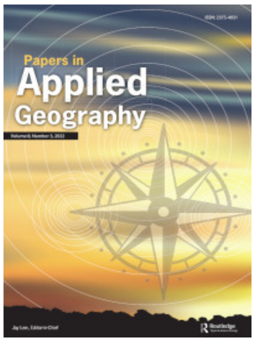

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Identifying Suitable Location for Surface Rainwater Harvesting Using GIS and Analytical Hierarchy Process

Sarbeswar Haldar[a] and Arijit Majumder[b]

[a]Department of Geography, Haldia Government College, Haldia, West Bengal, India; [b]Department of Geography, Jadavpur University, Kolkata, West Bengal, India

ABSTRACT
Rainwater harvesting is old but auspicious technology of sustainable water resource management. In general, the immediate barriers for installing rainwater harvesting techniques is a universal problem which includes the availability of suitable place, initial cost, lack of desired, sound technology etc. The present paper mainly focuses on finding suitable locations for surface rainwater harvesting structures, validation and characterization of these areas using GIS and AHP methods. For validation and characterization of the location google earth and associated thematic layers have been used. The identification of appropriate locations for RWH structures for the Asansol Urban Area in Paschim Burdwan district of West Bengal has been made by utilizing eight different thematic layers in GIS environment. Different GIS layers such as surface elevation, land-use/land-cover, drainage, depression, geology, slope, rainfall and lineament have been used for identifying the suitable location. The result of the study depicts that most of the identified locations as high (10.62%) and very high (4.12%) are suitable for constructing any kind of natural or manmade RWH structure. The present method is comparatively cost effective and time saving which may be convenient for sustainable water resource management planning across the water scarce area in the world.

KEYWORDS
Analytical hierarchy process; characterization; geographical information system; rainwater harvesting

Introduction

Water is an essential means for the existence and sustainable development of the society. It is next to impossible to continue any kind of developmental activities without water. From the very beginning of the society, rainwater harvesting plays a major role to meet the requirement of water. At present accessibility of fresh water throughout world is decreasing progressively mainly because of increasing urban industrial activities and over draft of ground water which requires alternative water managing scheme. (Selvam et al. 2015; Tiwari et al. 2015, Tiwari, Goyal, and Sarkar 2018). For addressing the problems of disparity between water availability and requirement under varying climatic situations rainwater harvesting is a very useful technique (Kanta, Jha, and Chowdary 2017).

In India Rain Water Harvesting (RWH) techniques is very useful as rainfall occurs only for 3–4 months during rainy season (Rahimi 2017). The potential advantages from RWH are reducing potable water demand from main water sources, reducing overflow into urban storm water, and reduction of overflow risk from storm events (Eroksuz and Rahman 2010; He et al. 2009; van Roon 2007; Villarreal and Dixon 2005; Zhang et al. 2012). Many traditional RWH system in

CONTACT Arijit Majumder arijit.majumder83@gmail.com Department of Geography, Jadavpur University, Kolkata, West Bengal 700032, India.

India either not working properly or fail to meet the rising demand of modern communities (Singh and Ravindranath 2006). In Indian history of water development, the past two decades are characterized by a boom in water harvesting which remarkably different from traditional harvesting in terms of purpose and context due to scientific and technological up gradation (Kumar, Patel, and Singh 1998). RWH is treated as a sustainable technique for urban water cycle management which also helps to restrict the unscientific rising tendency of surface and ground water extraction (Matos et al. 2015). In developing countries, the possibility of RWH as an substitute water source in city spaces have been unnoticed (Temesgen et al. 2016). Public participation is the key factor for emerging RWH as an alternative which is mainly a local intervention with local benefits on ecosystems and human livelihood. RWH is a practical choice for water supply and a low cost mitigation approach for urban runoff (Nnaji and Mama 2014). RWH is the auspicious means of augmenting the limited surface and underground water resources in areas where present water availability is insufficient to encounter the rising requirement (Aladenola and Adeboye 2010).

RWH is the simple technique of collecting rainwater and use accordingly. Surface RWH is the process of storing rainwater on naturally depressed surface area or on constructing artificial storage on earth surface. It is really hard for water engineers to select appropriate area for RWH structure together with evaluation of RWH potential (Al-Ghobari and Dewidar 2021). It is very essential to find the appropriate area of surface RWH based on physical parameters like geology, geomorphology, slope, drainage, soil, vegetation, rainfall and lineament to enhance the rate of natural storage on surface.

From the above discussion it is clear that RWH has a multiple advantages starting from reducing pressure on main water source, urban flood control, low cost etc. Considering the immense importance of RWH, the present work has been designed to identify the suitable location for surface rainwater harvesting in Asansol urban area by using GIS technology and AHP method as it has a long history of summer water scarcity. The prime goal of the work is i) to identify the suitable location for surface rainwater harvesting ii) to analyze the characteristics of selected location.

This method may be useful for any regions of the world facing seasonal water crisis mainly because of following reasons-

i. The present method is comparatively cost effective and time saving as it is based on freely available data
ii. The different layers have been used in this methods have a similar impacts on surface runoff and infiltration throughout the world
iii. This method will help to reduce the pressure on main water source of any regions.
iv. Finally, by creating an alternative source of water and reducing pressure on conventional water sources of any regions this method may be convenient for sustainable water resource management planning across the water scarce areas in the world.

Study area

Asansol, 2nd largest Urban Agglomeration in the State of West Bengal after Kolkata, is situated at western end of Paschim Burdwan. The latitudinal and longitudinal extension of the study area are 23°35′12″N to 23°46′37″N and 87°09′35″E to 86°47′40″E (Figure 1). In June 2015, the municipal areas of Raniganj, Jamuria and Kulti have been incorporated within the authority of Asansol Municipal Corporation and it's now considered as 2nd largest urban agglomeration of West Bengal in Eastern India (Asansol Municipal Corporation (AMC)) 2020). The total area is 326.48 Km^2 having a population of almost 1.243 million (Census 2011). The urban agglomeration is physiographically situated at junction of the Chottanagpur plateau and the Ganga plain in west and east respectively. Ajay and Damodar rivers have bordered the urban area southern and

