Site Suitability analysis for artificial groundwater recharge potential zone using a GIS approach in Basaltic terrain, Buldhana District, Maharashtra, India

Monica Chakraborty (monicachakraborty1@gmail.com)
Deogiri College
Ashok Tejankar
Deogiri College
Ramamoorthy Ayyamperumal
Lanzhou University

Research Article

Keywords: Artificial Recharge Structure, Geomorphology, Weighted Overlay Analysis, Groundwater, GIS

Posted Date: April 12th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-405615/v1

Abstract

We have selected the site suitability for artificial groundwater recharge in basaltic terrain in India. The overarching aim of this research is to identify appropriate locations for artificial groundwater recharge in the Godavari river basin in the semi-arid zone of Buldhana district, Maharashtra, India. The research involves the selection of an appropriate location with an artificial recharge, the use of weighted values in a (GIS) environment, and the development of thematic layers. The precise type of artificial recharge system, such as a check dam, nullah bund, drainage ditch trying to plug, or percolation ponds, is chosen. Water harvesting considers the availability of land, conventionally, while on the local conditions depends the suitability of a particular artificial recharge technique and the area which is to get benefited. As a result, decisions on the site for water conservation and structure construction could only be undertaken after detailed field research. In stipulated time, the GIS modelling approach provides an excellent tool for the identification of recharge zones with suitable structures. The integrated study helps in designing a suitable groundwater management plan for the areas such as the basaltic terrain.

Introduction

Groundwater stands as a very important natural resource and also a reliable one for different purposes are including irrigation, drinking, and other basic needs in several states of India. Upwards of 90% of the rural population and nearly 30% of the rapid urbanization depend on this for drinking water (NRSA.,2008). Unsustainable use, as well as ongoing poor management of this vital resource, have led to the world's already availability of water, increasing waste, degraded habitats, and biodiversity degradation of many species in general, and India in particular (Tsakiris 2004; Jha et al 2007; Aggarwal et al 2009b; Rodell et al 2009; Chawla et al 2010, Anand J., 2020). The principle of using advanced methods such as remote sensing (RS) and the Geographic Information System (GIS) in groundwater management studies is comparatively modern. The groundwater is diverse and interdisciplinary, an integrative approach to RS and GIS technologies is quite essential in different groundwater management studies. Remote sensing offers a range of datasets over a wide, inaccessible region that can be easily controlled and evaluated within the GIS system.

The combination of groundwater and hydrogeology information such as topography, rainfall, water density, geology, and hydraulic properties relies on the measurement methodology used and the assessment of groundwater recharge (Alley., 1999; Carver 1991; Thomas., 1999). The GIS and RS Techniques have been useful in identifying prospective groundwater areas. These maps have been used to indicate groundwater recharge activity and groundwater development. A comparatively modern, effective method for excellent quantification of groundwater aquifers in basaltic hard rock terrain has been recognized as the geographic information system (Cherkauer., 2004; Baker., 2003). Geographic modeling framework estimated using the application of RS and GIS systems by groundwater potential zones (Corwin., 1996; Minor., 2007; Murray., 2003: Das B., 2020).

A few research studies have been reported for groundwater potential zone in both India as well as abroad (Jaiswal., 2003; Solomon., 2006; Singh., 2011; Mukherjee.,2012). Previous research has also shown that work on an integrative approach to remote sensing and GIS for the delineation of artificial recharge zones and sustainable groundwater management is minimal in the world and India in general (Saraf., 1998; Anbazhagan., 2005; Ravi Shankar., 2005; Ghayoumian., 2005; Chenini., 2010; Chowdhury., 2010: Sharama.,2021). In comparison, except for Saraf., 1998) and Chowdhury., 2010), the remaining studies have been on the rocky terrains of southern India and not in the district of Buldhana, Maharashtra. Besides, minimal research in the Indian subcontinent's large basins is published. Consequently, a few of these experiments have to be conducted in various hydrogeological regimes to devise an effective groundwater management scheme.

The major purpose of this research is to study the identification of suitable sites for artificial recharging of Groundwater using GIS and Remote Sensing techniques. Previous studies have shown that we cannot find the exact and appropriate region only by the weighted value method. The principle aims and purposes of this analysis are to establish possible locations for identifying groundwater recharge systems using Geospatial Techniques and GIS technologies. Which can be noted as follows:

1. Study the Groundwater recharge structures (check dam, percolation tanks, recharge pits, etc.) for the recommendation of suitable locations.
2. Application of the weighted overlay rule. (ArcGIS. 10.1 overlay tool)
3. Create a map of appropriate artificial recharge systems (check dam, percolation tanks, recharge pits, etc.)

Materials And Methods

We have obtained for the analysis of Indian research satellite (IRS) LIII Image, Cartosat DEM (http://bhuvan.gov.in), Survey of India (SOI) topographic data from 47J/2 on a 1: 50,000. Water level fluctuation data (2016-17), Rainfall-Runoff data (2008-2017) of Sindkhed Raja village. Remote Sensing (RS) and Arc GIS are advanced technologies that are very useful methods for the groundwater studies of this research. The primary and secondary data were combined in the GIS network, and “thematic” maps have been generated utilizing data obtained from different sources such as satellite and topographic data. To make thematic data accessible, thematic maps provide a variety of detail about any physical substance or theme. To get the spatial component referenced, the spatial data is assembled in digital format and properly registered. Comparatively more reliable information is provided by the namely sensed data on various themes. Different thematic maps were generated for this research using a visual representation of the SOI Topo sheet and satellite imagery. With the aid of the numerous data gathered, thematic maps at scales ranging from 1:140,000 to 1:150,000 have been developed.

Modeling Methods based on GIS

Geographic data’s volume being high, the analysis becomes very complex and time-consuming. Maps could be generated using GIS factors of complexity in fuzzy terms, and hence the different inconsistencies that occur due to classification in GIS can be reduced. Using this type of overlay analysis, new composite maps have been generated which include various features, which can be noticed in the thematic maps and a final composite map for artificial groundwater recharge zones have been created. We have followed the steps are given:

1. Spatial database building
2. Spatial database analysis
3. Data integration through GIS

Results

Digital Elevation Model (DEM) and Thematic Maps

For the percentage slope map, DEM data has been used. The DEM data was acquired from 'ASTGTM2 N18E073 &74' using ArcGIS 10.1. Various mosaic techniques were used to create Aster DEM data in the ArcGIS framework. Using the spatial analyst tools in ArcGIS 10.1, topographic and gradient maps have been developed, and then the sample locations were clipping out as per its coordinate system, and the imageries were obtained. For the zoning of Artificial Groundwater Recharge, the data is converted into a raster image and overlaid using the weighted overlay process for the thematic map. (Weightage-wise thematic maps).

