JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

GIS-Based Multi-Criteria Decision Making For Identifying Groundwater Recharge Potential Zones During Waterlogging Situation In Siliguri Metropolitan Area, West Bengal, India

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Abstract: Most often, waterlogging happens when unusually high rainfall overwhelms local drainage systems and exceeds the ground's ability to absorb it. In this regard, the Siliguri Metropolitan Area, a fast expanding city in West Bengal's Darjeeling district, is plagued with waterlogging brought on by excessive orographic rainfall during the south-west monsoon season, as well as physical, socioeconomic, and environmental issues. The weighting of the factors has been analysed using the GIS-based Multi-Criteria Decision Making (MCDM) Analytical Hierarchical Process (AHP) method, which takes into account various criteria created by RS and GIS. For GWPZ and WLZ, the computed consistency values are 0.051 and 0.065, respectively. Following that, each necessary layer was superimposed based on its weight in order to create the Ground Water Potentiality Zone (GWPZ) and Water Logging Zone (WLZ). Additionally, when creating the Ground Water Recharge Potentiality Zone (GWRPZ) map, the two final plans were connected. Every plan is divided into five groups, such as very high, high, moderate, low, and very low. According to the waterlogging zone, the research area's northwest exhibits the greatest susceptibility, while the southeast exhibits the lowest. Likewise, the groundwater potential zone has shown the opposite. When these two criteria are taken together, the groundwater recharge potential zone in the study region exhibits the highest potentiality running through the southeast and the lowest potentiality in the northwest. It makes it very evident that the GWPZ and WLZ have a reverse relationship. This unequivocally shows that the GWPZ and WLZ have a reverse relationship. As a tool for future urban planning applications, this study identifies the high to low zones for WLZ and GWRZ and their combined effect on the study area's GWRPZ.

***Keywords* - Siliguri Municipality, Analytical Hierarchical Process, Ground Water Recharge Potentiality Zone**

I. INTRODUCTION

One of the most serious natural hazards that endangers people's lives and property in the modern world is pluvial flooding. This natural calamity, which is linked to comparatively high humidity or precipitation, happens when exceptionally heavy rainfall overwhelms the area's drainage systems and surpasses the ground's capacity to absorb it (Neuendorf et al., 2005). The majority of small and medium-sized Indian cities, including Siliguri, face physical, socioeconomic, and environmental problems as a result of urban waterlogging brought on by excessive precipitation, which is a major problem globally and considerably more common in urban settings (Chatterjee et.al, 2021). City's natural surfaces are being replaced by impervious hard surfaces that keep rainwater from penetrating the soil, a process accelerated by rapid urbanization (Singh & Singh, 2011). The accumulation of rainwater leads to an increase in the amount of surface runoff, which causes the streets of the city to operate as a stream. This phenomenon has become one of the most predisposing factors for urban waterlogging (Singh and Singh 2011; Radford and James 2013; Hassan and Nazem, 2016; Shao et al., 2019; Shukla and Jain, 2019; Nowak and Greenfield, 2020). Numerous earlier studies have demonstrated that heavy rainfall is not the only significant factor that can have a major impact on the waterlogging issue; unplanned urban growth, low landscape profile, changes in land use and cover, and inadequate drainage infrastructure and management are also important factors (Sajikumar and Remya, 2015; Tam and Nga, 2018; Subrina and Chowdhury, 2018; Rahmati et al., 2020).

The world's greatest availability of freshwater is groundwater. At least half of the worldwide population gets their drinking water from aquifers, which also supply 43% of all irrigation water. Additionally, 2.5 billion people around the world rely completely on the availability of groundwater to meet their basic needs (UNESCO 2015). Globally, groundwater is essential to economic development and food security and is also necessary for human survival. The accessibility of ground water resources is in danger now as a result of overexploitation and subpar management techniques. Since the availability of fresh groundwater is threatened globally, it is essential for a sustainable way of life to comprehend the methods and solutions for managing surface water and groundwater recharge as well as raising groundwater levels locally, nationally, and internationally (Muniraj et al. 2019).

Groundwater has a crucial role in both urban and rural regions for the reliable and affordable supply of drinking water. It also significantly affects human health and the terrestrial and marine habitats (Magesh et al. 2012; Teshome et al. 2020). The availability of groundwater resources, coupled with increased anthropogenic activity and rapid population growth, has made managing the world's water supply a dynamic task (Qadir et al. 2020). Groundwater is a dynamic resource that depends on a wide range of factors, including topographic changes, lithology, slope, topography, geomorphology, soil, rainfall, drainage patterns, vegetation coverings, and land use/land cover (LULC) (Deshmukh 2011; Singh et al. 2011; Kalpana and Elango 2013; Shailaja et al. 2018). Through the processes of water penetration, storage, and drainage, groundwater potential zones and waterlogging are intimately related. Because of things like permeable soils, fractured rocks, and suitable recharge conditions, locations with higher capacity for storing and transporting groundwater are referred to as groundwater potential zones. Therefore, although groundwater potential zones are essential for the storage and supply of water, they may also become susceptible to waterlogging without adequate management, which could have an impact on the quality of the water and the usability of the land. However, an increase in the water table might result in waterlogging at the surface if the normal drainage of these zones is hindered or if recharge surpasses storage capacity. Even in places with good groundwater capacity, water stagnation is further exacerbated in urban or low-lying areas by inadequate drainage infrastructure and excessive surface runoff. On the other hand, by sealing the soil surface and changing penetration rates, prolonged waterlogging might eventually lower groundwater recharge. Therefore, although groundwater potential zones are essential for the storage and supply of water, they may also become susceptible to waterlogging without adequate management, which could have an impact on the quality of the water and the usability of the land.