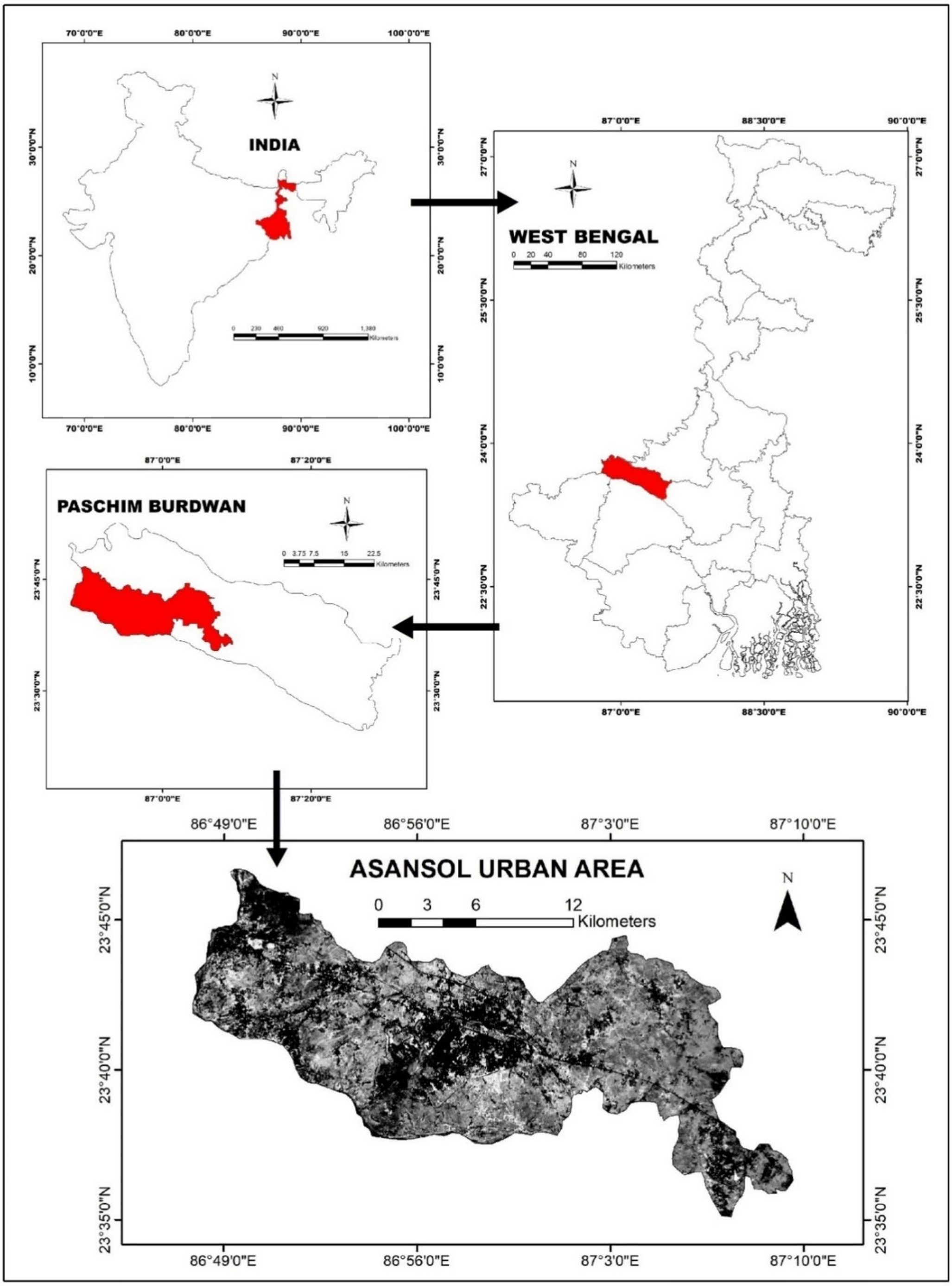

Figure 1. Location of asansol urban area.

western part respectively. In this area mainly five broad categories geomorphological features are found namely flood plain, pediment pediplain complex, quarry and mine dump, river and others water bodies like ponds, canals etc. Maximum part of area is mainly covered by pediment pediplain complex area which is followed by quarry and mine dump. A very insignificant portion comes under flood plain. Rest of the area is covered by river and inland water bodies. The entire region is predominantly dominated by humid tropical climate having three different seasons (summer, Monsoon and dry winter) which comes under the subtype of Aw (Tropical Savanna) in Koppen Climatic Classification. North-west to south east slope is observed having an average height of 122metre above mean sea level in the urban area (Asansol Municipal Corporation (AMC) 2020).

Materials and methods

Collection of required materials

For the present study various kinds of data have been collected from diverse sources. Topographical sheet of study area has been collected from Survey of India and geological sheet from Geological Survey of India. West Bengal Soil sheet (NBSS LUP) has been collected from NBSS, Kolkata followed by the procurement of Landsat 8(OLI) imagery of October, 2020 from the USGS earth explorer. Rainfall data was collected from the office of Irrigation and Waterways Department, Durgapur Division, WB.

Preparation of different layer

Firstly, DEM has been prepared by collecting required elevation information from topographical sheet in software environment and from that DEM, four layers, i.e., drainage density, lineament density, depression map, and slope and have been prepared in Arc GIS 10.3 software. Depression map has been created by subtracting the filled DEM from normal DEM utilizing raster calculator in Arc GIS. For preparing the above mentioned map DEM has been processed through flow direction, flow accumulation and stream network.

Soil map and geological map have been created by digitizing the study area in Arc GIS from the geo-referenced NBSS Soil Sheet of West Bengal and Geological quadrangle sheet bearing numbers 73 M and 73I.

Mean annual Rainfall map of Asansol Urban Area was prepared based on the rainfall data of last ten years (2010 to 2020) composed from the office of Irrigation and Waterways Department, Durgapur Division by utilizing IDW tool in Arc GIS.

After the necessary radiometric and geometric correction, Landsat 8 imagery has been used to create LULC map of the study area in Erdas Imagine 13.0(ESRI) Software. Supervised image classification techniques is used to prepare LULC map. After classification accuracy assessment (Kappa Coefficient) also has been done by using Google earth (Table 1).

Assignment of weight by AHP method

Analytical Hierarchy Process (AHP), a multi-criteria decision making tool was established by Thomas L. Saaty in 1970 (Hell, Krneta, and Krneta 2013; Podvezko 2009). It is a organized decision- making procedure that includes using experts' knowledge to govern the rank and weights by creating an eigenvalue pairwise comparison matrix (Saranya and Saravanan 2020). The main use of the AHP is the determination of choice difficulties in a multi-criteria situation (Forman and Gass 2001). Recently AHP method for multi-criteria decision making has been extensively used (Mallick et al. 2019) (Figure 2).

AHP is a semi-quantitative method popularly used for multi criteria decision making. In AHP method score indicates the significant of each individual factor and the preference values are given for every parameter ensuing the Saaty's 1 to 9 scale for calculating the comparative significance in connection with objectives (Saaty 1977). Eight different parameters including depression area, geological unit, slope, LULC, rainfall, soil texture, lineament density and drainage density which have a direct impact on surface runoff and infiltration have been used in AHP methods. Rank and Weights for all the parameters or layers have been assigned based

Table 1. Accuracy assessment.