Slope Type and percentages:

We used a DEM map with a scale of 1:145000 to estimate the slope percentage here. Weightage values are assigned to various slopes based on their recharge priorities. The potential for groundwater recharge decreases as the slope elongates. When the degree of slope is on the higher side, the highest weightage value is assigned (0 to 4). In the study area, five categories of slopes were discovered: slightly leveled slope, gentle slope, moderate slope, strong slope, and steep slope.

Soil

According to the data obtained, the research region includes 3 types of soils. i.e. alluvium, loamy, and mountain. On the one side, alluvium soil is relatively more favorable than loamy soil since its penetration rate is greater than the other 2 types of soil. On the other hand, we noticed that the penetration rate of mountain soil is quite low attributed to the prevalence of mountains and hard rock formations, and therefore groundwater recharge is very low in this region. In the Alluvial area, the construction of 9 EW, 4 OW, and 8 Piezometers (Pz) was done. The wells' depth ranges between 61.50 to 311.20 m bgl, while the thickness of alluvium was found to be more than 300 m. The discharge which led from these wells was between traces to 10 lps. Static water levels were found between 3.57 to 16.65 m bgl. Down to the depth of 302 m, aquifer zones were encountered in the wells thus establishing that the groundwater can be seen to be occurring under the confined conditions even up to the depth of 300 m underneath. However, in the deeper zones below 80 m, the yields are restricted as they occur in the older Alluvium, being more clayey.

The younger Alluvium is more productive than the older alluvium as the younger mask is found to be occurring down to the depth of 70 – 80 m bgl. This zone of younger Alluvium can also be used for agricultural purposes using the shallow tube wells which were constructed deep inside to the depth of about 65- 70 m and yielding up to 10 lps for a 30 m lift.

Geomorphology

Figure 7 depicts the geomorphology of the study area and was generated use IRS LIII (March-2012) data and image representation elements with confirmation of the limited area. To select the artificial recharge sites various geomorphological units are very useful. The present investigation shows various landforms based on geomorphology, these can be classified as (A) Structural hill (B) Denudational hill (C) plateau

Valley (Drainages)

In structural hill provinces, where the denudation rate is high, valleys are found to be normal. Valleys are active basins or troughs for receiving degraded sedimentary rocks, also including valley fill, which contains poorly consolidated material. This could retain a large amount of water and therefore sustain a large amount of vegetation. While studying the satellite images, we found that the drainages were found all along the valley region originating from the north. The map has a reddish color appearance owing to the combination of vegetation in an erratic pattern.

Plateau and Denudational Hills

Plateaus can be noticed as the areas which have a plain area with a gentle slope towards a direction. The denudational hills are seen to be formed due to the resistive part of hills in the plateau area which facilitates some infiltration and mostly acts as runoff areas.

Land Use Land Cover

The study area enclosed agricultural land (130 Km^2), some built-up areas (0.83 Km^2), and the rest leftover is wasteland (61.56 Km^2). Water bodies have also been observed in the study area. Rest another area of the watershed has been mostly altered due to extension in the cultivation land. The built-up area, the elevated portion, and the region that have been identified as wasteland are inappropriate for an artificial recharge system. Still, the plain land which remains uncovered under any construction or vegetation, like the agricultural land and the land occupied by the water bodies can become the most suitable locations for it. As a result, weightage must be assigned to the different regions in the GIS area where the land used and covering section is visible.

Drainage

The study area includes the watershed areas, that have been thoroughly depleted to Godavari river with the presence of many streams from source to mouth by dendritic drainage having several 1st order, 2nd order, 3rd order, and 4th order according to Strahler’s method. As we know according to the same, 3rd and

4th order drainage carries more runoff water. We have used the order of the stream and followed in Strahler's System (1952):

The order of the stream is 1 if a stream has no contributing tributaries.

If more than one tributary is seen to be present, in i and j orders then:

if i = j then the order of the resulting stream will be i +1 or j +1

else if i < j then the order of the resulting stream will be j

else if i > j then the order of the resulting stream will be i

Two streams of the same order merge to create a new stream of order i+1, and if streams of different orders combine, the new stream preserves the order of the highest order stream, as seen in figure 6.

Weighted Indexing Table and water level

every raster value was modified into shapefiles of the available data and thus assigned weightage values, as seen in Table 1, and these values were then converted back into raster data. The percentage of the areas has been determined based on the specified weightage. The values in this report were drawn from the knowledge of other professionals based on their prior findings and statistics obtained. For the selection of appropriate zones or artificial groundwater recharge locations, it would be critical to investigate the water level in groundwater. Database collected for this watershed study has been derived from 3 observation wells which were located in the study area, they represented the three basic morpho zones i.e. runoff zone, recharge zone, and storage zone. These observation wells indicated the periodic and routine monitoring of the depth of the water level. After performing the careful study of different meteorological parameters and the static groundwater levels of the study area, the study of two seasons has been carried out.

Availability of Rainfall- Water

Rainfall data is collected from the last 10 years to analyze the trend and pattern. It has revealed that in the monsoon year of 2016, the study area received a very high amount of rainfall i.e. 1190 mm while in the year 2012 received a low amount of rainfall i.e. 496 mm. Rainfall occurs in the peninsula of India, where the study area is located, as a result of the southwest monsoon winds that pass through this area (June-October). The total annual precipitation in this area ranges between 400 and 600 mm (according to IMD, Pune). The final overlay map indicates the chosen appropriate location for the artificial groundwater recharge owing to the accessibility of water as runoff and the variations present in the groundwater level during the pre and post-monsoon season.

Discussions

Artificial Recharge Site Selection

A few artificial recharge techniques are used to supplement the normal flow of surface water into underground formations. Such as building the percolation ponds, recharge Pitts, cement Nullah bunds, creating artificial floods to induce recharging procedures, and construction of other water impounding and infiltration structures have been practiced successfully everywhere in the world but this process can also be applied in the study area to increase the yielding capacity of the groundwater in this place. Various other types of water conservation methods that have been adopted by other countries commonly can also be accepted in this study area such as contour trenching; terracing, Nulla bunding, etc. These procedures can be adopted and various problems of inadequate rainfall and errant water supply can be sorted. Selecting suitable locations for the implementation of adequate artificial-recharge techniques is a crucial situation for successful recharge, and this is dependent on many criteria that have been studied together in a GIS context. The penetration capability of the unsaturated zone above the aquifer determines the recharge potential of a terrain area. It also depends on the geological and hydro-geomorphological parameters present in the area alongside, the slopes present in the terrain region, the land used or the land cover i.e. the vegetation present or construction in the location, and the density of the drainage available.

