Site Suitability Analysis for Rainwater Harvesting Structures in Jhargram District

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for the Partial Fulfillment of the Degree of
Master of Science (Geography)

Submitted by

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Declaration

I do hereby declare that the present Master thesis entitled 'Site Suitability Analysis for Rainwater Harvesting Structures in Jhargram District' embodies the original research work carried out by me in the Department of Geography, Midnapore City College, Paschim Medinipur, West Bengal, India under the supervision of Dr. Kartic Bera, Assistant Professor, Dept. of Geography, Midnapore City College, Paschim Medinipur, West Bengal, India. No part thereof has been submitted for any degree or diploma in any University.

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This project report entitled "**Site Suitability Analysis for Rainwater Harvesting Structures in Jhargram District"** by (……Name …….) is approved for the degree of Master of Science (Geography).

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(Dr. Pradip Ghosh)
Director
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Date :_____________
Place:_____________

Dedicated to

my Parents

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[Name]

Abstract

Water is precious asset of humanity forever. Water requirement for domestic, agricultural and agro-industrial is met mainly by the subsurface water resources. Due to dynamic climatic conditions the region's water table is showing a declining trend and backward people (socially) are affected daily. Keeping in view this dictum the present study has been carried out pertaining to the West Bengal dry land area. This region is situated under Choto Nagpur Plato region belongs to semi-arid region. This study is based on data and limited field check to identify the most suitable site for the planning of rainwater harvesting structures in, mainly to surface water urticiation and increase the ground water resources for sustainable development. Determination of Rainwater Harvesting (RWH) potential sites study uses various thematic layers such as rainfall, slope, land cover/ land use, geology, drainage density, hydrological soil group, lithology and socio-economy activity. All these layers were prepared with the help of images and numeric data and integrated using weighted overlay techniques in a GIS environment to derive suitable sites for soil and water conservation structures. Based on site suitability results and topographic characteristics, locations for conservation structures select some cheek Dam, tanks, Ponds for implementing of soil and water conservation structure. These locations are ecologically sound and economically viable. This will sustain the productivity of surface water urtication and increase the groundwater resources for the future in and around Bengal's dry-land area. The outcome of this study may be replicated in a somewhat similar terrain condition for sustainable development.

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Chapter 1: Introduction

1. Introduction

Water plays a vital role in fulfilling the basic human need for life and health and in socio-economic development (Payen et al. 2012 & Kumar et al. 2018). Throughout the world does not have access to clean water for domestic purposes? The biggest challenge (CGWB. 2011) 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 (Lokesh and Rao. 2014). 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 (FAO.2003, Nan et al. 2014 & Zheng et al. 2018). As the primary source of water is rain, it becomes necessary for us to harvest it effectively. We can maximise the storage and minimise 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, to address this issue, it is important to understand the potential zones of rain water in the district and how they can be sustainably managed 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 (Sazakli et al. 2007, Moon et al. 2012, CGWB, 2011 & Zheng et al. 2018). 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. 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 .The study aims to identify RWH suitable sites using GIS model for rainwater harvesting structures for the conservation and better utilisation of rainwater in and around the West Bengal dry-land area. Integration of Remote Sensing (Floyd 1986 & Mugo et al. 2019) 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 the present study endeavors to locate the site for water harvesting structures in Jhargram District dry-land area (Bera et al 2022). The people are practicing the unplanned manner to store the water .This study also provides the suggested sites for water structures planned for conservation and better water utilisation. 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. In this study, various remote sensing and GIS techniques (Rahman 2017) is used to analyze the physical and geomorphological characteristics of the area and identify the potential zones for rain water harvesting .Remote sensing data is used to create digital elevation models and to extract information on land use and land cover, (Meijerink et al. 1994) soil properties, and hydrological features such as drainage patterns, rivers and streams, and wetlands. Such information will be combined with data on precipitation, temperature, and evapotranspiration to create a comprehensive understanding of the rain water harvesting potential zone in Jhargram district.

In addition to the physical and geomorphological analysis is also considered the social and economic factors that influence the sustainable management rainwater harvesting in Jhargram district. For example, the study analyzed the demographics of the area, including population density, poverty levels, and access to basic services such as water and sanitation. The study also considered the current and projected water demands of different sectors, such as agriculture, industry, and domestic use, and assesses the impacts of these demands on the groundwater resources in the district.

.The results of the study used to create a GIS-based map of the rain water harvesting (Prasad et al. 2014 & Adham et al. 2018) potential zones in Jhargram district. The map will be accompanied by a set of recommendations decision-makers and stakeholders in water resources management, as well as for communities in the district to management water crisis for their daily needs. The map will be accompanied by a set of recommendations for sustainable groundwater management, including strategies for reducing water demands, improving water use efficiency and promoting equitable access to rain water uses.

Chapter 2: Literature Review

2. Literature Review

“Water management in India: a review of current practices and challenges” by Singh et al. (2019) provides an overview of the current state of water management in India, including issues such as groundwater depletion, water pollution, and inadequate infrastructure. The paper also discusses potential solutions to these challenges.

One of the key issues related to water resources management in Jhargram district is the uneven distribution of rainfall throughout the year. The district experiences an average annual rainfall of 1,500 mm, but most of it occurs during the monsoon season from June to September. The uneven distribution of rainfall leads to water scarcity in the dry season, affecting agriculture and other economic activities. A study conducted by Roy et al. (2018) found that water availability for irrigation in Jhargram district is limited, leading to low crop productivity and income for farmers.

Another challenge for water resources management in Jhargram district is the depletion of groundwater resources due to over-extraction. Several studies have highlighted the issue of declining groundwater levels in the district, leading to increased dependence on surface water sources (Pandey et al., 2018; Saha et al., 2019). However, the quality of surface water sources, including rivers and ponds, is also a matter of concern due to pollution and contamination.

“Water management strategies for agricultural sustainability in West Bengal, India” by Mandal and Bhattacharyya (2016) explores different water management strategies that can be implemented to ensure agricultural sustainability in West Bengal, including rainwater harvesting and groundwater recharge.

“An assessment of water management practices in West Bengal, India” by Dasgupta and Basu (2015) reviews the various water management practices in West Bengal, including irrigation methods, water conservation measures, and wastewater management.

“A review of water management practices in India’s urban areas” by Gupta et al. (2017) examines the challenges faced by urban areas in India regarding water management, including water scarcity and pollution, and discusses potential solutions to these problems.

“Water management practices for sustainable agriculture in West Bengal, India” by Roy and Saha (2018) discusses various water management practices that can be implemented to ensure sustainable agriculture in West Bengal, including crop diversification and efficient irrigation methods.

“Water management and governance in West Bengal, India” by Chakraborty and Sengupta (2019) reviews the current state of water management and governance in West Bengal, including the role of government agencies and community participation.

“Assessment of water management practices in rural West Bengal, India” by Ray et al. (2018) examines the water management practices in rural areas of West Bengal, including traditional systems and modern methods, and evaluates their effectiveness.