Classes	Agricultural land	Built up area	Vegetation	Water body	Quarry and mining	Total	User's accuracy	Kappa Co-efficient
Agricultural land	117		2		1	120	97.50	0.94
Built up area	2	116		1	1	120	96.66	
Vegetation	1	1	47		1	50	94.00	
Water body	1	1	1	47		50	94.00	
Quarry and mining	1		1	1	27	30	90.00	
Total	122	118	51	49	30	370		
Producer's accuracy	95.90	98.30	92.15	95.91	90.00			
Over all accuracy	95.67							

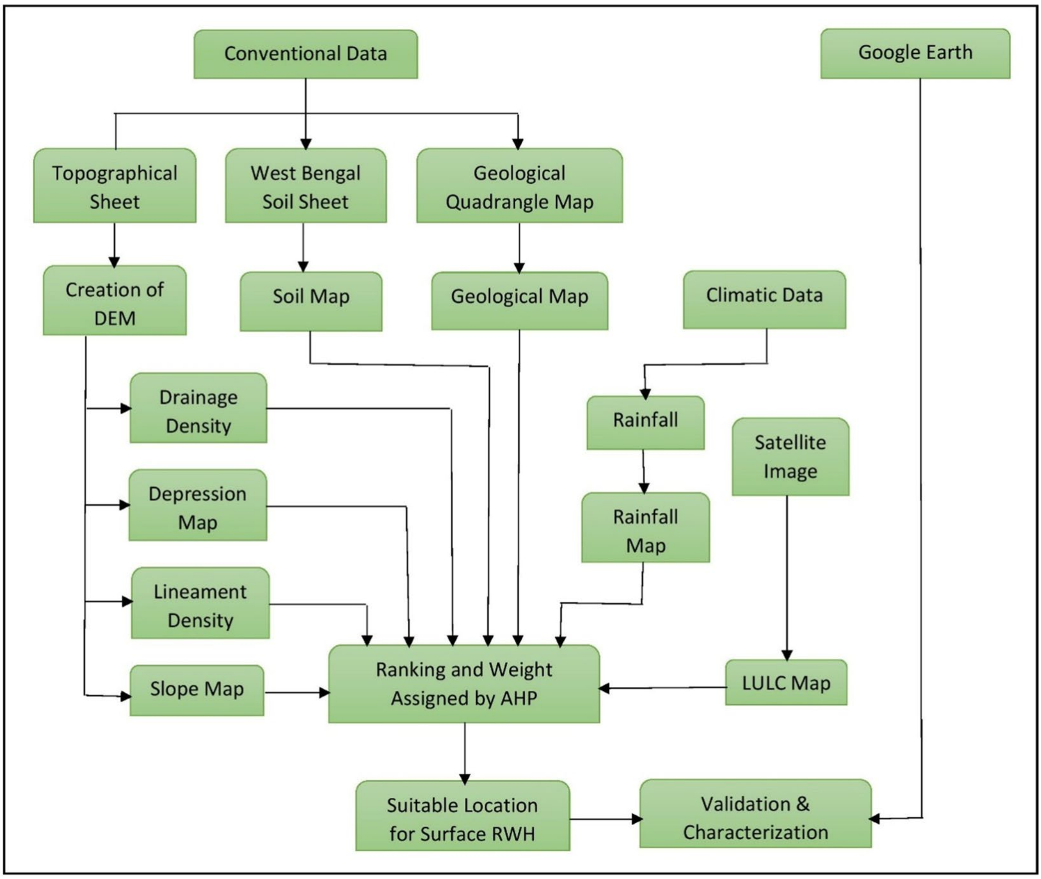

Figure 2. Methodological flow chart.

on the influence of each layer on accumulation of surface runoff and reducing infiltration capacity as the primary objective of this study is to find suitable location for Surface rain water harvesting. For the assignment of weights of each parameter, general controlling factors of surface runoff and infiltration have been considered. All the eight layers that have been used here have a direct influence on surface runoff and infiltration which ultimately determine the accumulation of water on the earth surface of any regions. Following the general factors controlling surface runoff and infiltration, maximum weight has been given on the depression area as it acts as a natural water accumulation point on the earth surface. In similar ways geological structure and slope have been ranked after depression by considering the influence of geological structure and slope on surface runoff and infiltration as geological structure of any regions determine infiltration rate and suitability of surface condition for accumulating water. On the other hand, slope has a direct relation to surface runoff as area having high slope is used to experience high rate of surface runoff. LULCs has been considered and ranked after geological units as it acts as a direct controlling factor of surface runoff and infiltration. Urbanized areas reduce the infiltration rate whereas increasing infiltration rate is experienced in agricultural land. LULCs of any region also determine the availability of open space for constructing surface rainwater harvesting structures. Soil texture has been considered and ranked after LULC as porosity and permeability of any regions directly depend on soil texture which ultimately control the infiltration rate. Similarly, rainfall has been considered as the amount of rainfall of any region ultimately determines the possibility that how much amount of water may be harvested. Ultimately, lineament density and drainage density have been considered and ranked after soil texture as lineament density explains the condition of existing joints and cracks on the surface which helps to increase the infiltration rate. Surface stability is also determined by lineament density which is the basic prerequisite of constructing surface RWH structure. On the other hand, drainage density is associated with low slope and high accumulation of water as the river itself acts as a surface water holding unit. For assigning the proper weights and ranks for each layer, field experiment results reflected on various hydrological literature and views of different experts available on existing literature also have been considered. Finally, by combining both considerations of the general controlling factors of surface runoff and infiltration and following the views of different experts, rank and weights for each criteria have been fixed for AHP methods.

For completing the AHP methods MS-Excel and Arc GIS 10.3 Software have been used. Following are the basic steps for AHP model which have analyzed in numerous literature (Jenifer and Jha 2017; Mallick et al. 2019; Pal, Ghosh, and Chowdhuri 2020; Patra, Mishra, and Mahapatra 2018) (Tables 2 and 3).

Establishment of judgement matrices (P) by pair wise comparison

$$\mathrm{P} = \begin{bmatrix} P11\,P12\,P1n \\ P21\,P22\,P2n \\ P1n\,P2n\,Pnn \end{bmatrix}$$

Where, P_{n} indicate the nth indicator element and P_{nn} is the judgment matrix element.

Normalized weight

$$\mathbf{W}_{\mathrm{n}} = \left(GMn / \sum_{n=1}^{Nf} GMn \right)$$

The Geometric mean of the ith row of the judgmental matrices can be calculated as

$$\mathrm{GMn} = \sqrt[Nf]{P1nP2n\ldots.PnNf}$$

Calculating consistency ratio (CR)

Consistency ratio is very important in AHP model. For assigning weightage only CR value less than 0.1 is consider in AHP model.

Table 2. Pairwise comparison matrix for AHP (Priority and rank of the layers).

Sl. No.	Layers	AHP Weightage values 1	2	3	4	5	6	7	8	Priority (%)	Rank	Normalized Weight
1	Depression Area	1	1.00	2.00	2.00	3.00	4.00	4.00	4.50	22.60	1	0.24
2	Geological Unit	1.00	1	2.00	3.00	3.00	3.00	3.50	4.50	24.17	2	0.24
3	Landuse/ Landcover	0.50	0.50	1	2.00	2.50	3.00	3.50	4.00	16.19	3	0.16
4	Slope	0.50	0.33	0.50	1	3.00	3.50	4.00	3.50	13.93	4	0.14
5	Rainfall	0.33	0.33	0.40	0.33	1	3.50	4.00	4.50	9.78	5	0.10
6	Soil Texture	0.25	0.33	0.33	0.29	0.29	1	3.00	4.00	6.17	6	0.06
7	Lineament Density	0.25	0.29	0.29	0.25	0.25	0.33	1	3.50	4.44	7	0.04
8	Drainage Density	0.22	0.22	0.25	0.29	0.22	0.25	0.29	1	2.73	8	0.03
CR = 0.06												

$$\mathrm{CR} = \frac{CI}{RCI}$$

For calculating Consistency Index (CI) formula given below are used

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

λmax represents the eigenvalue of judgmental matrix and calculated as follows

$$\lambda\max = \sum_{1}^{Nf} \frac{(PW)n}{NfWn}$$

where, W represents weight vector (Column) and RCI is found from standard tables (Alonso and Lamata 2006; Patra, Mishra, and Mahapatra 2018).