Both environmental factors and human activity influence the relationship between groundwater potential zones and waterlogging in urban areas. Water build up is common in areas with significant groundwater potential because of their shallow water table and permeable soils. Even in places that can store groundwater, waterlogging happens when surface runoff or rainfall surpasses the infiltration capacity or when urban drainage systems are inadequate. Furthermore, because of impermeable surfaces like buildings and roads, urbanization decreases natural infiltration, which leads to surface water accumulation rather than groundwater replenishment. Constant waterlogging can sometimes cause the water table to rise even more, which lowers the unsaturated zone needed for efficient recharge and starts a vicious cycle. On the other hand, if the soil is compacted or sealed, low-lying, poorly drained areas might still be wet but might not necessarily contribute significantly to groundwater recharge. Thus, urban elements such as land cover, drainage systems, and water management techniques have a significant impact on how groundwater potential zones and waterlogging interact with subsurface water dynamics.

II. RATIONALE

Water scarcity and waterlogging has become a serious issue throughout the world lately. This research has focused on identifying groundwater recharge zones in the Siliguri Metropolitan area and its surroundings by utilizing a combination of GIS techniques and an integrated Analytical Hierarchy Process (AHP). Despite its strategic location as the gateway to north-eastern India, Siliguri lacks sufficient data compliance. In addition, the occurrence of waterlogging in this city that is expanding rapidly affects at a disturbing rate. This city encounters this hazard annually, particularly during the monsoon season from June to August, without prior planning. Individuals lose their possessions, homes are damaged, property is lost, and chaos ensues. Furthermore, this city exerts a distinctive influence on the groundwater. While some regions have no issues with water, others contend with high iron concentrations in their water, and still others frequently experience water scarcity. There is a clear inverse relationship between waterlogging and zones of groundwater potential. This study aims to pinpoint areas at risk of waterlogging and those with groundwater potential, allowing for the identification of likely groundwater recharge zones. By doing so, it seeks to address waterlogging issues and make use of surplus water in areas with low groundwater recharge, thereby preventing further hazards in this multifaceted city and its vicinity.

III. METHODOLOGY

3.1 Study Area

One of India's West Bengal's fastest-growing cities is Siliguri. It is known as the "gateway of north-eastern India" because it is situated in a small corridor that links Bangladesh to the south, Bhutan to the north, and Nepal to the northwest (Bhattacharyya and Mitra, 2013). Rapid economic and population growth can be attributed to this favourable location. It includes portions of West Bengal's Jalpaiguri and Darjeeling districts. Siliguri is the third-largest urban agglomeration in West Bengal, behind Asansol and Kolkata. With the help of many migrants and a fast population growth, Siliguri has transformed from a village to a commercially advanced city over the ages, leading to the city's extraordinary growth (Bose and Chowdhury, 2020). Both the economy and the population have grown rapidly as a result of this favourable location. It includes portions of the West Bengal districts of Jalpaiguri and Darjeeling. After Kolkata and Asansol, Siliguri is the third-largest urban agglomeration in West Bengal. Over time, Siliguri has transformed from a village to a commercially advanced city by drawing a lot of migrants and experiencing a quick population surge, which has led to the city's extraordinary growth (Bose and Chowdhury, 2020). It is located at an average elevation of 122 meters (400 feet) on the banks of the Mahananda River in the foothills of the Himalayas. With a high population density, it has grown quickly in recent decades. The Siliguri Municipal Corporation occupies an area of roughly 41.9 km^2 and is surrounded by 47 wards that have grown fivefold since 1931. According to the 2011 census data, the city's population is growing faster than expected, going from over four lakh in 2001 to over seven lakh (Bhattacharyya and Mitra, 2013). Every year, Siliguri experiences waterlogging, primarily as a result of monsoon rainfall that causes chaos in the city. Due to the blocked drainage system caused by the sewer network's inability to handle the high amount of rainfall, certain low-lying districts of this city were frequently drowned by extreme rainfall during the months of July and August. The city's land-use trend has changed recently due to a number of factors, including major deforestation, climate change, rapid urbanization, and population growth. Furthermore, Siliguri's waterlogging risk is reduced by high-density roadways, paved surface expansion, and poor sewer system maintenance. Additionally, the groundwater recharge gradient in this metropolis is diverse. Physical features have contributed to the powerful groundwater recharged zones as a result of the abundant rainfall. Furthermore, two geographical parameters are always related. In light of this, the current study examines the relationship between the Siliguri Metropolitan Area's waterlogging zones and groundwater potential zones. The view of the study area has shown in fig 1.