“Water management challenges in the Sundarbans region of West Bengal, India” by Mukhopadhyay et al. (2017) explores the unique challenges faced by the Sundarbans region of West Bengal regarding water management, including saline intrusion and sea-level rise.

“A review of water management practices for sustainable urban development in India” by Kumar et al. (2018) discusses the challenges faced by urban areas in India regarding water management and explores various strategies for sustainable urban development, including rainwater harvesting and wastewater treatment.

“Water management practices in the Ganges Delta region of West Bengal, India” by Mukherjee et al. (2016) examines the water management practices in the Ganges Delta region of West Bengal, including traditional methods and modern technologies, and evaluates their effectiveness in addressing water scarcity and pollution.

Chapter 3: Aims and Objective

3. Aims and Objective

Aim: The study aims to identify RWH suitable sites for rainwater harvesting structures to conservation and better utilizing Rainwater in and around the Jhargram district.

Objectives:

1. To identify Rain water potential harvesting site by using remote sensing and GIS techniques.

2. Ensuring access to clean water for domestic as well as Agricultural use.

3. Maximizing the storage and minimizing the wastages of rainwater.

Location of the study area:

Jhargram is a district in the state of West Bengal, India. It was formed on 4 April 2017, after splitting from the Paschim Medinipur district as the 22 nd district of West Bengal state. The district has its headquarters at Jhargram. Jhargram is famous for its wooded beauty and topography culminating in the hill ranges of Belpahari, Kankrajhor to the north and Subarnarekha to the south. It is a favorite destination for people who love forests. The ancient temples, royal palaces, and folk tunes and rhythms make this area attractive. The West Bengal Government is planning to establish Jhargram as an independent district.Jhargram has one of the lowest population densities among the districts of West Bengal, with almost all its population living in rural areas. It is a popular tourist destination known for its sal forests, elephants, ancient temples and royal palaces. Jhargram is located at 22°52′0″N to

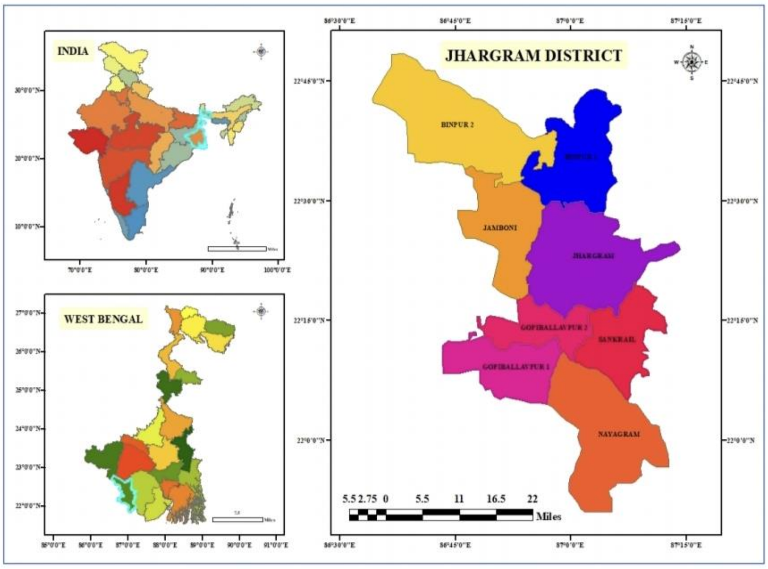


Fig. 1: Location Map of Study Area

22°48′0′N latitude and 86°34′0″E to87°20′0″E longitude. Jhargram district has 10 police stations, 8 community development blocks, 8 panchayat samitis, 79 gram panchayats, 2,996 mouzas, 2513 inhabited villages, 1 municipality and 1 census town. The single municipality is at Jhargram. The census town is Silda: The only subdivision, Jhargram Sub-Division, has its headquarters at Jhargram.

About the study area:

Topography

The district is a part of Chota Nagpur Plateau which gradually slopes down towards east, hilly terrain occurs in the north-western part of the district. Kakrajhore area is having the highest altitude of about 300 metres. This area is covered with unfertile hard laterite soil/rocks. The altitude of southern areas of the district belonging to Nayagram, Gopiballavpur-I & II blocks are having the altitude of about 65 mts, the soil is comparatively alluvial in these areas. The altitude of Jhargram town is around 80 mts.

Geology

Jhargram district covers an area of 3037.64 sq/km. Out of the 268249 hectare is Agriculture land and 59497 hectare is under forest coverage.

The district is part of chota Nagpur Plateau, which gradually slopes down towards east, hilly terrain occurs in the north-western part of the district. This area is covered with unfertile hard laterite soil/rocks and alluvial soil. 90% cultivated area has lateritic soil and 10% area has alluvial soil. Quartzite, Genesis, Metamorphic, Schist, Limestone, conglomerate are common rocks and minerals found here in the Jhargram district. The Geology map was prepared using satellite data of 2021 and Bhukosh website the geological features digitized from the satellite image. Identified in the study area included Dalma gp, Dhalbhum fm (gravel beds), Kuilapal granite, Singbhum gp, Undiff-flivial/Aeolian/Coastal and Sediments (Figure 02).

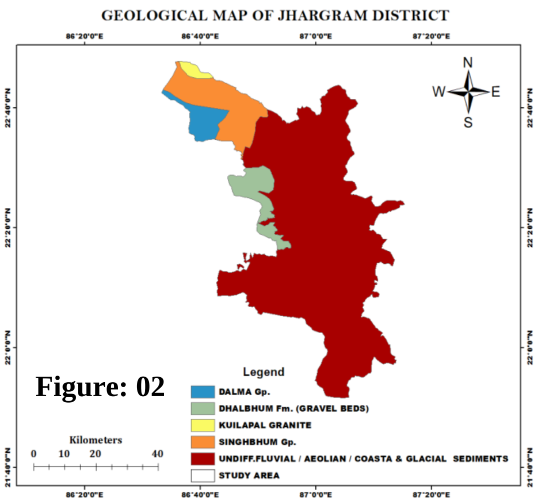


Figure: 02

Geomorphology

Geomorphological maps (Figure 03) help to identify various geomorphic units, surface and groundwater occurrence in each unit. Satellite data is the most useful tool to understand the Geomorphological setting of this area. The secondary data collected from GSI map of Jhargram district. It helps to verify the Geo-graphical feature massed up with the interpretation of the satellite image. The Geological map was prepared using satellite data from 2021 and Bhukosh website the Geomorphological features digitized from the satellite image. The landforms identified in the study area included Active flood plain, Older Alluvial plain, older flood plain, Upland and Plain (lateritic), Pediment, Pediplain, Channel bar, Meander scar, Abandoned channel and quarry, Residual hill,Water body Rivers, pond. Jhargram district other Geomorphological landforms–Cut off meander, Dam and reservoir, Lateral bar, Point bar, Oxbow Lake, Ridge, valley fill, High Low moderate dissected hills and valleys etc.