The above three steps of calculation including i) Establishment of Judgment Matrices (P) by pair wise comparison ii) Normalized Weight iii) Calculating Consistency Ratio (CR) have been performed by using MS-Excel.

Extraction of suitable location map for surface RWH

Respective weight of each thematic layer (Fi) and the weights of all variable under different thematic layer (Vi) have been allotted. All these layers' weights have been correctly distributed by utilizing raster calculator under Map algebra of Spatial Analysis tools in Arc GIS 10.3. Ultimately, a linear sum combination technique has been implemented for creating suitable location for surface RWH by utilizing raster calculator tool under Map Algebra in Arc GIS 10.3

Suitable location for surface rainwater harvesting.

$$= [(\mathrm{DAw} * \mathrm{DAwi}) + (\mathrm{GLw} * \mathrm{GLwi}) + (\mathrm{SLw} * \mathrm{SLwi}) + (\mathrm{LULCw} * \mathrm{LULCwi}) + (\mathrm{STw} * \mathrm{STwi}) + (\mathrm{RFw} * \mathrm{RFwi}) + (\mathrm{DDw} * \mathrm{DDwi}) + (\mathrm{LDw} * \mathrm{LDwi})]$$

Where, DA = Depression Area, GL = Geological map, SL = Slope map, LULC = Landuse and landcover map, ST = Soil texture map, RF = Rainfall map, DD = Drainage density map,

Table 3. Weightage of various parameters for selecting suitable location of surface RWH.

Category	Sub-category	AHP weightage values						Normalized weight
		1	2	3	4	5	6	
Geological Unit	Pink Granite	1	3.00	3.00	4.00	4.00	6.00	0.38
	Barakar formation	0.33	1	3.00	3.00	4.00	5.00	0.25
	Kulti formation	0.33	0.33	1	3.00	4.00	4.50	0.17
CR = 0.09	Panchet formation	0.25	0.33	0.33	1	3.50	4.00	0.11
	Raniganj formation	0.25	0.25	0.25	0.29	1	3.50	0.06
	Alluvium formation	0.17	0.20	0.22	0.25	0.29	1	0.04
Depression Area	Very High	1	3.00	4.00	5.00	6.00		0.46
	High	0.33	1	3.00	4.50	5.00		0.27
	Moderate	0.25	0.33	1	3.50	4.00		0.15
CR = 0.08	Low	0.20	0.22	0.29	1	4.00		0.08
	Very Low	0.17	0.20	0.25	0.25	1		0.04
Landuse/Landcover	Agricultural Lana	1	3.00	4.00	6.00	7.00		0.47
	Vegetation	0.33	1	3.00	4.00	7.00		0.26
CR = 0.09	Water body	0.25	0.33	1	4.00	7.00		0.16
	Quarry and Mining	0.17	0.25	0.25	1	4.00		0.07
	Built up area	0.14	0.14	0.14	0.25	1		0.03
Slope	Very Low	1	1.00	3.00	4.00	5.00		0.37
	Low	1.00	1	2.00	3.00	4.00		0.31
	Moderate	0.33	0.50	1	2.00	3.00		0.16
CR = 0.01	High	0.25	0.33	0.50	1	2.00		0.10
	Very High	0.20	0.25	0.33	0.50	1		0.06
Rainfall	High	1	2.00	3.00				0.53
	Moderate	0.50	1	3.00				0.33
CR = 0.05	Low	0.33	0.33	1				0.14
Lineament Density	Very Low	1	2.00	3.00	4.00	5.00		0.41
	Low	0.50	1	2.00	2.50	3.00		0.24
CR = 0.08	Moderate	0.33	0.50	1	4.00	5.00		0.20
	High	0.25	0.40	0.25	1	5.00		0.10
	Very High	0.20	0.33	0.20	0.20	1		0.05
Soil	Fine loamy	1	2.00	3.00	4.00			0.46
	Loamy	0.50	1	2.50	3.00			0.29
CR = 0.06	Coarse loamy	0.33	0.40	1	4.00			0.18
	Coal Quarry	0.25	0.33	0.25	1			0.08
Drainage Density	Very Low	1	2.00	3.00	4.00	5.00		0.41
	Low	0.50	1	2.00	2.50	3.00		0.24
	Moderate	0.33	0.50	1	4.00	4.50		0.20
CR = 0.07	High	0.25	0.40	0.25	1	4.00		0.10
	Very High	0.20	0.33	0.22	0.25	1		0.05

LD = Lineament density map. The small letter w indicates the normalized weight of specific layer and wi is the normalized weight of each features under a thematic layer.

Finally, for extracting the suitable location map for surface rainwater harvesting based on linear sum combination value Natural breaks (Jenks) classification method tool in Arc GIS 10.3 has been utilized.

Validation and characterization

Ultimately, the suitable location for surface RWH map has been validated and characterized by using google earth. For validation and characterization of suitable location 20 random points have been selected from Suitable Location for Surface Rainwater Harvesting map and the same points also have been identified in Google earth. Finally, by comparing the points in Google earth and Suitable Location for Surface Rainwater Harvesting map suitability for surface RWH has been justified. For characterization of suitable location different kinds of measurement like distance from nearest settlement, regional slope, covered area and surrounding associated features have been analyzed with the help of google earth and Arc GIS 10.3 by utilizing all the thematic layers included in present study.

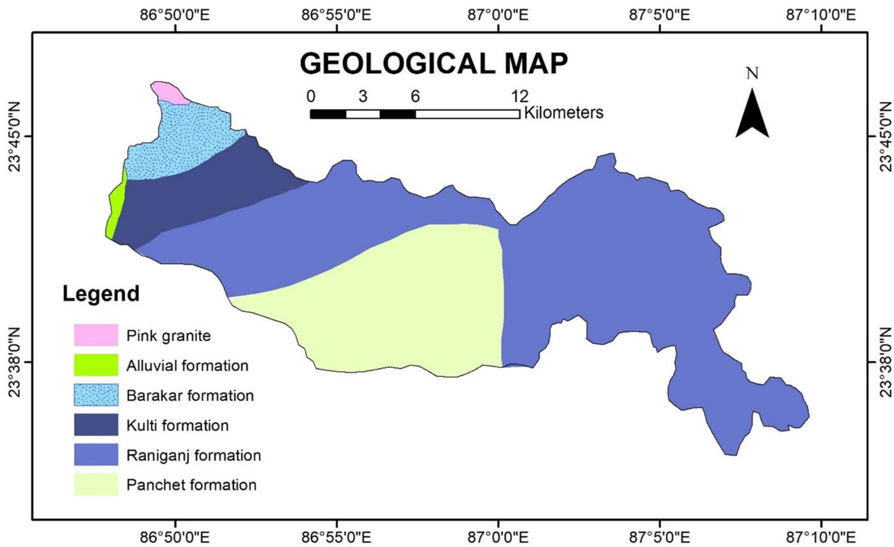

Figure 3. Geological unit of the study area prepared based on West Bengal geological quadrangle sheet (73 M and 73I).