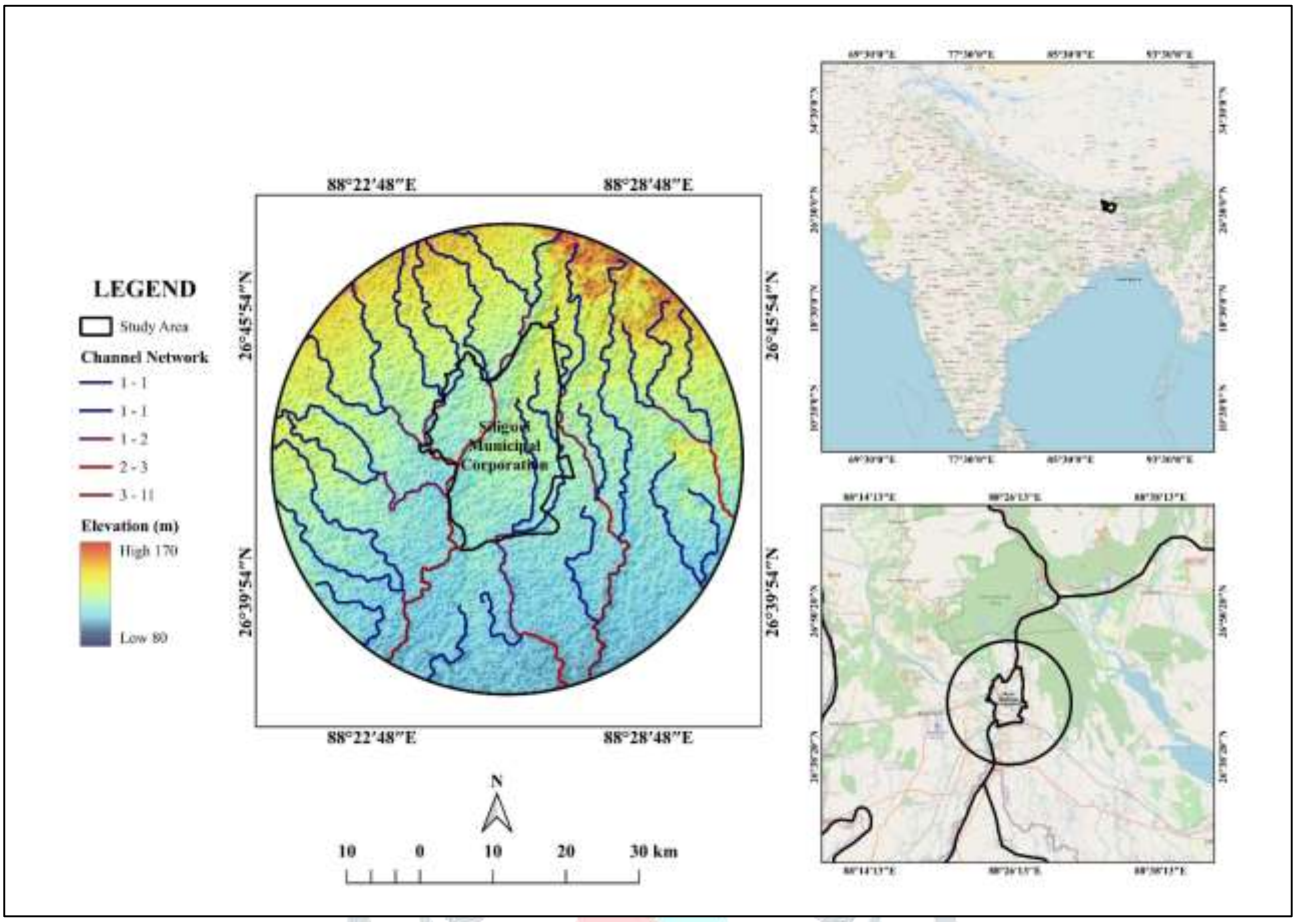


Figure1. Location of the Study Area.

3.2 DATABASE

When carrying out research, an authentic database is essential for developing an observable conclusion. This study will make use of both primary and secondary sources of data. Focus groups with the community, participatory rural assessment, key informant interviews with locals, and expert observations via questionnaire should all be used to gather primary sources of data directly from the field. When furthermore, sources that have been verified have been used to gather secondary data. This map was created using a GIS program's execution.

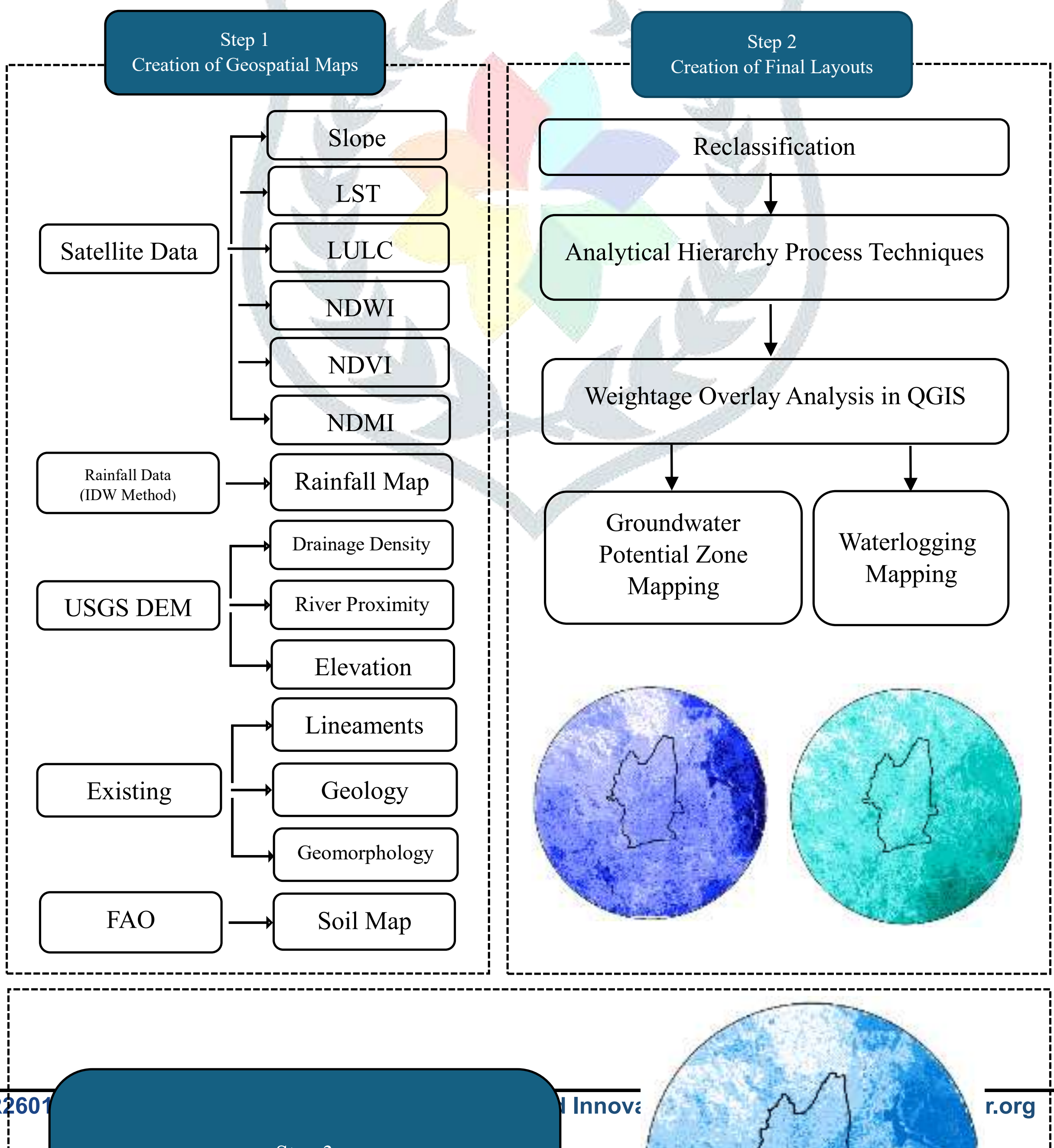
Sl. No	Data descriptions	Purpose	Source
1	Satellite data	Slope	USGS Earth Explorer
		LST	
		LULC	
		NDWI	
		NDVI	
		NDMI	
2	Rainfall	Rainfall Map	Point data, IMD
3	DEM	Drainage Density	USGS DEM
		River Proximity	
		Elevation	
4	Existing maps	Lineaments	Geological Survey of India
		Geology	
		Geomorphology	
5	Soil	Soil Map	FAO