Using the weightage index the groundwater recharge zone is prepared (Table. 1). It provides the necessary data for the map preparation. All of the thematic layers and weight tables required for the weighted model were generated using Arc GIS version 10.1 software. Finally, using the procedures mentioned earlier, we were able to create the most favorable recharge zone diagram. The yellow part of the final diagram or plot, Figure 7, has a weighted value of 1, which is appropriate for groundwater recharge. The dark blue section (14.1 percent) is quite inadequate for artificial recharge because the penetration rate was low due to the presence of hard rock and mountain form or rocky soil supply in that area. Because of the high velocity of rainwater flow, the infiltration rate decreases and thereby affecting the amount of groundwater recharge. The following recharge structures which have been suggested would be very helpful, to increase the specific yield of the soil in this area, increasing the level of the water table, and thus the following recharge structures have been suggested to be constructed in the area under study.

Artificial Recharge Structures and Percolation Tanks/ Farm ponds

The open water impounding bodies, such as percolation or infiltration tanks, should be excavated in a region of land enclosed by a riverbank and should not exceed 15,000 m3. These can store rainwater, but their primary purpose is to penetrate the water and transfer it to deep aquifers, where it could have been extracted utilizing boreholes, tube wells, and dug wells. These tanks should be constructed in locations where the tank or pond's base is permeable and the aquifer that requires to be recharged is close to the ground surface. Sites of low-potential areas and frequent medium-to-high water table variations are appropriate for these types of systems.

Check Dam /Cement Nala bund and Continuous Contour Trenching (CCT)

A **check dam** is a dam, which is comparatively quite smaller than the normal large dam projects. These can be either temporarily built as per the need of the season or else can be set permanently. These may be constructed across a minor canal or a drainage ditch, depending on which is more desirable, to avoid water leakage during rains and thereby retain the groundwater to increase penetration into the subsurface. Check dams have been strongly suggested in runoff recharge areas with low to moderate slopes along with 3rd and 4th order streams.

CCT is a famous agricultural method that could be effectively applied in dry and arid areas to preserve water and soil while also reducing soil erosion. In the study field, a trench 10 m long, 1 m wide, and 1 m deep can be very successful in increasing water availability. Water must be slowed uniformly around the whole slope on the hillside, so a stagger of the same design must be constructed to carry the water along. This technique is very useful, but it can only be used in areas where trench may not complicate field use.

Artificial recharge zones and groundwater conditions in basaltic terrain:

In hard rock (basaltic) terrain the groundwater conditions are multivariate due to the nature of the aquifer being heterogeneous because of the various composition, compaction, and density of weathering. The various direct benefits and space technologies have demonstrated their usefulness in understanding the factors which can be responsible for maintaining the hydrological cycle. It can be noted that the vegetal cover, surface water bodies, lithotypes, and landform. The various groundwater prospecting maps become a very good database and these also help us in identifying the various favorable zones (prospective zones) around the study area where the problems have been detected, thereby narrowing down the targeted areas. Hence, after conducting the detailed ground hydro-geological and geophysical surveys within these zones, the most appropriate sites can be selected for artificial recharge. Hence it can be seen that many times we have to consult the geophysical and drilling data for acquiring subsurface information, and decisions file shall be created through overlay by GIS technique if satellites alone cannot provide information regarding confined aquifers. The groundwater prospecting methods can serve in two ways and benefit field geologists by helping them to 1) identify quickly the prospective groundwater zones for conducting the site-specific investigations. 2) Selecting suitable sites for the planning of artificial recharge structures for the improvement of the sustainability of drinking water sources, wherever it is required. The current map displays that about 23% of the area is most appropriate, where runoff water from the hill enters the field through different drainage lines and flows directly into the main Nullah. Natural groundwater recharge happens in every catchment area during the monsoon season as a result of precipitation, but this rate is quite low, and the water is dispatched by drains according to the slopes present in the area. To overcome this, a recharge structure is needed to mitigate water depletion. Some of it is evaporated by the heat, while the rest is evapo-transpirated by crops or plants. This water should be collected and then artificially recharged to keep the water level constant. More physical dimensions, such as holding capacity, possible evapotranspiration, and soil field capacity, are also taken into consideration. While conventional water harvesting approaches consider land availability, soil structure for groundwater capacity, potential groundwater zone inquiry, and the region benefited, the new multiparametric approach utilizes GIS and remote sensing to establish a holistic process. It may also minimize the cost and expense taken for the entire procedure, especially for determining suitable site-specific recharge systems on a regional and local scale, leading to more efficient water management decision-making. The identification of any artificial recharge site is based on a variety of parameters such as geomorphology, lithology, lineament density, slope, soil, and so on. Thematic data may be incorporated for the measurement of groundwater potential zones in the research area using remote sensing technologies. The number of parameters loaded, such as 4, 3, 2, and 1, in the studied region, was used to identify artificial recharge sites. Based on the number of parameters loaded using GIS integration, the research area has been divided into priority I, II, and III suggested for artificial recharge sites. The studied zones have been compared with the Land use and Landcover maps for adopting the suitable technique in the artificial recharge zones.

Conclusions

From this research, an innovative method for determining groundwater recharge characteristics using GIS technology has been suggested for the Basaltic terrain of India. This research provided a map of the basaltic terrain's groundwater recharge potential. This research is critical for the long-term usage of groundwater resources, thus improving groundwater recharge through careful management. The findings suggest that the use of GIS techniques assists groundwater research by expanding the areas of focus for comprehensive hydrogeological surveys on the site. According to the conclusions, the most efficient groundwater recharge potential region is situated in basaltic terrain. This research explores the complex relationships among groundwater recharge potential variables and groundwater recharge potential scores dependent on India's general hydrology characteristics. The maps generated by this approach could be used as a basic guide by government and water policy decision-makers when choosing appropriate locations for groundwater management practices.

Declarations

Acknowledgments

I would give my sincere thanks and would like to acknowledge the Department of Geology, Deogiri College, Aurangabad, to provide the laboratory and make the various instruments available to me to carry on the research work in their premises and Department of Science INSPIRE, Delhi for supporting me to carry out this study.