Results and discussion

Geological unit

Geology is very important for selecting suitable location for surface RWH as it controls the rate of infiltration. There are observed six lithological units in Asansol Urban Area. A major portion of Asansol Urban Area (AUA) is occupied by rocks of Raniganj formation which is followed by the structure of Panchet formation. Another two important formations are Kulti and Barakar formation. Raniganj, kulti and barakar formation belong to Damuda group and mainly consist of sandstone, shale and coal originated in Permian age. Panchet formation is mainly consists of sandstone and shale and belongs to Gondwana super group. A minor part of AUA is composed by pink granite and alluvium formation. Pink granite is a part of Chotonagpur granite genesis complex and biotite and quartz biotite granite gneiss are main elements. Alluvium formation is a part of recent formation consists of sedimentary deposition (Figure 3).

Depression area

Natural depression area acts as a good reservoir of water. This is why natural depression area of AUA has been identified for selecting suitable location for surface RWH. Due to mining activities some large depressions are found in AUA, otherwise most part is covered by minor undulating topography. Large weightage has been given for the area having large depression and vice versa (Figure 4).

Slope

Slope is a dynamic restraint for selecting of reservoir and RWH sites (Rajasekhar, Gadhiraju, and Kadam 2020). It is very important parameter for selecting suitable location for surface RWH as it controls the natural direction and speed of water on the earth surface. The Asansol Urban Area (AUA) is dominated by area having very high slope which is associated with quick runoff. Only very small portion of AUA has very low slope which is mainly related to mining activities. Maximum weightage has been given on areas having very low slope and minimum weightage has been given on high slope (Figure 5).

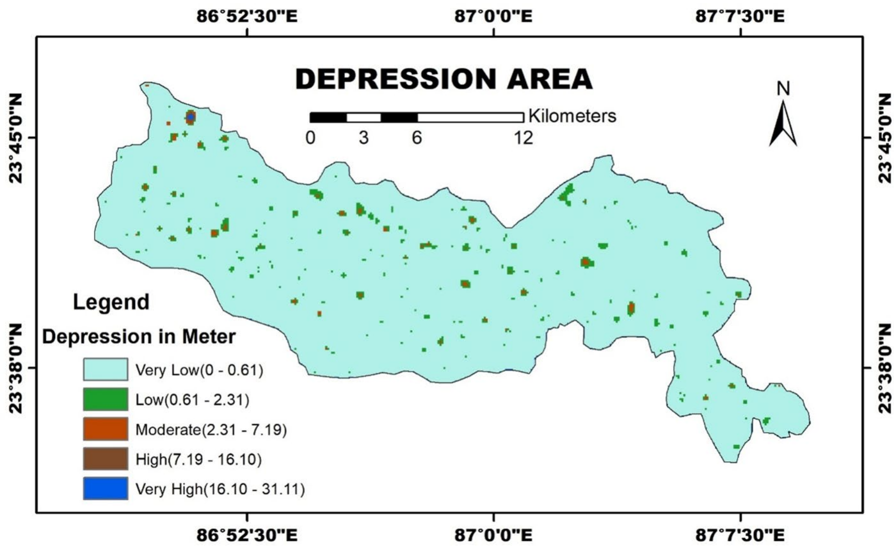

Figure 4. Depression area.

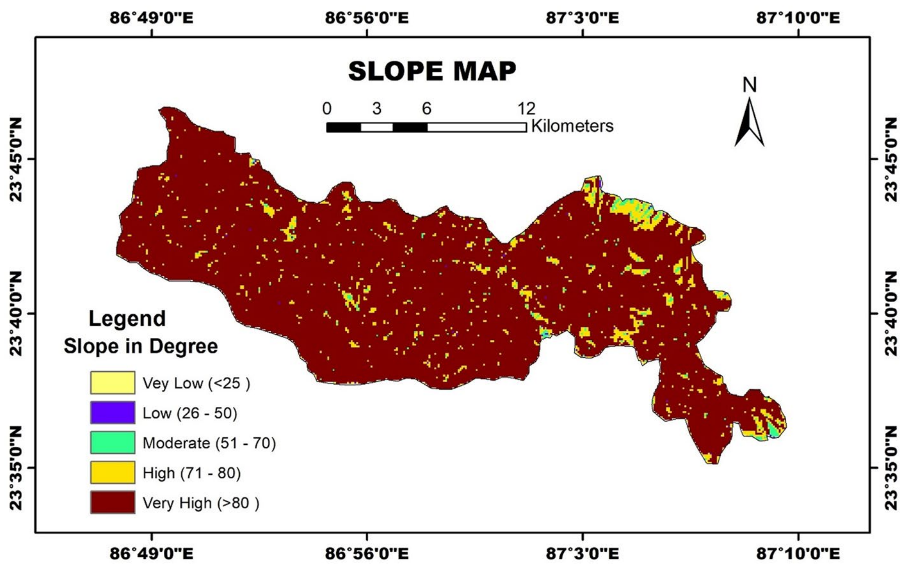

Figure 5. Slope map.

Land use and land cover

LULC study is essential for identifying surface RWH. In general, an open portion is required for surface rainwater harvesting which is impossible to identify without LULC study. Near about 24% of AUA is covered by built up area which is totally unsuitable for surface RWH. Agricultural land is the largest unit of AUA which occupied nearly 60% of the area. Some part of AUA is covered by quarry and mining areas. Another two important parameters are water bodies and vegetation. By analyzing the LULC pattern of AUC maximum weight has been given on agricultural land as it is the only area having potentiality of surface RWH (Figure 6).

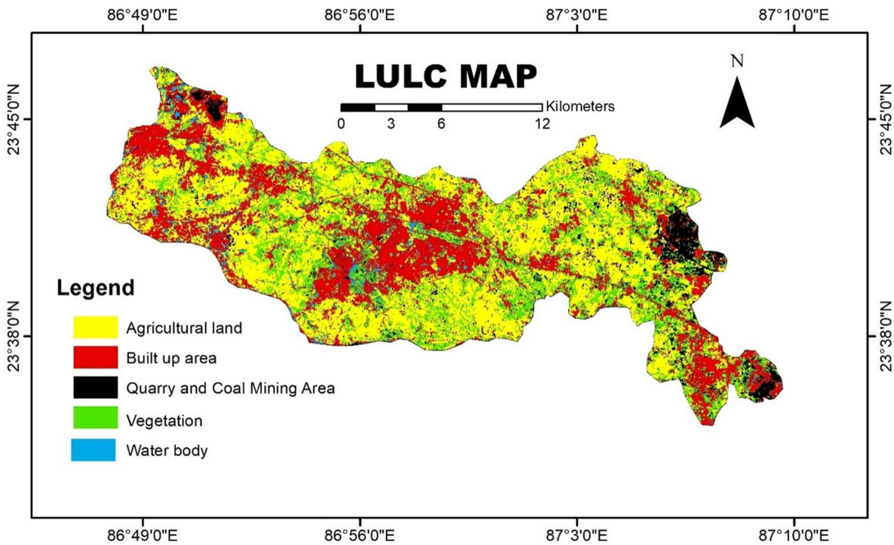

Figure 6. Land use/land cover map.