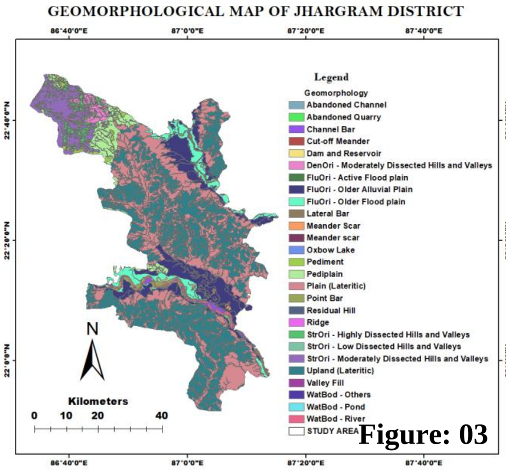


Figure: 03

Slope

The district part of Chota Nagpur Plateau which gradually slopes down towards Eas (Figure 04) the hilly terrain occurs in the north–western part of the district. Slope map has been prepared from DEM data. Slope map is prepared using ArcGIS slope tool. The district slope layer is divided by four classes, 0–3.4 range of slope indicate Very Low, 3.4–8.6 indicate Low, 8.6–20.3 indicate High and 20.3–87.7 range of slope indicate Very High. Kakrajhore area is having the highest altitude of about 300mts, Nayagram, Gopiballavpur-1 and 2 blocks are having the altitude of about 65mts and Jhargram town altitude is around 80mts.

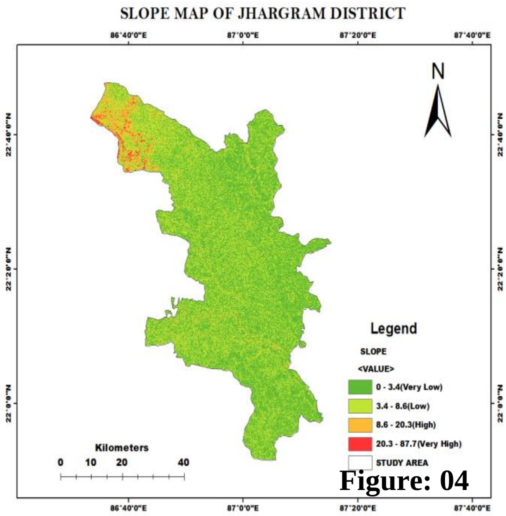


Figure: 04

Rainfall

Rainfall map has been prepared from Rainfall CRU (Climatic Research Unit) data 2021. Total Jhargram district area is divided into five classes, like 161 – 168mm, 169 – 175 mm, 176 – 181 mm, 182 – 188mm, and 189 – 195 mm (Figure 05).

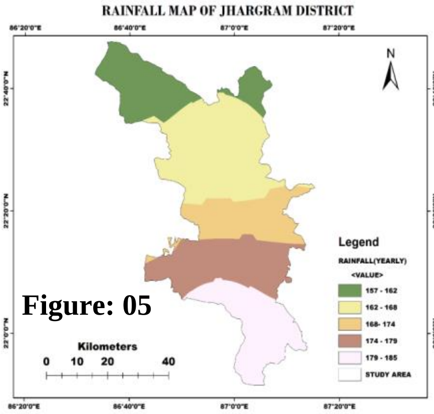


Figure: 05

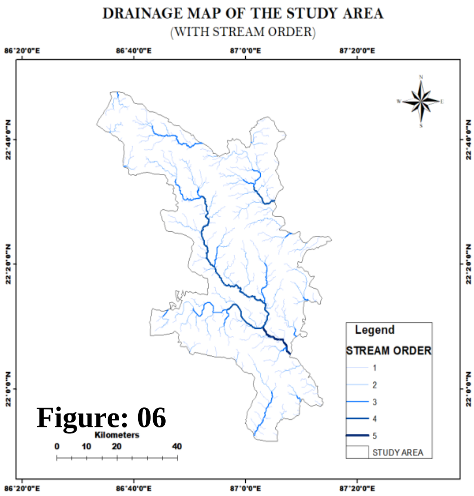


Figure: 06

Drainage

The important rivers of this division are the Kangsabati (popularly known as Kasai), the Tarafeni, the Subarnarekha, and the Dulong. Apart from the above rivers, there are several rivulets viz. 'Deb', 'Palpala', Rangium', 'Kupon' etc. Most of the above rivers flow from west to east as the Western side of the division is having higher altitude.

Surface water

Surface Water supply in this study area is Moderate. In this District most blocks of Agriculture are dependent on Surface Water. There are different types of Surface Water in this area (Figure 07). Permanent Surface Waters are present year-round, and includes lakes, rivers wetlands. New Permanent Surface Water is located channels, dammed artificial lakes and ponds. Ephemeral Permanent Surface Water refers to bodies of water that are only present of the year include channels such as some ponds, creeks, lagoons and waterholes. Seasonal Surface water is usually seen in Rivers, channels and some ponds during monsoons.

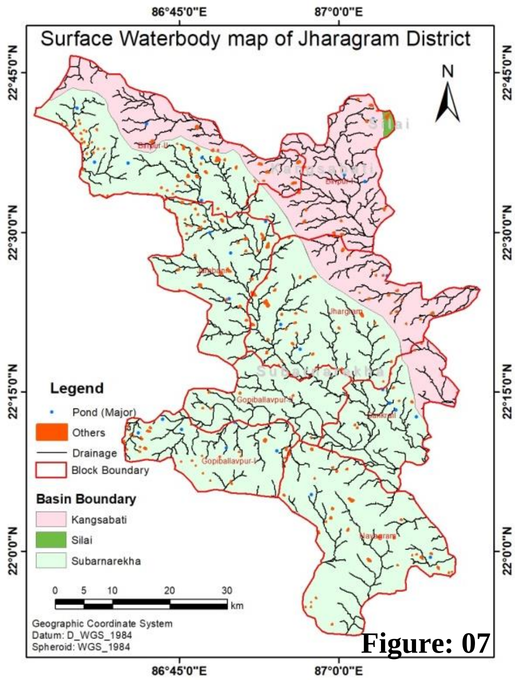


Figure: 07

Soil: This area is covered with unfertile hard laterite soil/rocks. The altitude of southern areas of the district belonging to Nayagram, Gopiballavpur-I & II blocks are having the altitude of about 65 mts; soil is comparatively alluvial in these area. The altitude of Jhargram town is around 80 mts. One of the main factors of soil pH (Figure 08) which is control the vegetation cover of the district.