References

Aggarwal R, Kaushal M, Kaur S, Farmaha B (2009b) Water resource management for sustainable agriculture in Punjab. India. Water Science and Technology 60(11):2905–2911

Anandha Parameshwari, N., & Kalpanadevi, K. (2006). Proceedings, Groundwater analysis of Rajavoor, Udumalpet- a case study, National Conference on Environmental degradation and pollution control, Coimbatore, India, December. 1209–1222

Ananda, J., Aheeyar, M. An evaluation of groundwater institutions in India: a property rights perspective. Environmental Development Sustainability, **22,** 5731–5749 (2020). https://doi.org/10.1007/s10668-019-00448-8.

Anbazhagan S, Ramasamy SM, Das Gupta S (2005) Remote sensing and GIS for artificial recharge study, runoff estimation and planning in Ayyar basin, Tamil Nadu, India. Environmental Geology, 48(2):158–170

Anji Reddy (2012) ‘Textbook of Remote Sensing & Geographical Information Systems’ by BS Publication. 124-131p.

APHA (2002). Standard methods for the examination of water and wastewater (20nd ed.). Washington D.C.: American Public and Health Association.

Baker ME, Wiley MJ, Carlson ML, Seelbach PW (2003) A GIS model of subsurface water potential for aquatic resource inventory, assessment, and environmental management. Environmental Management, 32(6):706–719

BIS (1991). Bureau of Indian Standards IS 10500, Manak Bhavan, New Delhi, India.

Central Groundwater Board (2010). Groundwater information of Aurangabad district, Maharashtra, 1- 16.

Central Ground Water Board-India (2007) Manual on artificial recharge of groundwater. Ministry of Water Resource Board, Government of India, India

Chawla JK, Khepar SD, Sondhi SK, Yadav AK (2010) Assessment of long-term groundwater behaviour in Punjab, India. Water Int 35(1):63–77

Chenini I, Mammou AB, May ME (2010) Groundwater recharge zone mapping using GIS-based multi-criteria analysis: a case study in Central Tunisia (Maknassy Basin). Water Resource Management, 24(5):921–939

Cherkauer DS (2004) Quantifying groundwater recharge at multiple scales using PRMS and GIS. Ground Water 42(1):97–110

Chowdhury A, Jha MK, Chowdary VM (2010) Delineation of groundwater recharge zones and identification of artificial recharge sites in West Medinipur district, West Bengal, using RS, GIS, and MCDM techniques. Environmental Earth Sciences, 59(6):

Corwin DL, Loague K (eds) (1996) Applications of GIS to the modeling of non-point source pollutants in the vadose zone. SSSA Special. Publ. no. 48. SSSA, Madison, WI.

Das, B., Pal, S.C. Assessment of groundwater recharge and its potential zone identification in groundwater-stressed Goghat-I block of Hugli District, West Bengal, India. Environmental Development Sustainability**, 22,** 5905–5923 (2020). https://doi.org/10.1007/s10668-019-00457-7.

Deshpande S.M. “Need for groundwater utilization and management in Aurangabad city, Maharashtra” Junior Geologist, Groundwater Surveys and Development Agency, Shivajinagar, Pune.

Ghayoumian J, Ghermezcheshmeh B, Feiznia S, Noroozi AA (2005) Integrating GIS and DSS for identification of suitable areas for artificial recharge, case study Meimeh Basin, Isfahan, Iran. Environmental Geology, 47(4):493–500

Ground Water pollution around Industrial cluster in MIDC areas, Aurangabad, Maharashtra, Report by Government of India, Ministry of Water Resources, Central Ground Water board- Nagpur (2013)

Haixia Zhao, Xueiun Duan, Becky stwert, Bansheng Yoy; Xiaowei Jiang (2013) “Spatial Correlation between urbanization and river water pollution in the heavily polluted area of Taihu lake basin, China” Journal of Geographical Science, vol.23, pp-735-752

IS 11624.1986 (Indian Standard guidelines for the quality of Irrigation Water-Reaffirmed 2001 –FAD 17), UDC 631-671-03:626-810 (026)

Kuik, O., Verbruggen, H. (Eds.), In search of Indicators of Sustainable Development. Kluwer Academic Publishers, The Netherlands, p. 126.

Minor TB, Russell CE, Mizell SA (2007) Development of GIS-based model for extrapolating mesoscale groundwater recharge estimates using integrated geospatial data sets. Hydrogeolgy Journal, 15:183–195

Mukherjee P, Singh CK, Mukherjee S (2012) Delineation of groundwater potential zones in the arid region of India—A remote sensing and GIS Approach. Water Resource Management, 26(9):2643– 2672

Murray J, O’Geen AT, McDaniel PA (2003) Development of a GIS database for ground-water recharge assessment of the Palouse Basin. Soil Sciences, 168(11):759–768

N.S. Elangovan, M. Dharmendiumar (2013), “Assessment of groundwater quality along with the cooum river Chennai, Tamilnadu, India,” Journal of Chemistry, id-672372

NRSA. (2008). Groundwater prospect mapping using remote sensing and GIS, Rajiv Gandhi National Drinking Water Mission Project Manual. National Remote Sensing Agency, Hyderabad.

Rodell M, Velicogna I, Famiglietti JS (2009) Satellite-based estimates of groundwater depletion in India. Nature 460:999–1002

Saraf AK, Choudhury PR (1998) Integrated remote sensing and GIS for groundwater exploration and identification of artificial recharge sites. International Journal Remote Sensing, 19(10):1825–1841.

Sharma, U., Khan, A. & Dutta, V. Long-term sustainability of groundwater resources in the central Ganga Alluvial Plain, India: Study from Gomti River Basin. Environmental Development Sustainability, (2021). https://doi.org/10.1007/s10668-021-01325-z.

Singh CK, Shashtri S, Singh A, Mukherjee S (2011) Quantitative modeling of groundwater in Satluj River basin of Rupnagar district of Punjab using remote sensing and geographic information system. Environmental Earth Sciences, 62(4):871–881

Solomon S, Quiel F (2006) Groundwater study using remote sensing and geographic information system (GIS) in the central highlands of Eritrea. Hydrogeol Journal, 14(5):729–741

Sudhakar M.Rao, K.Asha, S.Shivachidambaram, (2013), "Influence of anthropogenic contamination of groundwater chemistry in Mulbagal town, Kolar District, India." Journal Geosciences" Vol. 17, No.1, p.97-106, DOI 10.1007/s12303-013-0007-1

Tejankar A.V "GIS-based groundwater quality mapping in Aurangabad industrial and city area of Maharashtra. India". Paper accepted for 34th International Geological congress Brisbane Australia from 5th Aug to 10th Aug 2012

Tejankar A.V, "Influence of Artificial Recharge in Hard Rock of Deccan Trap Area in India". Published in GENIUS, vol no. 1, Aug- Jan 2012-13, ISSN No. 2279-0489, Page no. 6 to 13.