Soil texture

Surface water retention capacity depends on soil texture to great extent. For constructing surface RWH system soil having very low permeability is required. Mainly different types of loamy structure are found in AUA. Mainly three varieties of loamy soil, i.e., fine loamy, loamy and coarse loamy are observed in this area. Considering the permeability condition of this three categories soil, maximum weight for identifying suitable location for surface RWH has been given to fine loamy soil which is followed by loamy and coarse loamy (Figure 7).

Rainfall distribution

Without rainfall it is impossible to think about any kind of RWH. Slight variation is observed in rainfall distribution in AUA. Comparatively high precipitation is perceived in south west part of AUA whereas low precipitation is observed in north to north east area. The average precipitation of AUA is more than 1200 millimeter and the variation is under 100 millimeter. Considering the contribution of rainfall to RWH maximum weightage has been given to the area receiving high rainfall and vice versa (Figure 8).

Drainage and lineament density

Drainage density and RWH potentiality is negatively associated, higher the DD lower the RWH potentiality and lower the DD higher the RWH potentiality (Jha et al. 2014; Karimi and Zeinivand 2021). Drainage and lineament density both have similar effects on surface rainwater harvesting. Lineament and drainage density acts as a barrier for storing water on the surface by increasing infiltration capacity. For lineament and drainage density study, five categories are prepared base on their density. Considering the negative effects of LD and DD low weights have been allotted for the areas having high DD and LD, similarly high weightage has been given for the areas having low DD and LD (Figures 9 and 10).

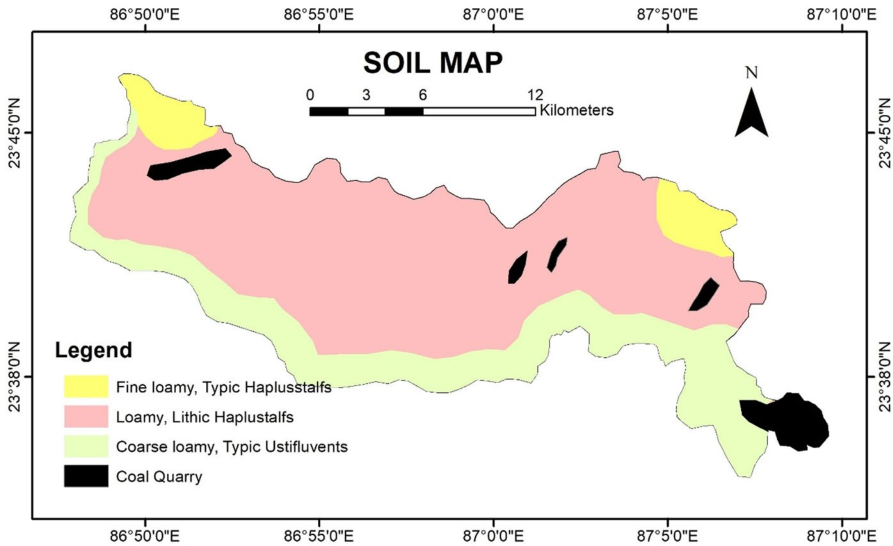

Figure 7. Soil texture map.

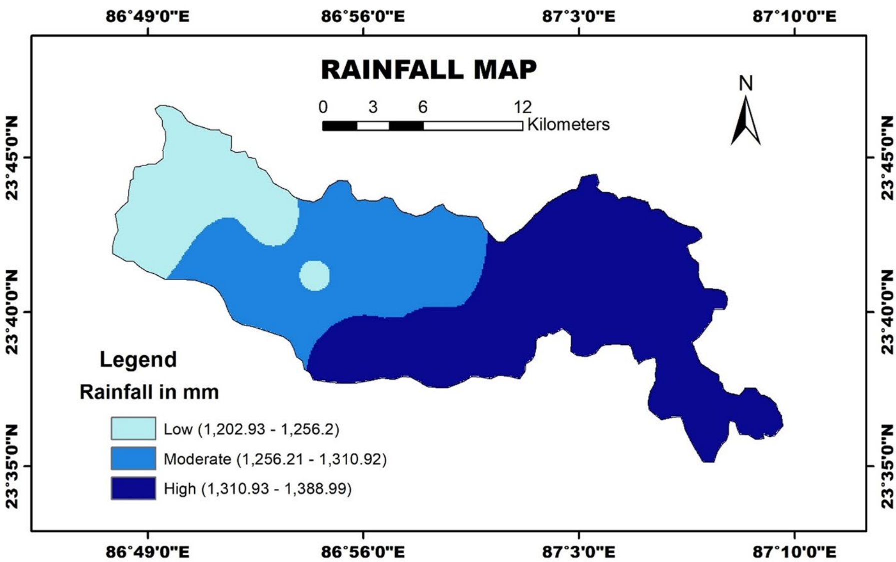

Figure 8. Rainfall distribution map.

Suitable location

On the basis of different weightage assigned by AHP method, suitable location map for surface RWH has been prepared and categorized into five classes. The following categories have been identified –very high suitable zone, high suitable zone, moderately suitable zone, low suitable zone and finally extremely low suitable zone. 32.10% of the AUA covered by very low suitable zone, 30.25% area under low suitable zone, 22.91% area under moderately suitable zone where as only 4.12% area of AUA is under very high suitable zone and 10.62% area is under high suitable zone. Very high and high suitable locations for surface RWH are mainly scattered throughout entire region surrounding by low slope and depression. Maximum suitable area is

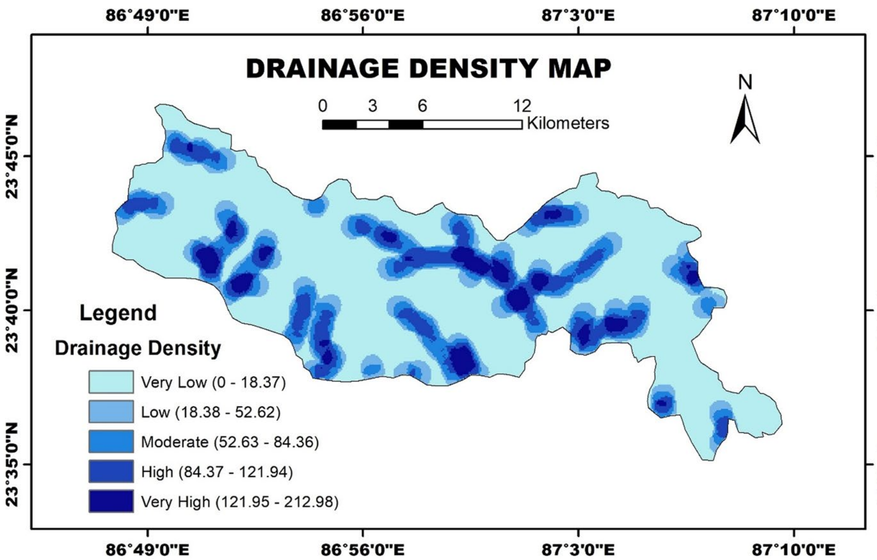

Figure 9. Drainage density map.

