream order is considered for selecting suitable sites for constructing stop dams. Eighteen sites have been identified suitable for the construction of stop dams.

Reservoir: A reservoir is an artificial lake where water is stored. The reservoir is formed by building a dam across a valley, excavating the land, or surrounding a piece of land with dykes and diverting a part of the river flow into the reservoir. During droughts or extended dry periods, the water level in a river is shallow and somewhere dries. Under these conditions, more water is released from the reservoir, and farmers water their crops and domestic use. Through WIO analysis total 21 highly suitable sites are identified for reservoir constriction.

Validation and Testing: The validation work was implemented using:

i) Superimposed technique and;

ii) Ground trothing and farmer discussion;

For testing and validating the accuracy of the identified potential surface rainwater harvesting sites in the area superimposed by existing water management structures and the model proposed suitability site (Figure 6).

The model results accurately represent the actual performance of field observations by using a hand-held GNSS receiver and in depth field responses from local farmers. The locations of all sites were then plotted against the proposed site and are shown in Fig 6.

These findings suggest that the used methodology is a helpful way to identify potentially suitable sites for reliable rainwater systems and can be used to predict potential sites for RWH structures implementation.

Conclusion

Rainwater harvesting is an alternative source of water in dry-land regions around the world. This study has provided an essential basis for establishing RWH facilities and alleviating water crises in dry-land areas. Hence, RWH could be one of the necessary water supplies for water sustainability, and development means using this source efficiently. Although the study area is situated within moderate rainfall zone, a large amount of it is lost through runoff. This study presented a Geographic Information System (GIS) enabling us to manage a large volume of data from various sources. Based on AHP analysis, all the data are normalized for infusing percentage weightage overlying in the GIS environment. Based on the weightage overlaying for suitable zones, locations for 76 check Dam, 12 percolation tanks, 348 ponds, 50 farm ponds, 18 stop dam and 21 reserves for construction were identified. These most suitable sites are an essential step for the alternative supplementary water source, for use in agriculture and domestic activities and toward maximizing water availability and land productivity in and around Bengal's dry-land area. Properly implementing structures improved groundwater levels, increased cropland area and crop yields, and assured and potable drinking water supply to household increased bore wells implementation. The outcome of this study June be replicated in similar terrain and climatic condition.

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Conflicts of interests

It is hereby declared that this article poses no conflict of interest. No specific research grants were received for the study. This article does not contain any studies with human or animal subjects.

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