Table 1. Database of the Study

IV. METHODS

A waterlogging zone map and a groundwater potential zone map can be created using the physical maps mentioned above. Saaty's Pairwise Comparison Method (1980) will serve as the foundation for this. In GIS-MCDA applications, the most used technique for determining criteria weights is the pairwise comparison method (Malczewski, 2006). To rate preferences in relation to two criteria, the approach uses an underlying scale with values ranging from 1 to 9. More precisely, AHP, or Analytic Hierarchy Process, is capable of doing that. It is employed in the pairwise comparison method to obtain ratio scales from both discrete and continuous paired comparisons. Either real measurements or a basic scale that represents the relative intensity of preferences and emotions may be used for these comparisons. The analysis has shown below.

Figure 2. Conceptual Framework of the Study



	EL	SL	RF	NDWI	NDMI	NDVI	RF	GL	GM	SO	LULC
EL	1	1/2	2	3	4	5	6	7	8	1/9	9
SL	1/2	1	1/2	2	3	4	5	6	7	8	9
RF	1/2	2	1	1/2	2	3	4	5	6	7	8
NDWI	1/3	1/2	2	1	1/2	2	3	4	5	6	7
NDMI	1/4	1/3	1/2	2	1	1/2	2	3	4	5	6
NDVI	1/5	1/4	1/3	1/2	2	1	1/2	2	3	4	5
RF	1/6	1/5	1/4	1/3	1/2	2	1	1/2	2	3	4
GL	1/7	1/6	1/5	1/4	1/3	1/2	2	1	1/2	2	3
GM	1/8	1/7	1/6	1/5	1/5	1/4	1/3	1/2	1	1/2	2
SO	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	2	1	1/2
LULC	1/9	1/8	1/8	1/7	1/6	1/5	1/4	1/3	1/2	2	1
TOTAL	**3**	**5**	**7**	**10**	**14**	**19**	**24**	**30**	**39**	**39**	**55**

{Individual criterion / Sum of individual criterion (vertically)} i.e. $\frac{a_{ij}}{\sum a_{ij}}$

4.1 AHP for WLZ

	EL	SL	RF	NDWI	NDMI	NDVI	RF	GL	GM	SO	LULC	WEIGHTAGE
EL	0.29	0.09	0.28	0.30	0.29	0.27	0.25	0.23	0.21	0.00	0.17	0.215
SL	0.15	0.19	0.07	0.20	0.22	0.21	0.20	0.20	0.18	0.21	0.17	0.181
RF	0.15	0.37	0.14	0.05	0.14	0.16	0.16	0.17	0.15	0.18	0.15	0.166
NDWI	0.10	0.09	0.28	0.10	0.04	0.11	0.12	0.13	0.13	0.16	0.13	0.125
NDMI	0.07	0.06	0.07	0.20	0.07	0.03	0.08	0.10	0.10	0.13	0.11	0.093
NDVI	0.06	0.05	0.05	0.05	0.14	0.05	0.02	0.07	0.08	0.10	0.09	0.069
RF	0.05	0.04	0.03	0.03	0.04	0.11	0.04	0.02	0.05	0.08	0.07	0.051
GL	0.04	0.03	0.03	0.02	0.02	0.03	0.08	0.03	0.01	0.05	0.06	0.037
GM	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.02	0.03	0.01	0.04	0.022
SO	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.05	0.03	0.01	0.022
LULC	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.02	0.019
TOTAL	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

The current GPZ study is conducted using the same AHP technique with remote sensing and GIS. Below are the results of other computations used to define groundwater potential zones.

Table2. Pairwise Matrix for WLZ

SCALE	1	3	5	7	9	2, 4, 6, 8	Reciprocals
IMPORTANCE	Equal Importance	Moderate Importance	Strong Importance	Very Strong Importance	Extreme Importance	For compromise between the values	If column is of much more importance than row

Next, the Normalized Pairwise Matrix must be computed. This is the formula:

Table 3. Normalised Pairwise Matrix for WLZ

A specific scale can now be found if the matrix is observed. The "Saaty's Nine Point Scale" is a scale used to provide weight to each criterion relative to the others. Below is a display of it:

Table 4. Saaty's Nine Point Scale

The Eigen Vectors must then be calculated. This is mostly done to extract the Principal Eigen Value. It is computed as follows:

This formula makes it simple to calculate the principal Eigen Value by averaging the Eigen Vectors. Next comes the most difficult step, which is to calculate the Consistency Ratio. This displays the accuracy of the entire calculation. Saaty says that if the consistency value is less than 0.10, the calculation is correct; if not, there may be a matrix issue. The consistency index is required for the consistency ratio. The formula below will be used for this:

((Principal Eigen Value – n) / (n – 1))

Where, ***n*** is number of observations.