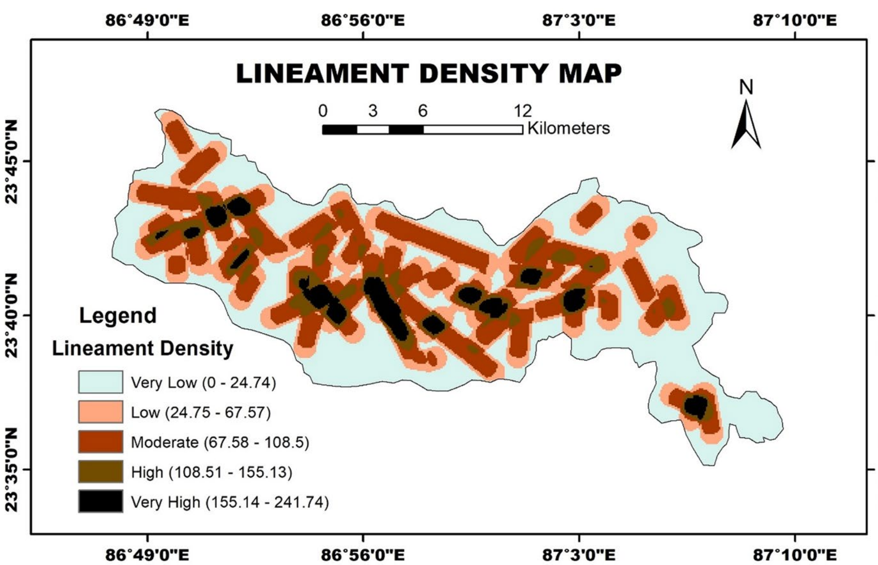

Figure 10. Lineament density map.

observed in the south eastern and north western part of AUA along with some portion of central east west of the AUA (Figure 11).

Validation and characterization

Validation point 1.

This point is located at Borira locality and highly suitable for surface RWH. It is a naturally downslope region surrounded by agricultural field. The distance from nearest settlement is

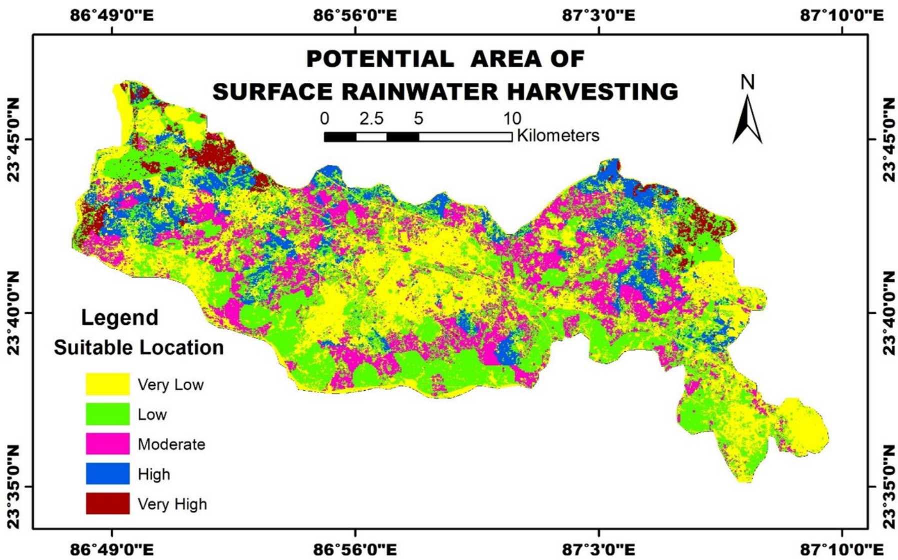

Figure 11. Suitable areas of surface RWH.

0.68 km. This area is highly suitable for the construction of large surface RWH structure as well as have the potentiality to act as a natural reservoir with minor construction.

Validation point 2.
This is located at Kulti locality and not suitable for surface RWH as it is covered by vegetation having comparatively high slope.

Validation point 3.
This is the Santoria area and also suitable for surface RWH. The distance from nearest settlement is 0.48 km and have low slope. This is also surrounded by agricultural land and small settlement unit. If necessary construction for surface RWH is done, then it may fulfill the demand of non-potable water of the local people during crisis period.

Validation point 4 and 5.
This two point are very near to the settlement (0.13 km). Being part of road side area and surrounded by settlement it is very useful for constructing small size surface RWH structure. If it is possible to maintain regular basis definitely it will help to reduce the pressure on main source of water.

Validation point 6.
This point is located at Mithani area and have the qualities to act as a good natural reservoir. This area is also naturally down slope area surrounded by settlement and suitable mainly for small size construction.

Validation point 7, 8, 11, 12.
Being a part of down slope region all these points has the potentiality of surface RWH. All these areas are suitable for large construction mainly for fulfilling the agricultural need as nearest settlement distance is more than 2 km from each points.

Table 4. Validation of suitable location.

Validation	Latitude	Longitude	Locality	Suitability
V1	23°44′36″N	86°51′45″E	Borira	High
V2	23°44′09″N	86°50′12″E	Kulti	Not suitable
V3	23°42′32″N	86°48′36″E	Sanctoria	High
V4	23°42′36″N	86°51′07″E	Bamandiah	High
V5	23°43′18″N	86°50′10″E	Kulti	High
V6	23°42′01″N	86°54′08″E	Mithani	High
V7	23°39′40″N	86°59′03″E	Mohishila	High
V8	23°41′07″N	87°04′18″E	Kedulia	Very high
V9	23°41′47″N	87°05′16″E	Damodarpur	Very high
V10	23°42′36″N	87°06′02″E	Jamuria	Moderately
V11	23°43′21″N	86°04′11″E	Jamuria	Very high
V12	23°38′47″N	86°00′11″E	Damra	High
V13	23°41′45″N	86°01′58″E	Girmint	Very high
V14	23°43′03″N	86°58′25″E	Asansol	Moderately
V15	23°39′09″N	86°55′11″E	Burnpur	High
V16	23°43′52″N	86°53′18″E	Sitarampur	High
V17	23°44′11″N	86°55′14″E	Talberia	Very high
V18	23°40′20″N	86°52′56″E	Aluthia	Moderately
V19	23°42′11″N	86°59′56″E	Kalla	Very high
V20	23°42′56″N	86°52′14″E	Neamatpur	High