Tejankar A.V., Chakraborty M. N. (2019). Geochemistry and Assessment of Groundwater Quality in Municipal & Industrial (MIDC) Area of Aurangabad City, Maharashtra, India International Journal of Innovative Science and Research Technology, Vol- 4.5, pp (436-448)

Tejankar A.V., Ghule P. "Impact of Artificial Recharge on Groundwater Dynamics in Deccan Trap Area Maharashtra State, India" published in International Journal of Earth Sciences and Engineering, vol 06 no. 02, April 2013, ISSN No. 0974-5904, Pg. No. 331 to 337.

Tsakiris G (2004). Water resources management trends, prospects, and limitations. Proceedings of the EWRA symposium on water resources management: risks and challenges for the 21st century, Izmir, 2–4 September 2004, pp 1–6

Tables

Table No 1- Weighted index of Thematic Maps

Maps	**Types**	**Classes**	**Weighted Value**
Slope (%)	Levelled (<1%)	Very suitable	1
	Gently (1-5%)	Suitable	2
	Moderate (5-25%)	Good	3
	Strongly (25-75%)	Moderately suitable	4
	Steep Slope (75-85%)	Unsuitable	4
Soil	Alluvium	Suitable	1
	Loamy	Moderately suitable	2
	Coarse	Unsuitable	4
Geomorphology	Valley	Suitable	1
	Denudational hill	Unsuitable	4
	Plateau	Moderately suitable	2
Land used Landcover	Waterbody	Very Suitable	1
	Agricultural land	Suitable	1
	Built-up area	Unsuitable	4
	Wasteland	Unsuitable	3
Geology	Vesicular Basalt	Very Suitable	1
	Mixed Basalt	Suitable	2
	Massive Basalt	Unsuitable	4

Table 2: Water Level Fluctuation Data (2016 to 2017)

Village Well	**Depth of Well**	**Post Monsoon Depth (m)**	**Pre-Monsoon Depth (m)**	**Water Level Difference (m)**
Gunjala	8.70	0.10	8.70	8.60
Mendgaon	10.45	2.10	10.40	8.30
Malkapur Pangra	7.00	0.10	7.00	6.90

Table 3: Rainfall Data (2008-2017)

Year	Rainfall	Normal rainfall	Difference
2008	658	706.00	-48
2009	523	706.00	-183
2010	1085	706.00	379
2011	782	706.00	76
2012	496	706.00	-210
2013	888.31	706.00	182
2014	584.58	706.00	-121
2015	711.8	706.00	5
2016	1190	706.00	484
2017	688.1	706.00	-17

Table 4: Final Map Data

Classes	Weighted Value	Area (%)
Most Favourable	1	44%
Favourable	2	25 %
Moderately Favourable	3	16 %
Non Favourable	4	15%

Figures

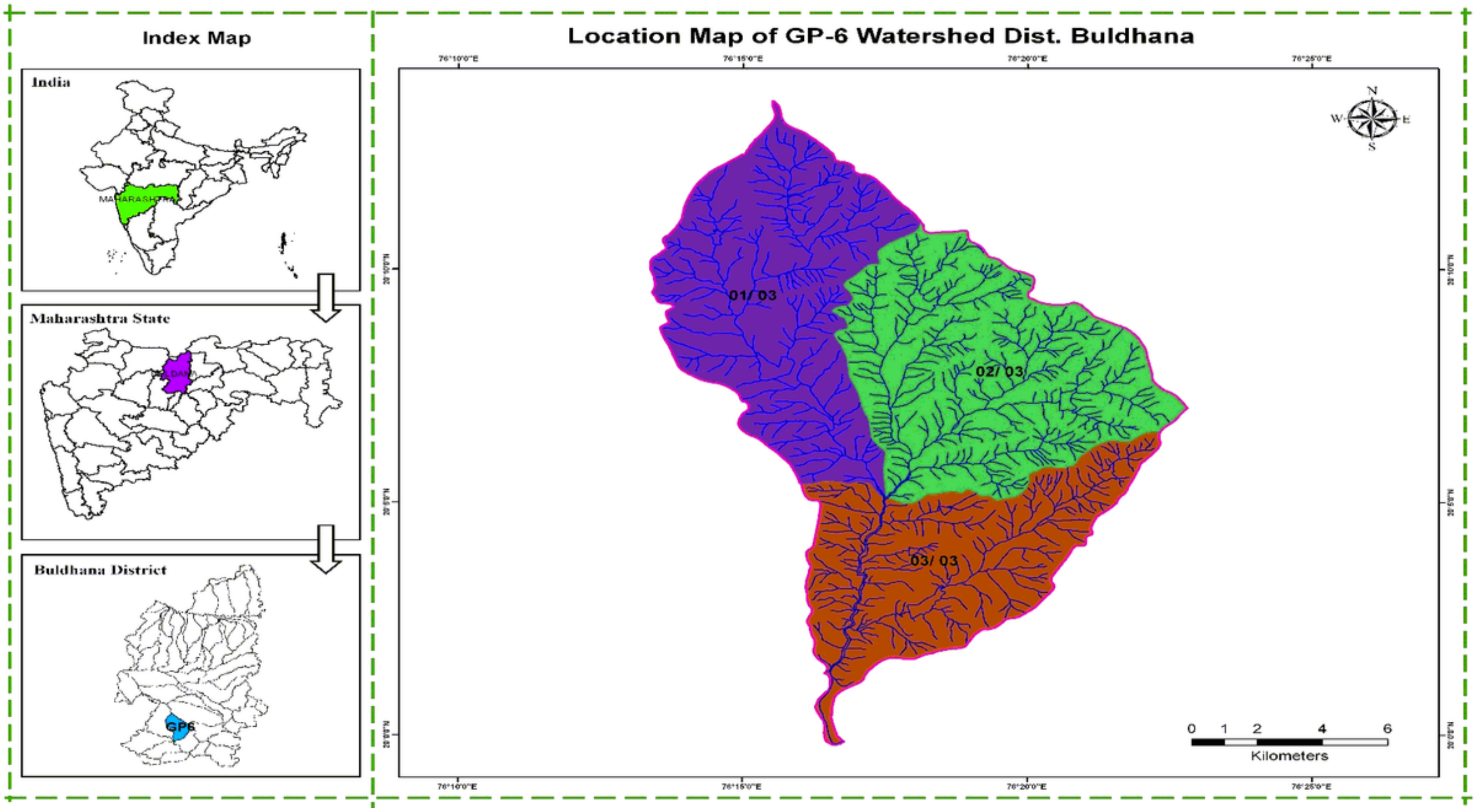

Figure 1

Location Map of the Study Area. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