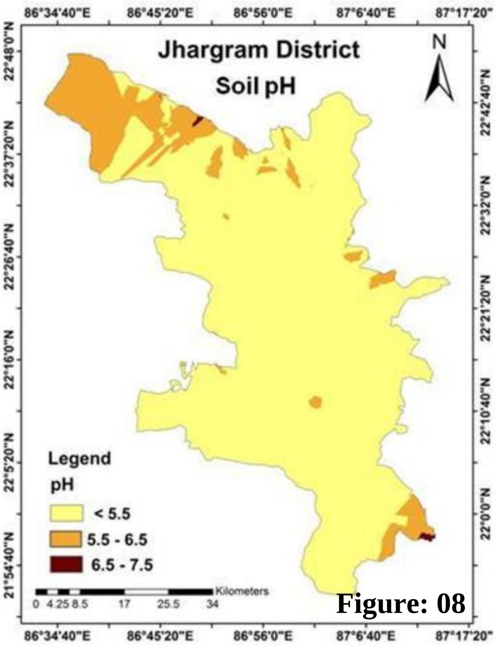


Figure: 08

Demographics:

Jhargram district had a population of 1,136,548, of which 67,436 (5.93%) live in urban areas. Jhargram district has a sex ratio of 977 females per 1000 males. Scheduled Castes and Scheduled Tribes made up 235,506 (20.11%) and 333,848 (29.37%) of the total population respectively.

Chapter 4: Materials and Methods

4. Materials and Methods

Materials: Topographic, soil, rainfall, and land use data from Meteorological department. Analyzed the collected data using GIS tools to identify areas with high potential for rainwater harvesting. This analysis can help us to determine the land use patterns, topography, soil types, and rainfall patterns in the said district (Figure 09).

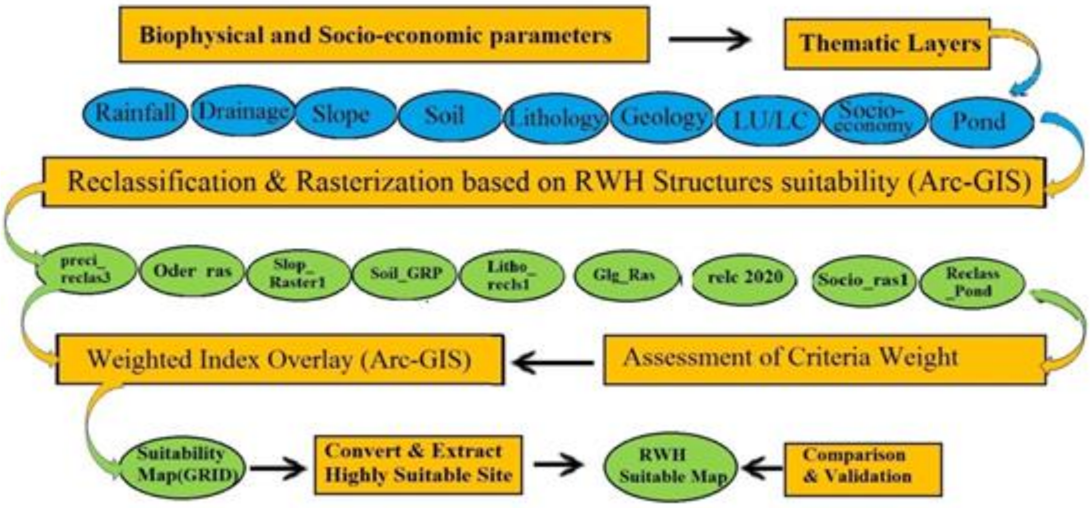


Figure 09 Conceptual Methodology for generation of RWH sturctures site suitabelity maping

Suitable Sites: On the basis of IMSD & FAO guidelines, the following parameters were selected as requirements for suitable site. The methodology adopted in this study for finding the RWH suitable site of the structure (Table 1) is given in as following 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 following:

Table: 1	**Specification of proposed RWH Structure's & Application**	
RWH Structure	Type	Application
Recharge Structure	Check 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
		Sources: D Ramakrishnan et al, 2009

Selected important parameters (Table 2) for determining appropriate areas of RWH systems evaluated by several experts 'selection criteria and then all parameters and their sub classes wise suitability categorized as following.

Table 2: General Criteria of each Thematic Layer and Constraints for RWH Suitability

Parameters	Sub Classes	Suitability	RWH Structures Remarks
1 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
2 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		
3 Slope	Flat	High to Very High	Check Dam, Reservoir, Percolation Tank
	Undulating/gently sloping		
	Sloping	High	Farm Pond, Ponds
	Hilly	Medium	
	Steep	Low	Restricted
4 Hydrological Soil	Group A	Moderate	Check Dam, Reservoir, Percolation Tank
	Group B		
	Group C	Medium High	Pond, Farm Pond
	Group D	High	
5 RainfallWeekly (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	
6Drainage	1st & 2nd order	Medium High	Pond, Farm Pond,

(Stream order)	3rd & 4th order		Check Dam
	5th & 6th order	High	Reservoir, Percolation Tank
7 Pond Density	High Density	High	Pond, Farm Pond
	Moderate Density	Medium	Percolation Tank
	Low Density	Medium to High	Check Dam, Reservoir
	Very low Density		
8 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
9 Potential Groundwater Zone	High	High	Pond, Farm Pond
	Moderate	High	Check Dam, Reservoir, Percolation Tank
	Low		
10 Socio Economy Criteria (Activity)	Class 1	Medium High	Check Dam, Reservoir
	Class 2	Medium	Percolation Tank, Pond, Farm Pond
	Class 3	High	

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 (Chowdhury & Paul 2021) are based on each criterion's relative importance weight (parameter). Several methods are available for the determination of these weights. 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 (Mosate 2016 & Drobne et al. 2009). Table 3 shows the rating used to compare the two criteria on a 9 point continuous scale proposed by Saaty (2008).

Table 3: The Scale of Pair wise Comparison (Source: Saaty, 2008)

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*.

RWH related parameters pairwise comparison has been made (Chowdhury & Paul 2021) according to their influence in the study area. To fill a table matrix (Table 4), 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 7 represent the quantitative terms of how each factor affect the selection of site search analysis.

Weights are calculated by normalizing the eigenvector associated with the maximum eigenvalue of the matrix (Khaled & Khalil 2021). Then the consistency ratio (CR) is computed to check the consistency of comparisons by using the following formulas:

$$\mathrm{CR} = \frac{\text{Consistancy Index (CI)}}{\text{Random Inconsistency Index (RI)}\#}$$

$$CI = \frac{\lambda\ \max - \mathrm{n}}{\mathrm{n} - 1}$$

Where:

$\lambda\ \max - \text{Principal Eigen} - \text{value} = \text{sum of products between each elements of the priority vector and column toatal.}$

n=number of comparisons/criteria.

According to Saaty (2008), 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 CR < 0.10 is reached (Table 6).

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 1) and parameters (Table 2).
ii. Classification of suitability for each parameter and their sub-classes (Table 2).
iii. Parameters pair wise comparison (Table 3) for their influences calculation (Table 4).
iv. Normalized the matrix (Table 4) for weightage calculation.
v. Statistical and GIS analysis (Table 7) for generation of suitability maps through weighted overlay index model (Table 8).
vi. Most RWH suitable site identification (Figure 4, 5& 6).