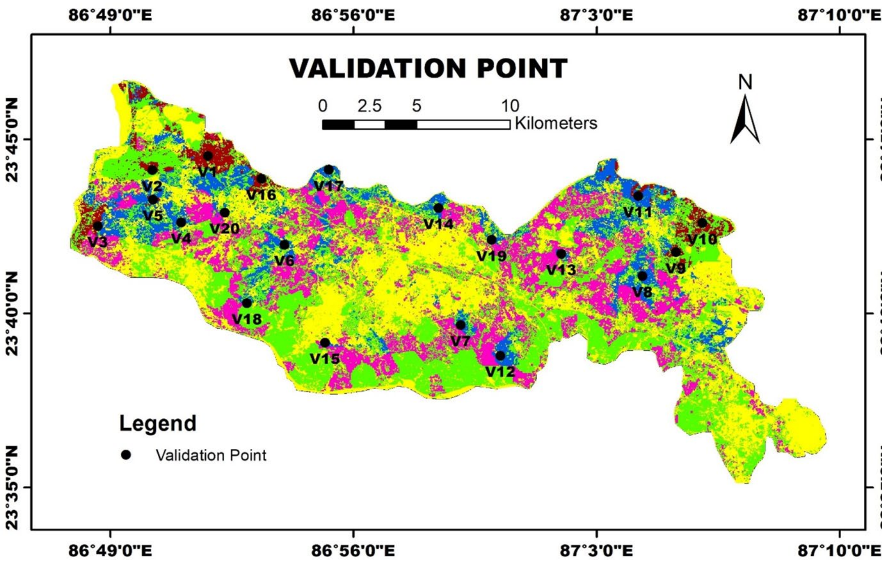

Figure 12. Location of validation point.

Validation point 9, 10.

Point nine is located near Damodarpur and ten is Jamuria locality. Point nine is natural downslope region and surrounded by agricultural land have the high potentiality for surface RWH but point ten have comparatively high slope and not suitable surface RWH.

Validation point 13, 14.

Point thirteen is located near Girmint and have very high potentiality for surface RWH. This is a naturally down slope area and suitable for large construction. But point fourteen has comparatively low potentiality because of high slope and dense settlement.

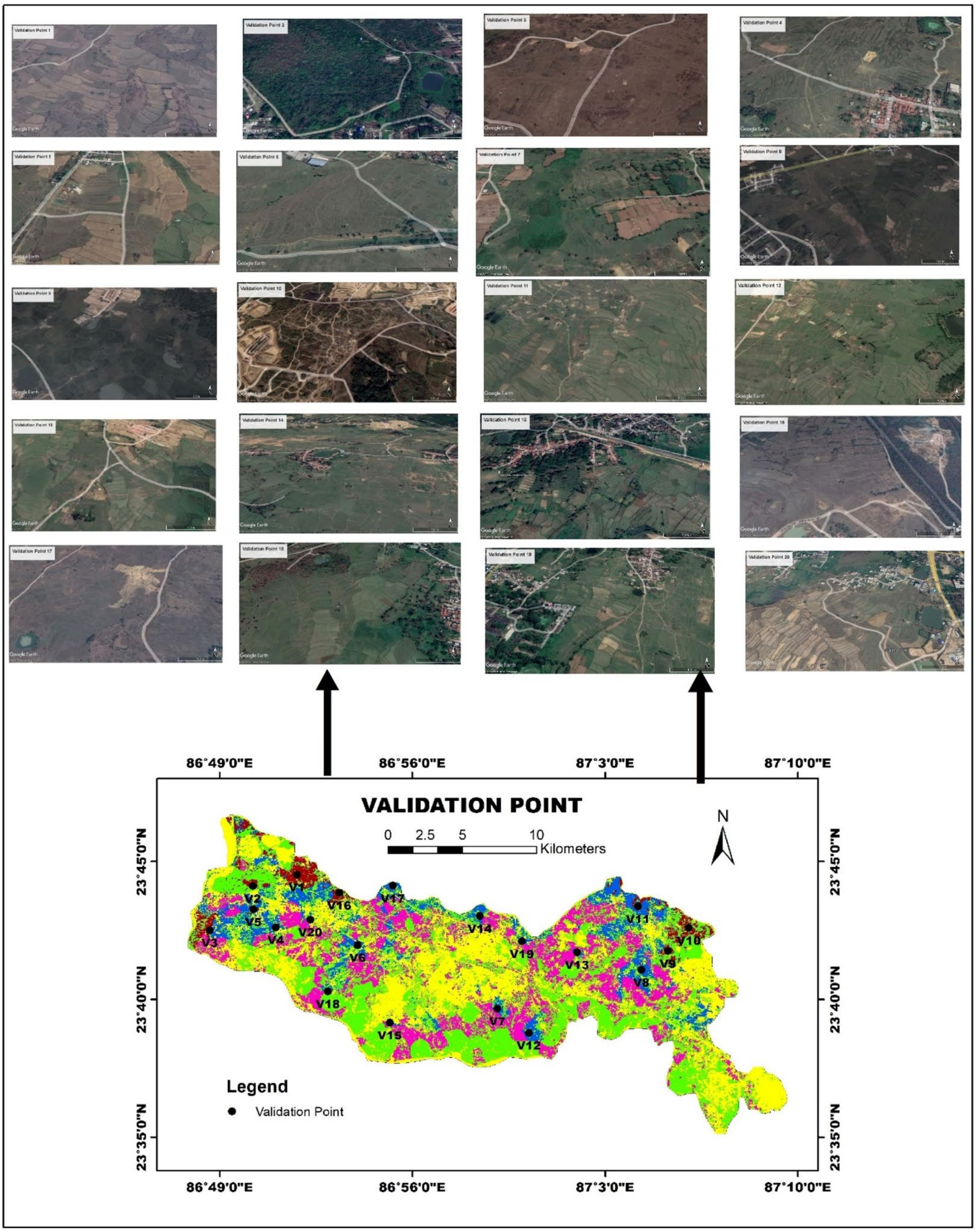

Figure 13. Integration of validation point with Google earth.

Validation point 15, 16, 17,18,19,20.

The above mention five locations have potentiality of both small and large structure for using either domestic or agricultural purposes. All these points are located at down slope region, so all points have the quality of being natural reservoir. All these points have nearest settlement unit (within 1 km) as well as agricultural land (Table 4). These areas are highly suitable for installing both manmade and natural surface RWH structure (Figures 12 and 13).

Conclusion

RWH is the best cost effective technology to meet the demand of non-potable water in water scarce region. In the present study area five different zones of suitability for surface RWH system have been identified, but after validation and characterization of this zone it is found that only zones having very high and high potentiality of surface RWH are practically suitable for constructing any kind of natural and artificial surface RWH structure. Others three zone, i.e., moderate, low and very low potential zones are totally unsuitable for surface RWH structure because of typical geo hydrological setting of these areas.

From previous experiences of surface RWH system, it is proved that regular maintenance is key to the success of any kind of rainwater harvesting systems which is the important barrier of constructing surface RWH structure along with willingness of the public. Although the selecting areas are suitable for meeting the demand of agricultural as well as domestic to some extent but roof top rainwater harvesting may be the best solution for meeting the non-potable household demand of the AUA. Another vital issues related to installing surface RWH system in the selecting cites is the right to use of property as maximum suitable areas come from private agricultural land. So, before step forward regarding this issues it is crucial to consider others socio-economic factors of the study area.

In spite of the above mention problems it is essential to make the provision of installing surface rainwater harvesting system in AUA for addressing the problems of summer water crisis and managing the water resource in sustainable way. Concerned government should restructure the plan regarding urban water resource management and must include the provision of utilizing RWH system to ensure the sustainable future.

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