Eigen Vector										
EL	**SL**	**RF**	**NDWI**	**NDMI**	**NDVI**	**RF**	**GL**	**GM**	**SO**	**LULC**
2.65	2.15	1.92	1.48	1.1	0.81	0.59	0.44	0.25	0.24	0.21
12.3	11.92	11.55	11.8	11.8	11.76	11.76	11.82	11.41	11.04	10.93
Principal Eigen Value										
11.6										

Table 5. Eigen Vector & Principal Eigen Value

The Consistency Index is taken out by applying the above formula and then the Consistency Ratio by applying the formula ***(CI / RCI)*** where, *CI* = Consistency Index; *RCI* = Random Consistency Index. Therefore:

Table 6. Consistency Index

CONSISTENCY INDEX	0.065

Table 7. Consistency Ratio

CONSISTENCY RATIO	0.0427

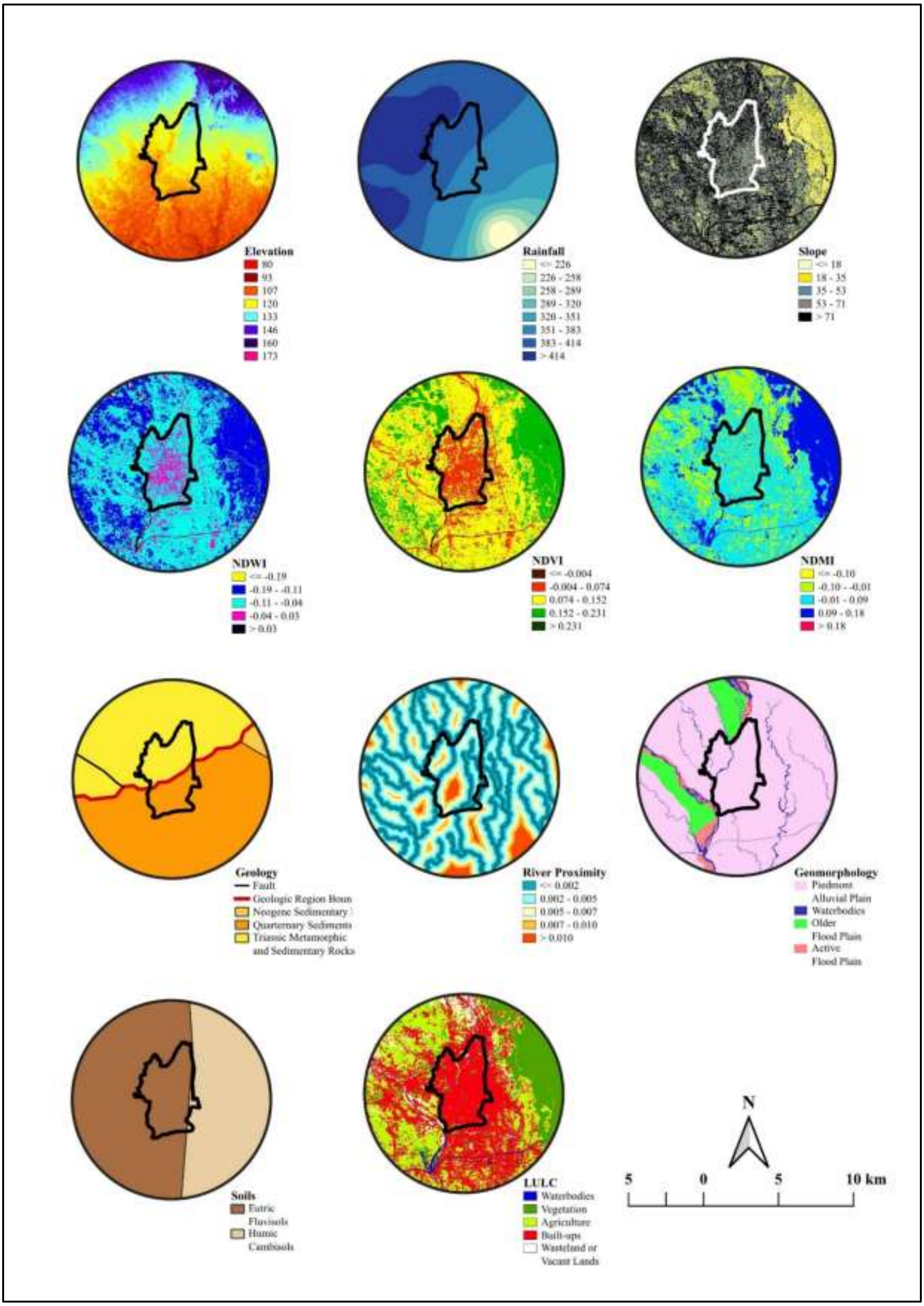
This Consistency Ratio is measured on the Saaty's Relative Importance Scale (1990 – 1980):

n	3	4	5	6	7	8	9	10	11	12	13	14	15
RCI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Table 8. Saaty's Relative Importance Scale

$$\begin{pmatrix} a_{11} & \cdots & a_{ij} \\ \vdots & \ddots & \vdots \\ a_{ij} & \cdots & a_{ij} \end{pmatrix} * \begin{pmatrix} w_1 \\ w_2 \\ w_3 \end{pmatrix}$$

Figure 3. Criterions for addressing Waterlogging Zones



4.2 AHP for GPZ

The current GPZ study is conducted using the same AHP technique with remote sensing and GIS. Below are the results of other computations used to define groundwater potential zones.