Table 4, Pair wise comparison of parameters										
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	0.20	0.25	0.33	0.5	1	2	3	4	5	6
Geology	0.17	0.20	0.25	0.33	0.5	1	2	3	4	5
Pond	0.14	0.17	0.20	0.25	0.33	0.5	1	2	3	4
LU/C	0.13	0.14	0.17	0.20	0.25	0.3	0.5	1	2	3
Socio-eco	0.11	0.13	0.14	0.17	0.20	0.25	0.33	0.5	1	2
GWP	0.10	0.11	0.13	0.14	0.17	0.20	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 6, Random Indices (RI)[#]	
N	**RI**
1	0.00
2	0.00
3	0.58
4	0.90
5	1.01
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51

Table 5	**Normalized Matrix with results**										
Parameters	Rainfall	Drainage	Slope	Soil	Lithology	Geology	Pond Den	LU/C	Socio-eco	PGW	**Priority vector**
Rainfall	0.341	0.414	0.388	0.345	0.303	0.269	0.240	0.217	0.197	0.182	0.290
Drainage	0.170	0.207	0.259	0.258	0.243	0.224	0.206	0.190	0.175	0.164	0.209
Slope	0.112	0.103	0.129	0.172	0.182	0.179	0.171	0.162	0.153	0.145	0.151
Soil	0.085	0.068	0.064	0.086	0.121	0.134	0.137	0.135	0.131	0.127	0.109
Lithology	0.068	0.051	0.042	0.043	0.060	0.089	0.103	0.108	0.109	0.109	0.078
Geology	0.058	0.041	0.032	0.028	0.030	0.044	0.068	0.081	0.087	0.091	0.056
Pond	0.047	0.035	0.025	0.021	0.020	0.022	0.034	0.054	0.065	0.073	0.040
LU/C	0.044	0.028	0.022	0.017	0.015	0.013	0.017	0.027	0.043	0.055	0.028
Socio-eco	0.037	0.026	0.018	0.014	0.012	0.011	0.011	0.013	0.021	0.036	0.020
GWP	0.034	0.022	0.016	0.012	0.010	0.008	0.008	0.008	0.010	0.018	0.015
λ max	0.849	1.013	1.169	1.267	1.295	1.256	1.164	1.046	0.927	0.835	
CL	(10.825-10) /(10-1) = 0.091										
CR	0.061										

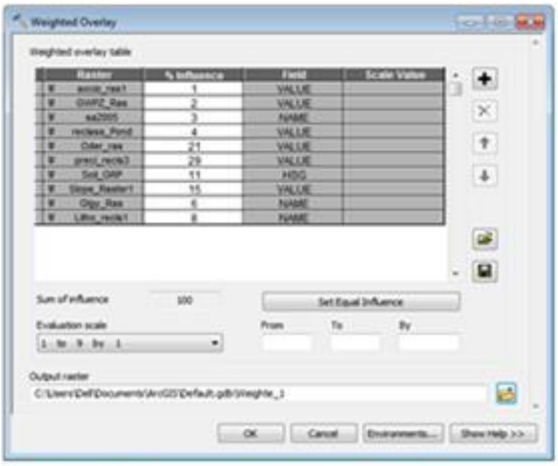
Chapter 5: Results

5. Results

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 (Khaled & Khalil 2021), 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 (Hashim & Sayl, 2020) and assign a relative importance value to each layer (Table 7). 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 (Table 8).

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 (Prasad et al. 2014).



Weighted Overlay

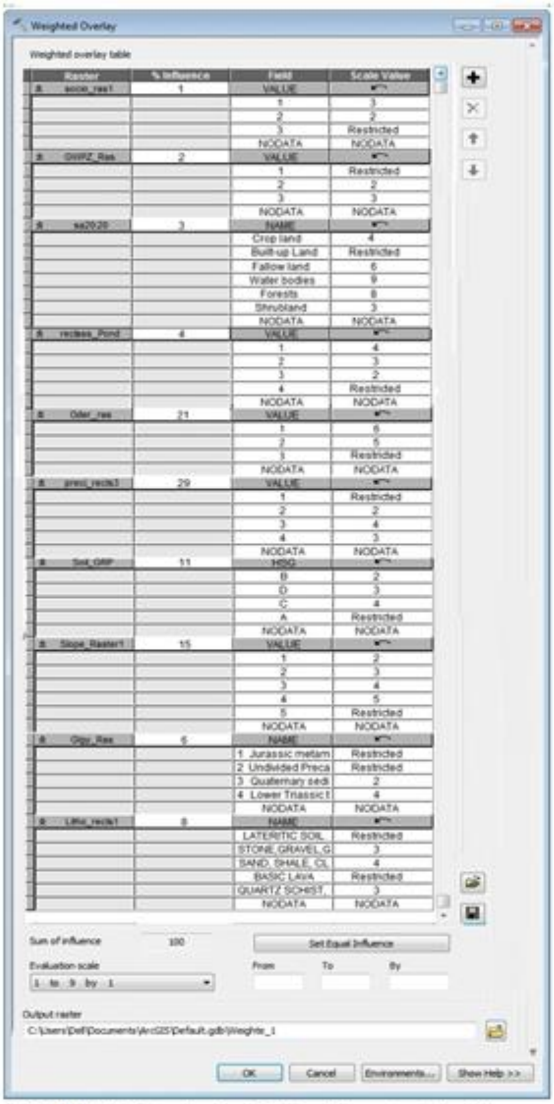
Weighted overlay table

Raster	% Influence	Field	Scale Value
socio_ras1	1	VALUE	
GWPZ_Ras	2	VALUE	
sa2005	3	NAME	
reclass_Pond	4	VALUE	
Odar_ras	21	VALUE	
preci_recls3	29	VALUE	
Soil_GRP	11	HSG	
Slope_Raster1	15	VALUE	
Glgy_Ras	6	NAME	
Litho_recls1	8	NAME	

Sum of influence 100

Evaluation scale 1 to 9 by 1

Table 7 Weight Value (Arc GIS)



Weighted Overlay

Weighted overlay table

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
sa2020	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
Odar_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

Sum of influence 100

Evaluation scale 1 to 9 by 1

Table 8 Weight Determinarion of Different Parameters (Arc GIS)

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 (Prasad et al. 2014), 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 (Chowdhury & Paul 2021). 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 4). 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 9in table 9. 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 1):

i) Check dams, Percolation Tank under recharge structure and

ii) Pond, Farm Pond, 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 (Figure 4 & 5) for different water harvesting structures in the study area. Technical guidelines suggested by IMSD (1995) and Ziadat et al. (2012) were used for selecting suitable sites for conservation structures. These guidelines are used as a knowledge base for identifying sites (Perumal et al. 2003). The decision rules used in the present study to identify suitable zones for water conservation structures are shown in the figure.

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

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 (Figure 10).