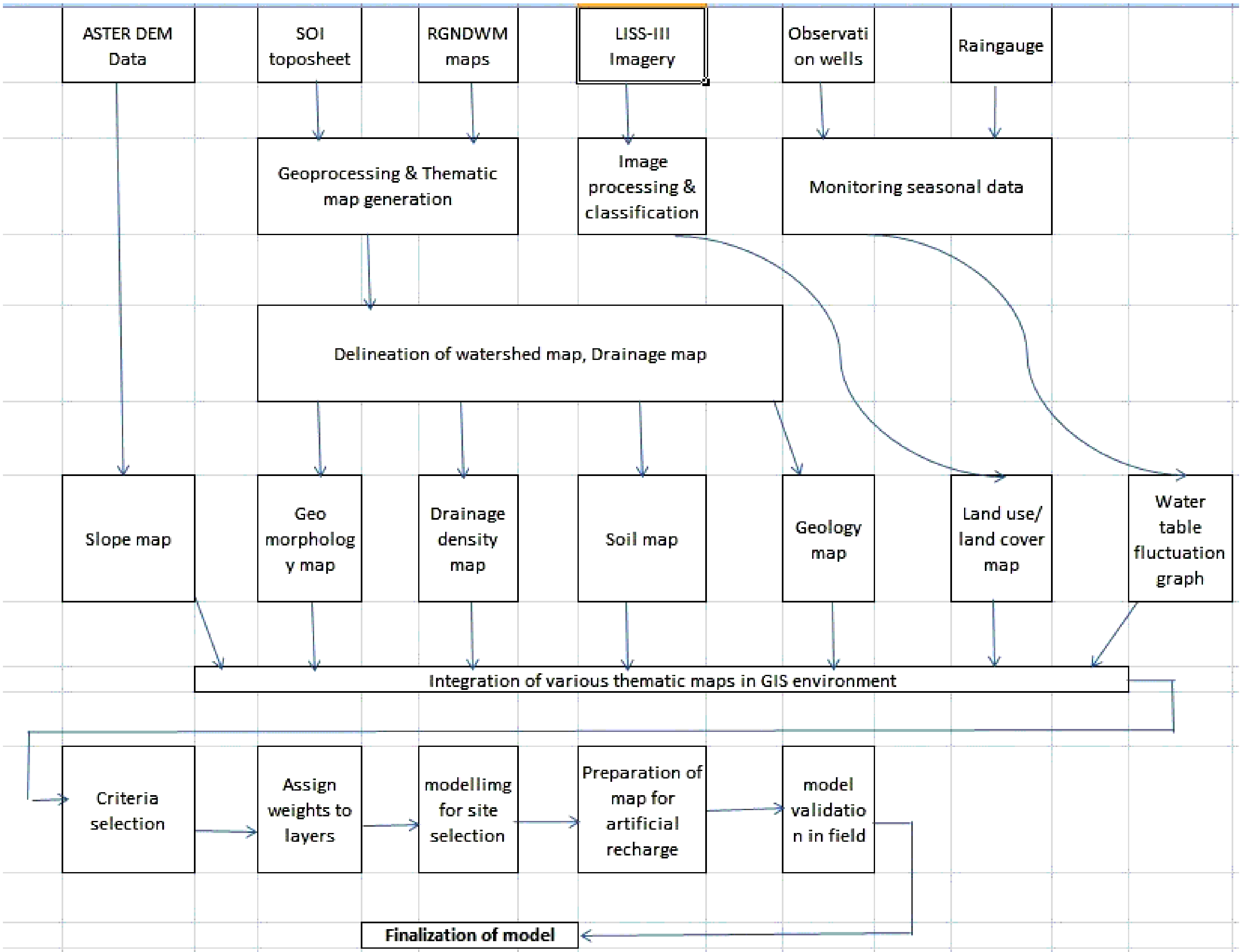

Figure 2

Flowchart of Various Steps Involved in the AGR,

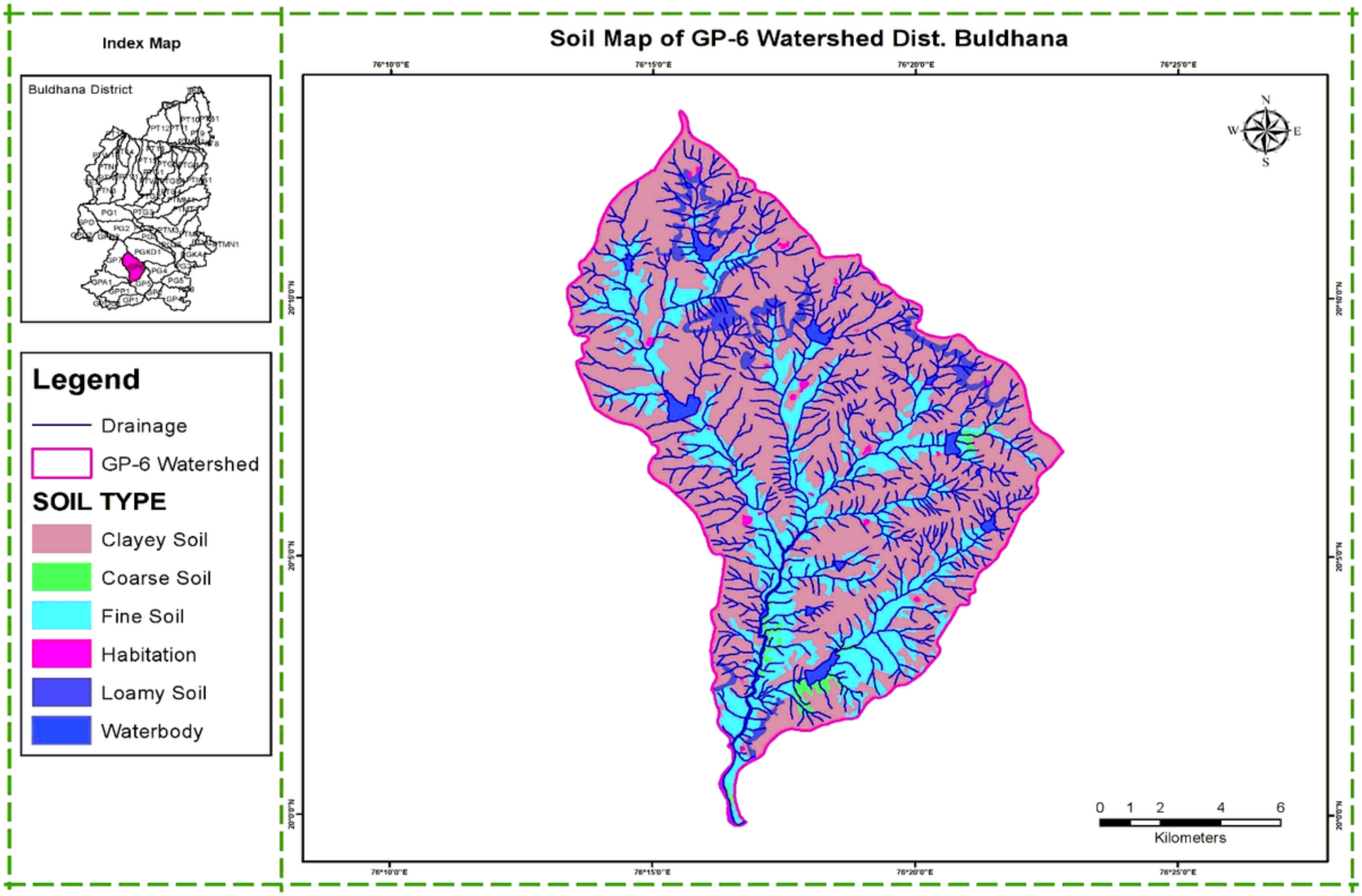

Figure 3

Soil Map with Types of Soil. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