Table 8. Pairwise Matrix for GPZ

	SL	LI	LST	RF	DD	LULC	GL	GM	SO
SL	1	2	3	4	5	6	7	8	9
LI	1/2	1	2	3	4	5	6	7	8
LST	1/3	1/2	1	2	3	4	5	6	7
RF	1/4	1/3	1/2	1	2	3	4	5	6
DD	1/5	1/4	1/3	1/2	1	2	3	4	5
LULC	1/6	1/5	1/4	1/3	1/2	1	2	3	4
GL	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3
GEO	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2
SO	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1
TOTAL	**3**	**5**	**8**	**11**	**16**	**22**	**29**	**37**	**45**

Table 9. Normalized Pairwise Matrix for GPZ

	SL	LI	LST	RF	DD	LULC	GL	GM	SO	WEIGHTAGE
SL	0.35	0.42	0.40	0.35	0.31	0.27	0.24	0.22	0.20	0.307
LI	0.18	0.21	0.26	0.26	0.25	0.23	0.21	0.19	0.18	0.218
LST	0.12	0.11	0.13	0.17	0.18	0.18	0.17	0.16	0.16	0.154
RF	0.09	0.07	0.07	0.09	0.12	0.14	0.14	0.14	0.13	0.109
DD	0.07	0.05	0.04	0.04	0.06	0.09	0.10	0.11	0.11	0.076
LULC	0.06	0.04	0.03	0.03	0.03	0.05	0.07	0.08	0.09	0.053
GL	0.05	0.04	0.03	0.02	0.02	0.02	0.03	0.05	0.07	0.037
GEO	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.026
SO	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.019
TOTAL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

After pairwise comparison matrix & normalized pairwise matrix, Eigen vectors & Principal Eigen value are calculated.

Table 10. Eigen Vector & Principal Eigen Value

Eigen Vector								
SL	**LI**	**LST**	**RF**	**DD**	**LULC**	**GL**	**GEO**	**SO**
2.98	2.13	1.5	1.04	0.71	0.49	0.34	0.24	0.17
9.71	9.78	9.72	9.55	9.34	9.17	9.08	9.10	9.22
Principal Eigen Value								
9.41								

Lastly, consistency index & consistency ratio are calculated as under:

Table 11. Consistency Index

CONSISTENCY INDEX	0.050999277

Table 12. Consistency Ratio

CONSISTENCY RATIO	0.035171915

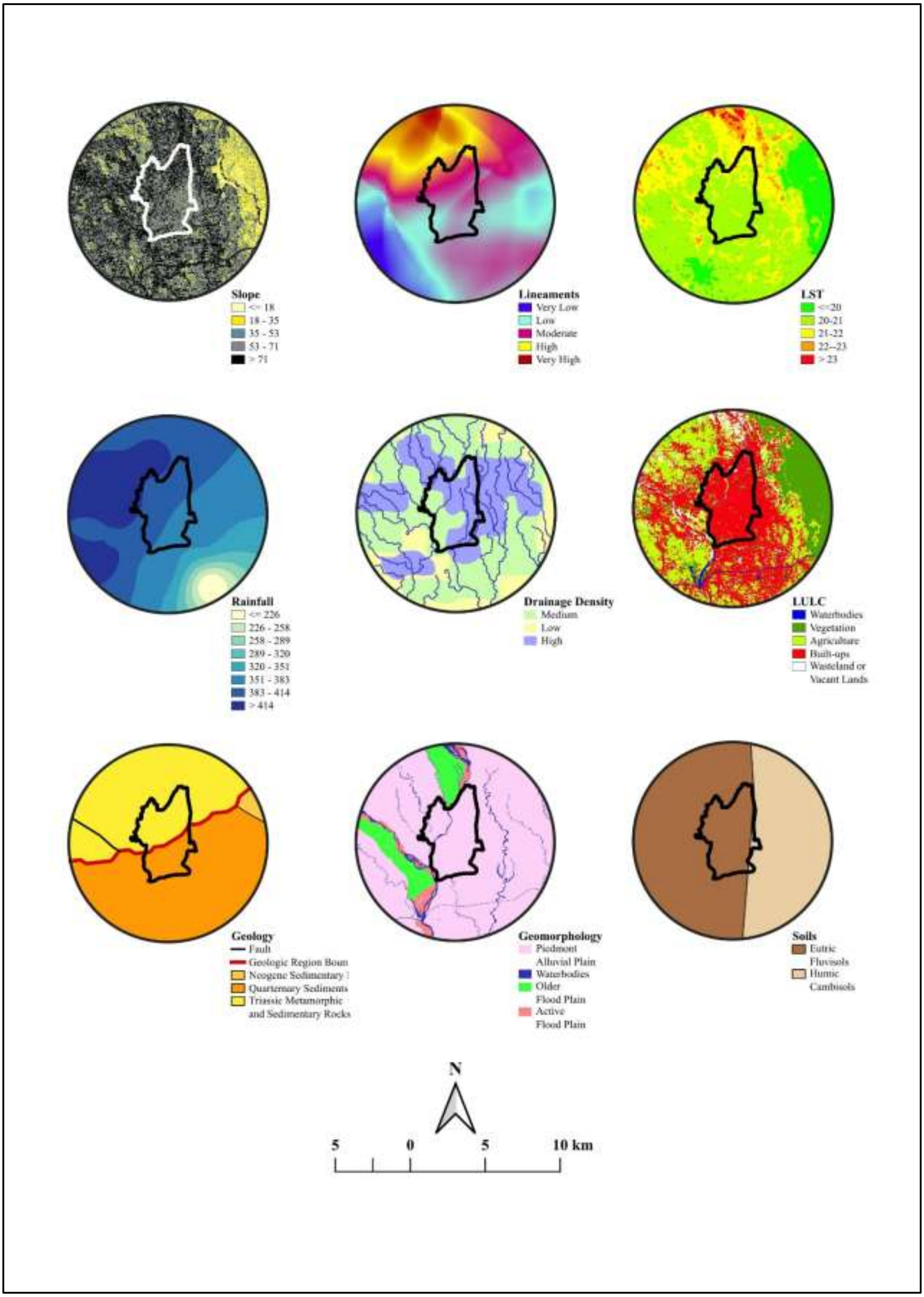
With a consistency ratio of >0.10, the computation is appropriate to move forward with. So, the final layouts are now created. All the layers have been classed and then normalized in order to create this map. The following equation was then used:

$$(IC_{w1} * IC_{r1}) + (IC_{w2} * IC_{r2}) + (IC_{w3} * IC_{r3}) + (IC_{w4} * IC_{r4}) + (IC_{w5} * IC_{r5}) + (IC_{w6} * IC_{r6}) + (IC_{w7} * IC_{r7}) + (IC_{w8} * IC_{r8}) + (IC_{w9} * IC_{r9}) +$$