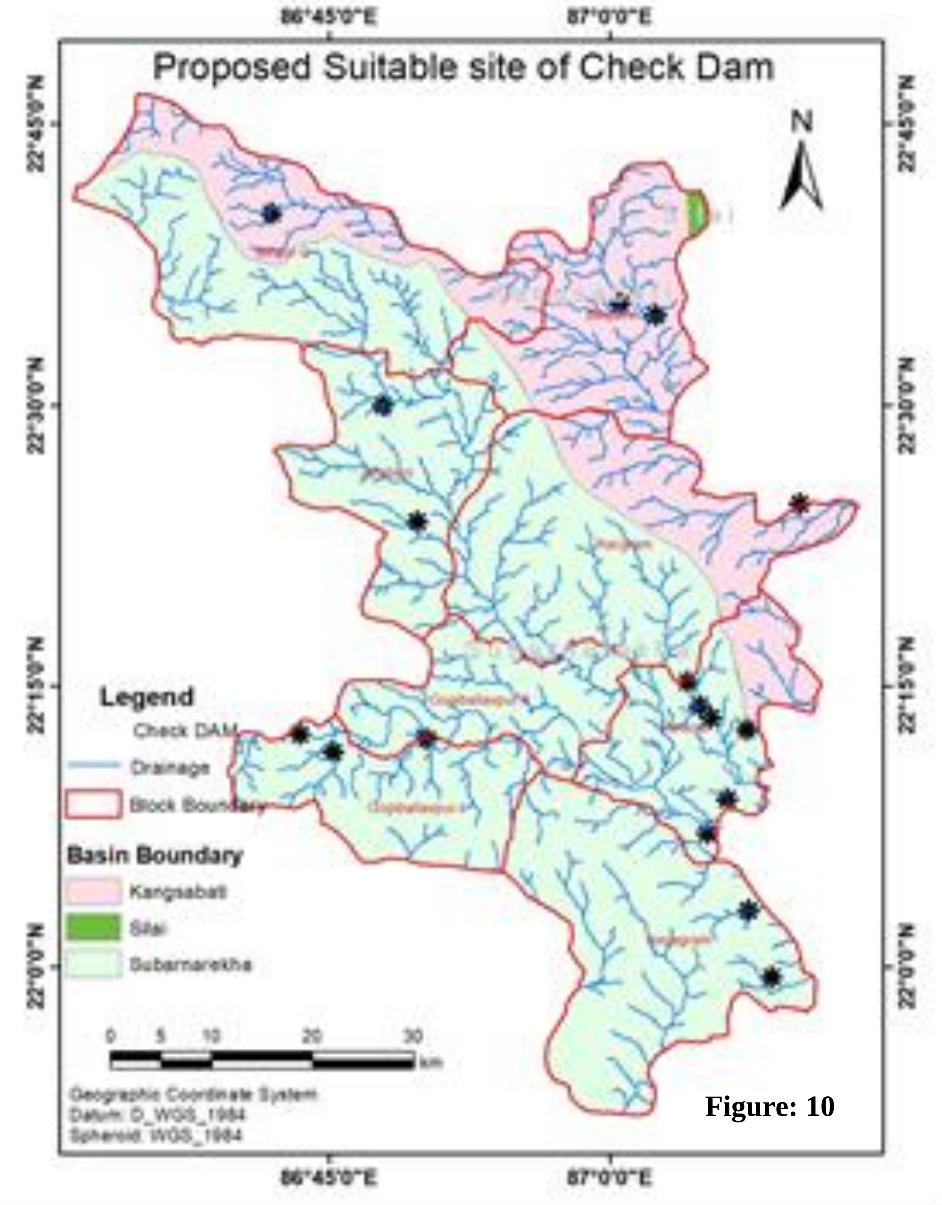


Figure: 10

Percolation Tanks: Percolation Tanks are another recharge structure for recharging groundwater (Saha et al. 2021). 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 (Figure: 11).

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

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 (Figure: 11), and farmers water their crops and domestic use (Dunn & Margery 1993).

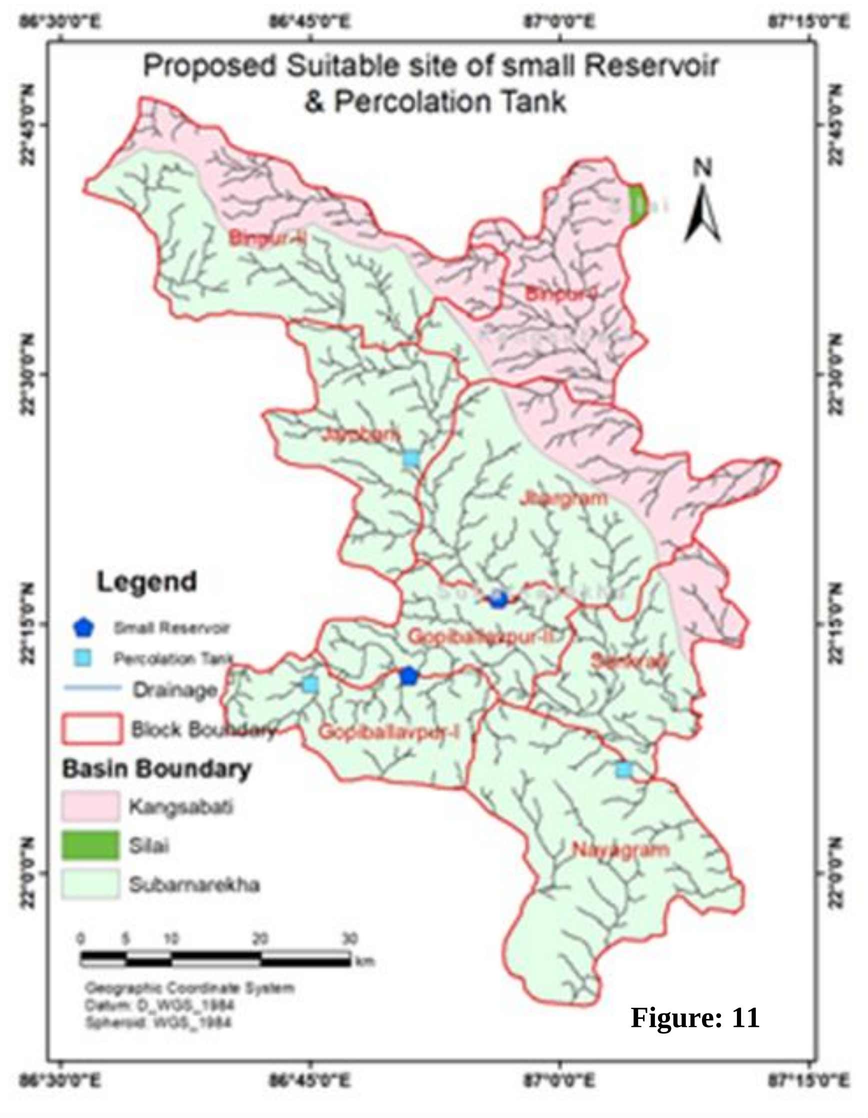


Figure: 11

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 (IMSD. 1995). 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 (Figure 12).