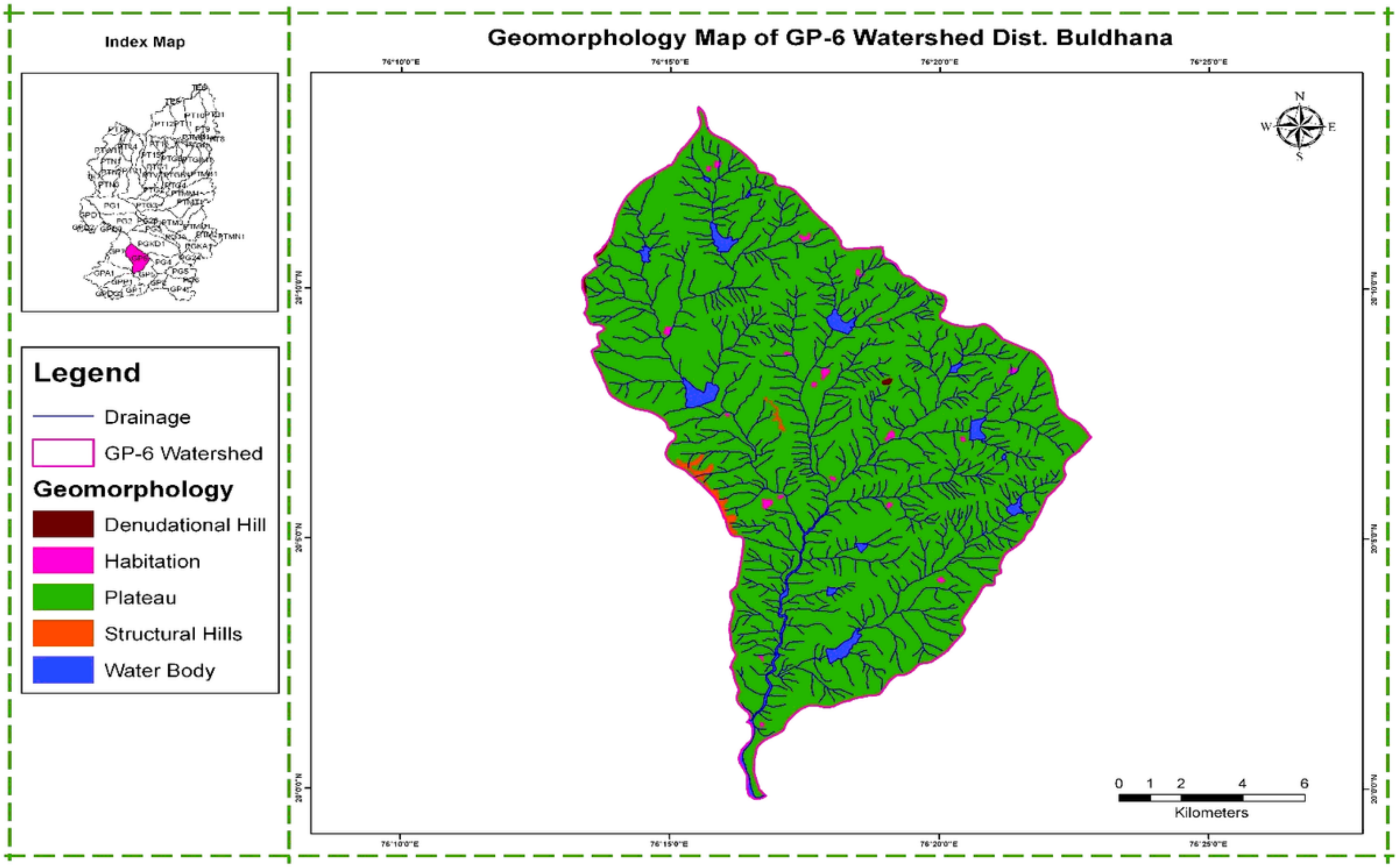

Figure 4

Geomorphology Map. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

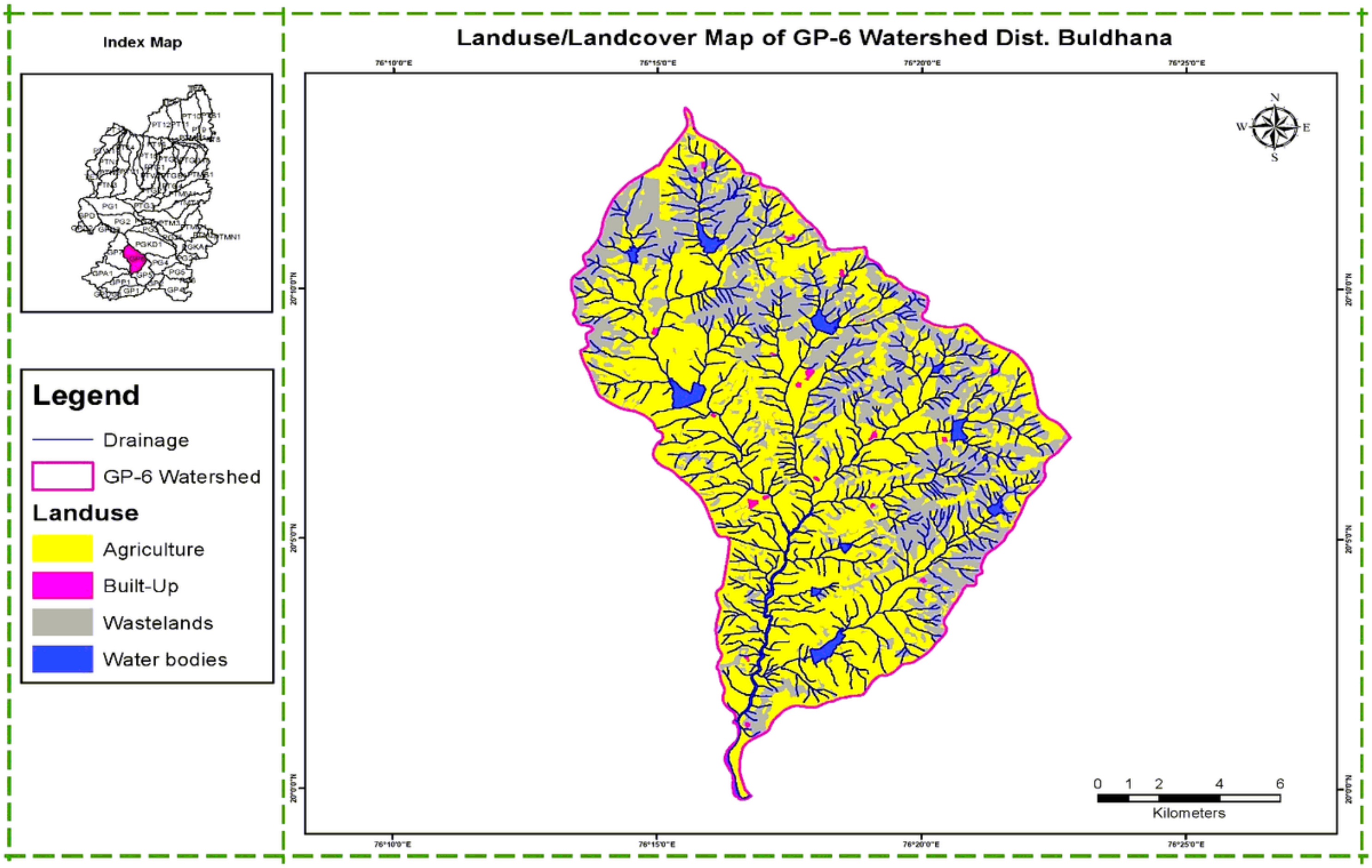

Figure 5