IC = Individual Criterion; *w* = weightage; *r* = ranks of IC

Where, **EL** = Elevation; **SL**= Slope; **RF** = Rainfall; **NDWI** = Normalized Different Wetness Index; **NDMI** = Normalized Different Moisture Index; **NDVI** = Normalized Different Vegetation Index; **PR** = Proximity; **GL** = Geology; **GM** = Geomorphology; **SO** = Soil. **LI**= Lineaments; **LST** = Land Surface Temperature; **DD** = Drainage Density; **LULC** = Landuse Landcover Map;

Figure 4. Criterions for addressing Groundwater Potential Zones



V. RESULTS

Regarding the groundwater recharge potential zone map, it is evident that the waterlogging and groundwater potential zone maps have been combined to provide a positive result, which is consistent with the established inverse link between those two key study elements. Additionally, the relationship between these ultimate outcomes and specific criteria has been discussed below.

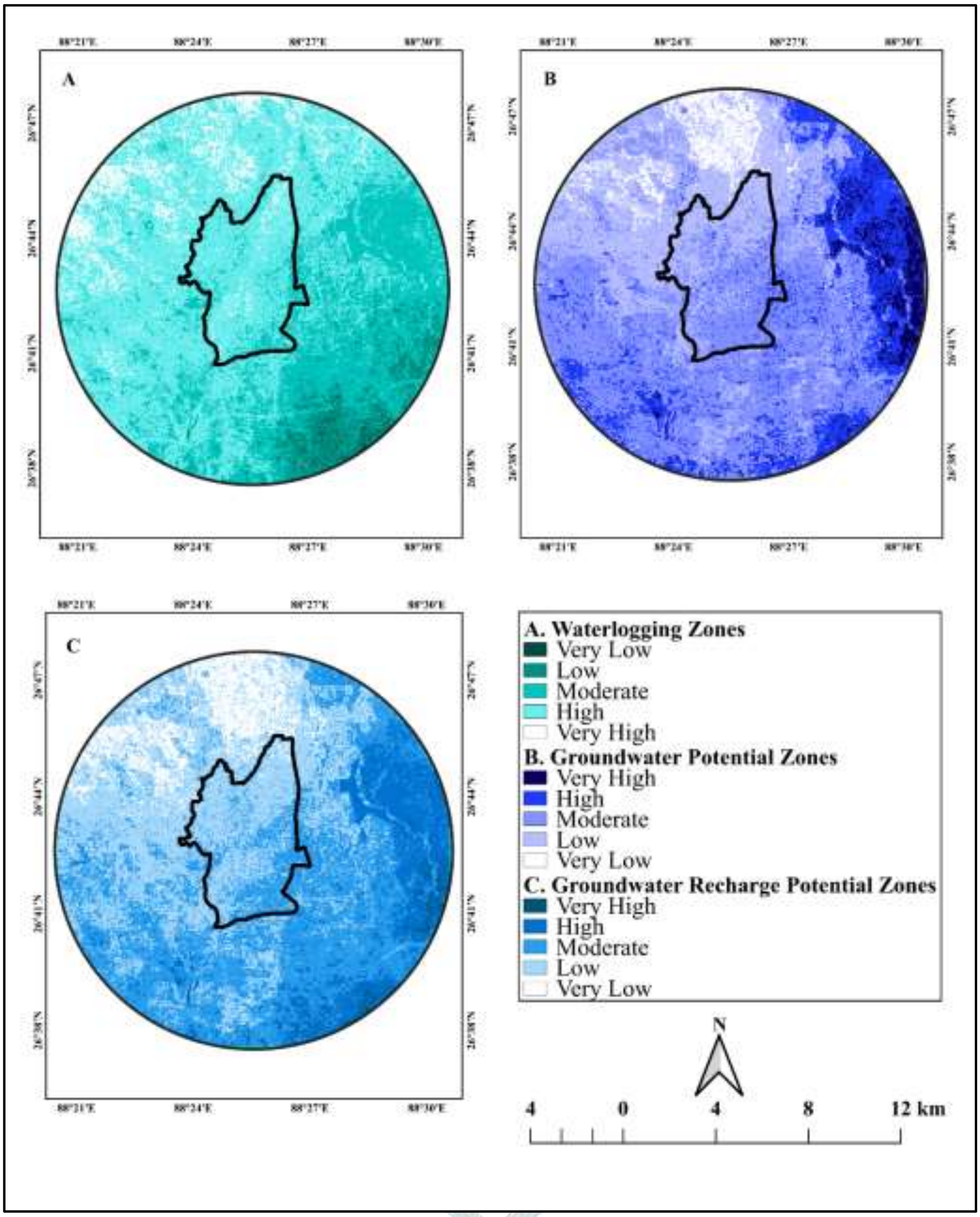
First, the slope. The study area's western region, for example, has comparatively high groundwater potential and minimal waterlogging, which results in a larger groundwater recharge. In a similar vein, higher slopes result in decreased groundwater potential and a higher rate of waterlogging, which in turn reduces groundwater recharge. Although lineaments and groundwater potential have a promising relationship—a higher lineament density is likely to have a higher potential—they also oversaturate the subsurface area, which results in waterlogging and inadequate groundwater recharging. Depending on the topography, waterlogging and groundwater potential are frequently linked to lower LST, and vice versa. However, based on the final results, LST hardly affects waterlogging due to the nature of the terrain structure there. Increased rainfall causes areas to overflow with water, which combines with inadequate drainage systems to create severe waterlogging zones. Lower rainfall also results in reduced waterlogging, which raises groundwater potential according to other factors, leading to higher groundwater recharge zones. Low groundwater potential and increased waterlogging are caused by drainage density linked to inadequate drainage. Furthermore, low waterlogging and high groundwater potential zones—which in turn lead to higher groundwater recharge potential zones—are the direct results of good drainage with a relatively promising drainage density.