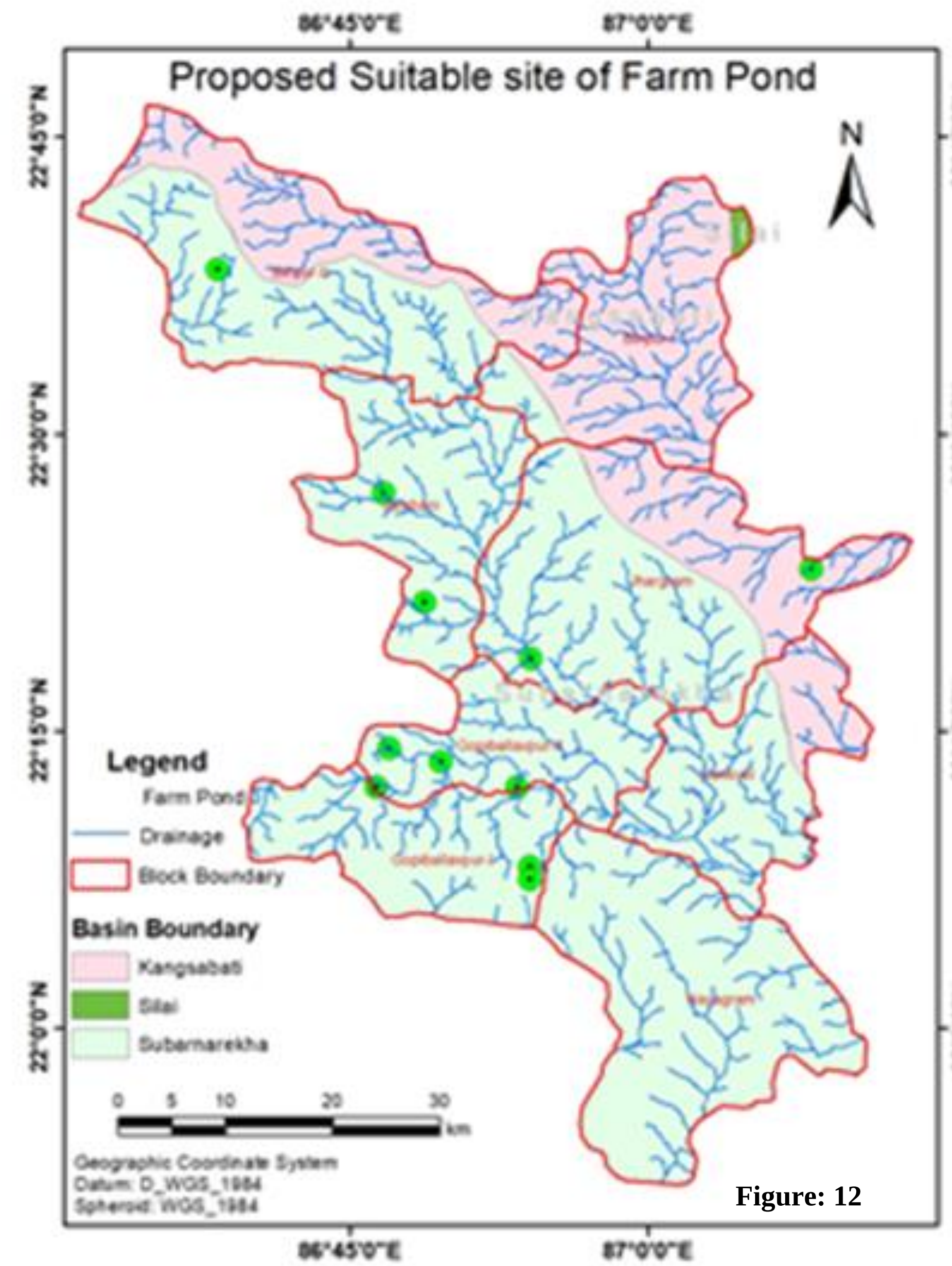


Figure: 12

Pond: Ponds are small freshwater bodies with shallow and still water, marsh, and aquatic plants. Ponds may be freshwater or brackish (Clegg 1986). Ponds are frequently manufactured or expanded beyond their original depths and bounds by anthropogenic causes. Most of the ponds (Figure 13) in dry-land area anthropogenic causes are useless due to physiographic setup (Juan et al. 2021). But in dry-land areas, ponds play an essential role in domestic and vegetable cultivation in the dry period.

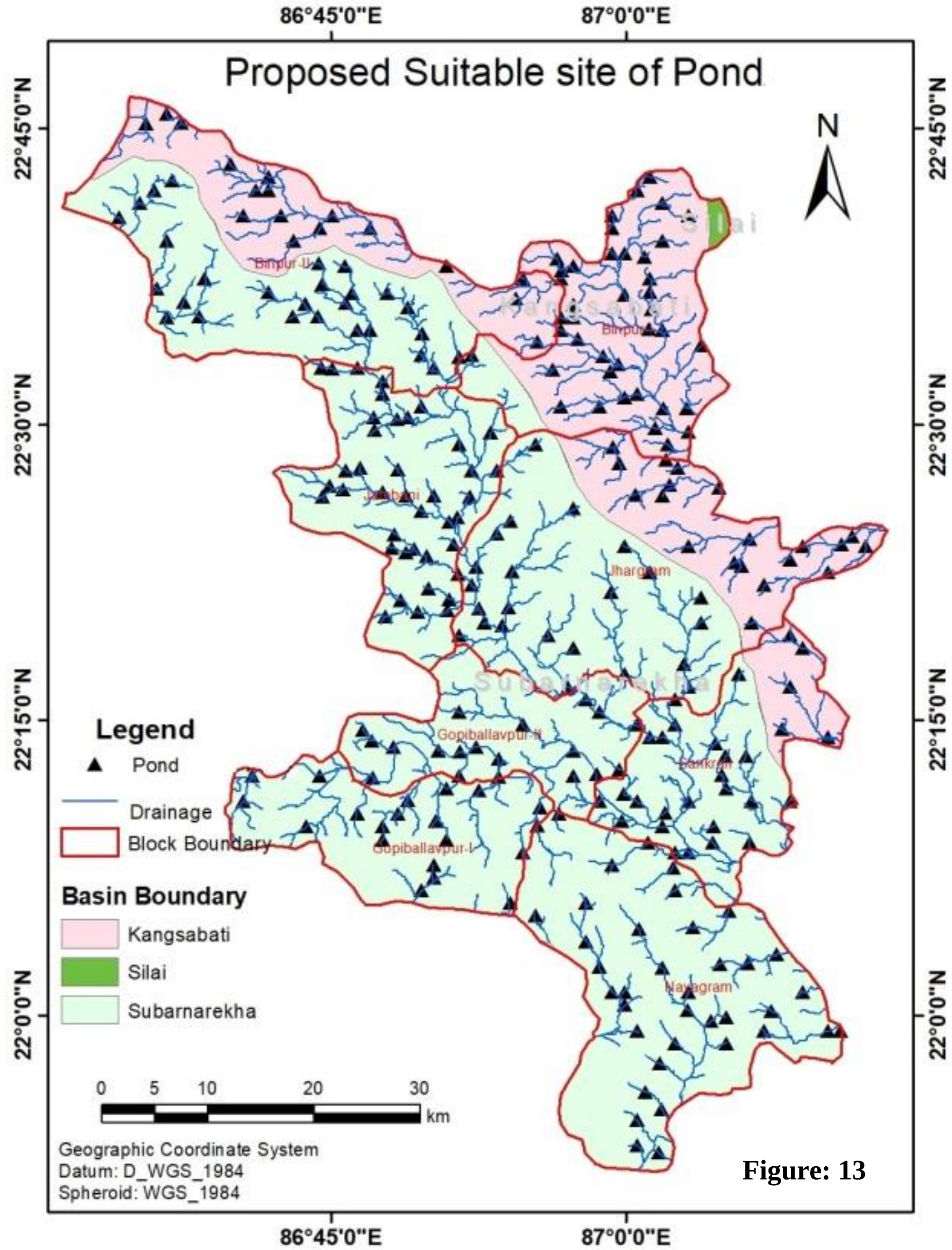


Figure: 13

Chapter 6: Discussion

6. Discussion

Validation Testing: The validation work is done by superimposed technique and finally finds out (Figure 14) the RWH suitable structure as flows:

Check dam: There are seventeen 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 tank: There are three sites identified as highly appropriate for the construction of percolation tanks.

Reservoir: Through WIO analysis only two small reserves highly suitable are identified for reservoir constriction.

Farm ponds: However, only eleven highly suitable sites were identified for the construction of farm ponds based on parameters.

Pond: Based on pond suitability parameter's identified twenty eight pond sites are in the Jharagram district.

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.

Properly implementing strictures improved groundwater levels, increased cropland area and crop yields, and assured and potable drinking water supply to household increased bore wells implementation.

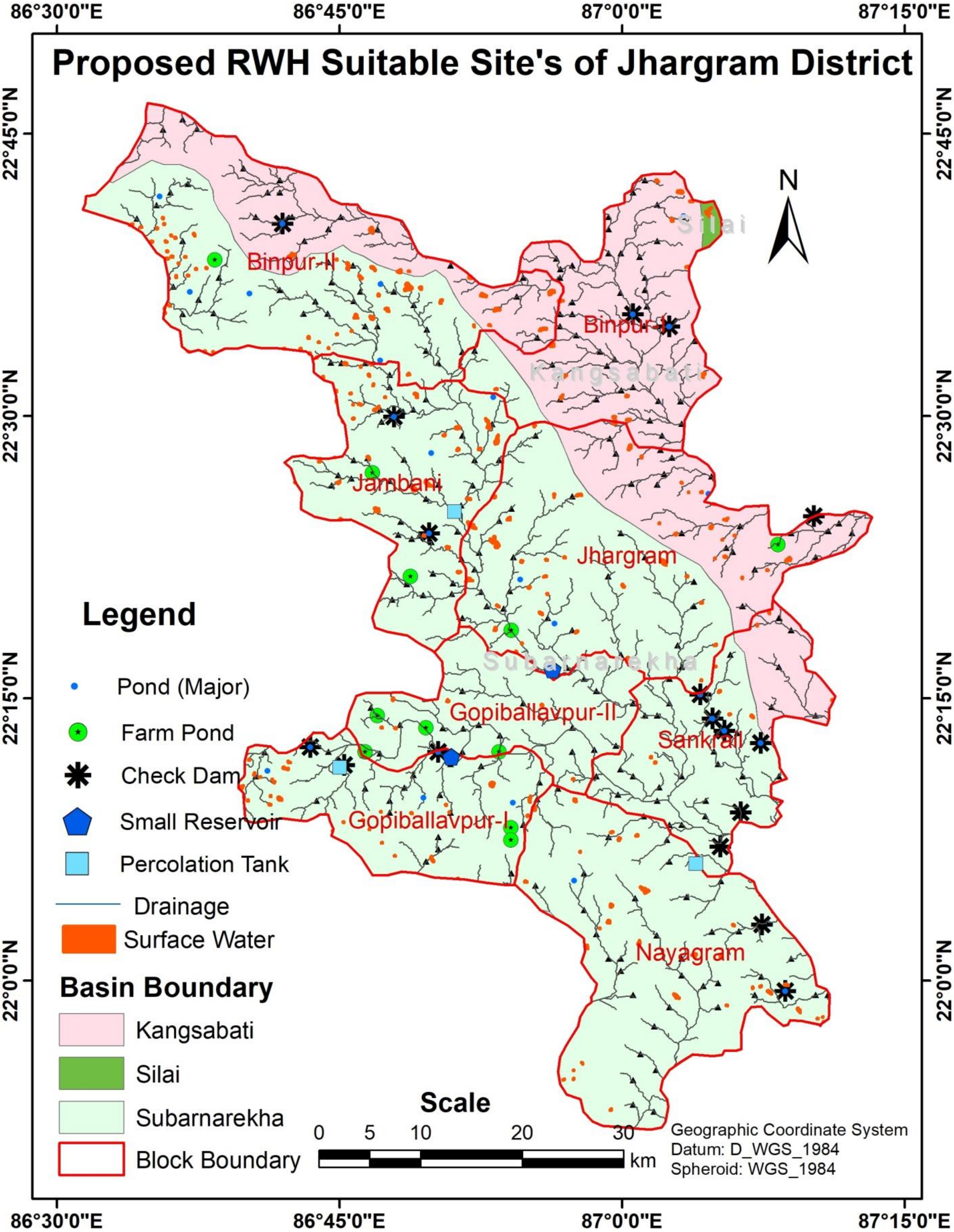


Figure: 14

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Chapter 7: Conclusions

7. Conclusions

Rainwater harvesting is an alternative source of water in the regions. The study can provide an essential basis for establishing rain water harvesting facilities and alleviating water crisis in the district. Hence rain water harvesting could be one of the necessary water supplies for water sustainability.

The study can assist decision makers by providing information on sub-surface and ground water potential zones for water structures planned for conservation and better water utilization.

This study can provide sustainable water condition through rain water harvesting method for the next generation.

By implementing structures there will be improve ground water level with increase in ground water management system crop land will be also increase.

The outcome of this study may be replicated in somewhat similar terrain and climatic condition.

Chapter 8: Future Scope

7. Future Scope

There is a positive future scenario of rainwater harvesting in Jhargram district. As water scarcity continues to be a global concern, rainwater harvesting will become an increasingly important and popular water management solution. The integration of smart technology, eco-friendly systems, and increased integration with other water management technologies will further improve the efficiency and effectiveness of rainwater harvesting. Additionally, education about water conservation will play a crucial role in shaping the future of this in Jhargram District.

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