Both groundwater potential and waterlogging are significantly impacted by LULC. Due to improved infiltration, agricultural and vegetated areas frequently exhibit high groundwater potential; yet, agricultural areas are more susceptible to waterlogging, particularly in low-lying locations. Conversely, built-up areas may suffer from waterlogging brought on by surface runoff and limit infiltration, which lowers groundwater recharge.

Understanding the groundwater recharge potential zones is thus aided by the LULC pattern. Since they are porous and unconsolidated, quaternary and Neogene sedimentary formations have high groundwater potential and comparatively low waterlogging because they retain water better. Low permeability in Triassic Metamorphic and Consolidated Sedimentary Rocks, on the other hand, causes severe waterlogging and low groundwater potential zones. The resulting groundwater recharge potential zones were thus directly concentrated by the geological configuration. Low-lying and highly permeable, active flood plains frequently exhibit significant groundwater potential as well as frequent waterlogging as a result of inadequate drainage and frequent flooding. Good groundwater potentiality is also supported by older flood plains, but they are somewhat vulnerable to waterlogging. Because of their minor elevation and good drainage, piedmont alluvial plains often have a decreased risk of waterlogging and exhibit moderate to good groundwater potential, depending on the sediment compositions. This provides a slight interpretation of groundwater recharge based on geomorphology. Although eutric fluvisols, which are prevalent in floodplains, have a high groundwater potential, low-lying areas are vulnerable to waterlogging. With a lower danger of waterlogging, humic cambisols contribute to moderate to high groundwater recharge through effective infiltration and moisture retention. This paints a clear picture of the differences in the zones where groundwater can replenish.

Because of their propensity to retain surface water, low elevation regions are more vulnerable to waterlogging but are also better for groundwater recharging. Higher elevation zones, on the other hand, have greater drainage, which lowers the risk of waterlogging, but they also frequently have lesser groundwater potential. Greater surface water presence is indicated by high NDWI readings, which are frequently associated with waterlogged areas and zones with higher soil moisture content. Because of the ongoing recharge, these regions might also exhibit good groundwater potential. Dry conditions with little waterlogging and a lower possibility for recharging are indicated by low NDWI values. Particularly in agricultural or natural green areas, dense vegetation is indicated by high NDVI values, which are frequently linked to high groundwater potential and good soil moisture. If drainage is inadequate, these places may also be vulnerable to waterlogging. Sparse vegetation is reflected in low NDVI values, which are generally associated with arid, less productive regions with little waterlogging and little groundwater recharge. Greater vegetation moisture is indicated by high NDMI values, which are frequently associated with regions with high groundwater potential and probable waterlogging as a result of saturated soil conditions. Poor NDMI readings indicate poor groundwater recharge and little chance of waterlogging since they represent dry vegetation and little subsurface moisture. Because of alluvial deposits and ongoing recharge, areas near rivers typically have high groundwater potential. Nevertheless, these areas are also more vulnerable to waterlogging, particularly in flat areas, during floods, and in cases where the drainage system is inadequate. Therefore, the presence of a river has a significant impact on the risk of waterlogging as well as groundwater availability.

Figure 5. Waterlogging, Groundwater Potential Zone & Groundwater Recharge Potential Zone Map



VI. DISCUSSIONS

This study delineates GWPZ and GWRPZ maps of the Siliguri Metropolitan area and its surroundings using RS, GIS, and AHP techniques. The findings indicate that these methods are useful for comprehending groundwater behaviour in any region. The GWPZ map, as delineated, was divided into five categories: 'very high', 'high', 'moderate', 'low', and 'very low'. The very low zone denotes the area least conducive to groundwater prospects; while the very high zone denotes the area most conducive to groundwater prospecting. The GWRZ map of the study area has also been classified into five recharge categories: 'very high', 'high', 'moderate', 'low', and 'very low'. The WLZ and map of Siliguri Metropolitan and surrounding are also delineated using RS, GIS and AHP techniques. The delineated WLZ map was also classified into five zones, viz., 'very high', 'high', 'moderate', 'low' and 'very low'. The very low zone indicates the most favourable area for groundwater prospect; whereas the very high zone indicates the least favourable area for groundwater prospect. The western part of the area is most suitable for recharge, as it has very high groundwater and low waterlogging prospects. The developed GWPZ, WLZ and GWRZ maps can assist decision-makers in identifying appropriate locations for well drilling and in safeguarding essential groundwater resources. Furthermore, this method can be applied broadly as a valuable tool for addressing groundwater issues in vast, rugged terrains characterized by data scarcity and multi-criteria analysis (Agarwal and Garg, 2016).

VII. CONCLUSION

The present study has been conducted over waterlogging and groundwater potential zone of Siliguri Metropolitan and surrounding area and how they influence and control the groundwater recharge potential zone. The approach of this study is to show that as a growing and developing area, Siliguri and its surrounds suffers seasonal hazard i.e. waterlogging due to some physical and anthropogenic factors, while some of those factors control the groundwater potential zone, which is to show the potential area to hold groundwater. It can be observed from the discussion that in this study area, the GPWZ and GWRPZ have a positive relation while the WLZ and GWRPZ have an inverse relationship. High potential zones means high recharge zones and low waterlogging zone. Similarly low potential zones means low recharge zones and high waterlogging zones. The selected layers are also supporting the decision. The present study can be a useful tool for delineating a project of the utilization of the groundwater and to mitigate the waterlogging hazard by proper utilization of the excess water or to artificially infiltrate them to those areas where groundwater is seriously low. By these, the problem of water scarcity over some areas while waterlogging and such can be normalized and the waterlogging hazard can be controlled to an extent.

VIII. REFERENCES

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