Land Use Land Cover (LuLc) Map. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

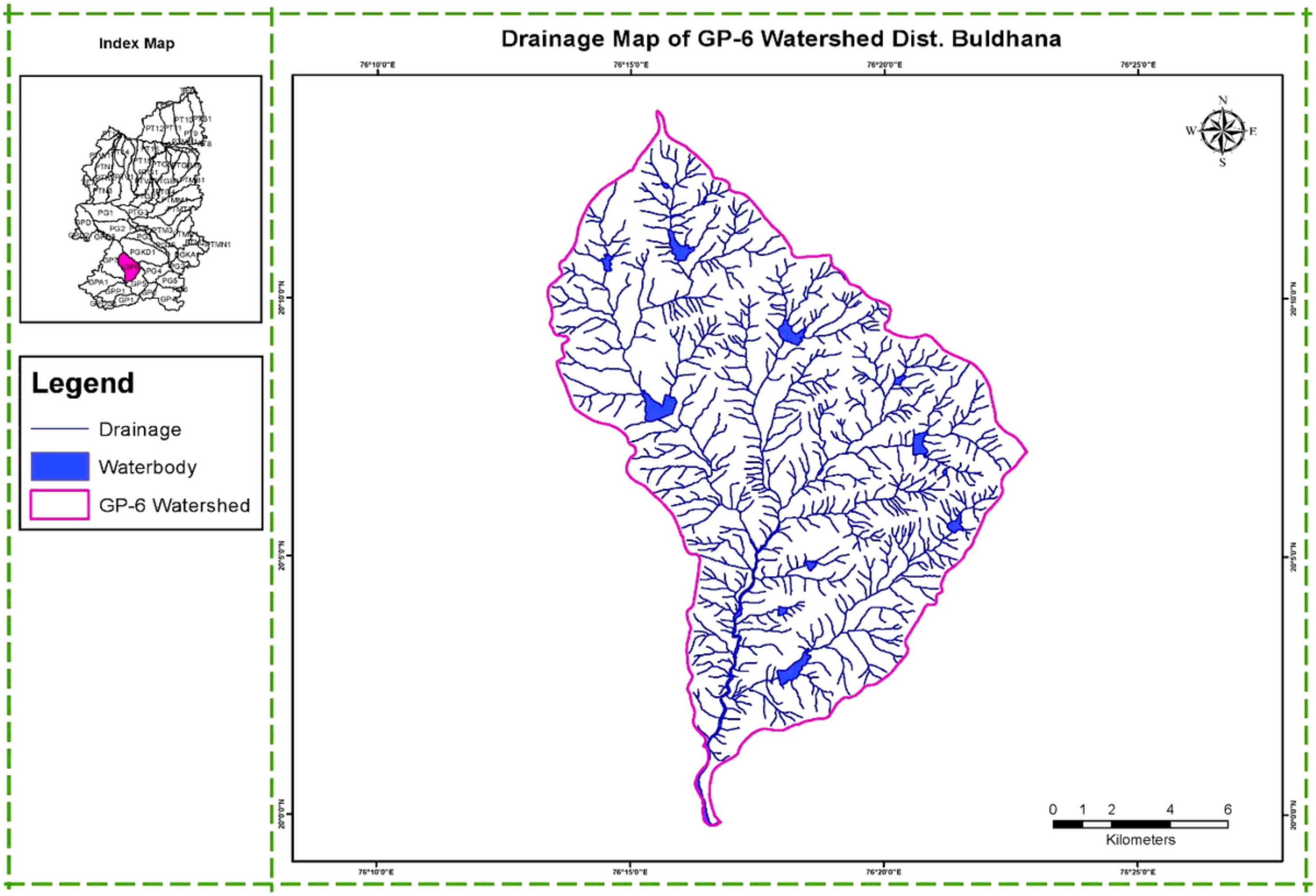

Figure 6

Drainage Map. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

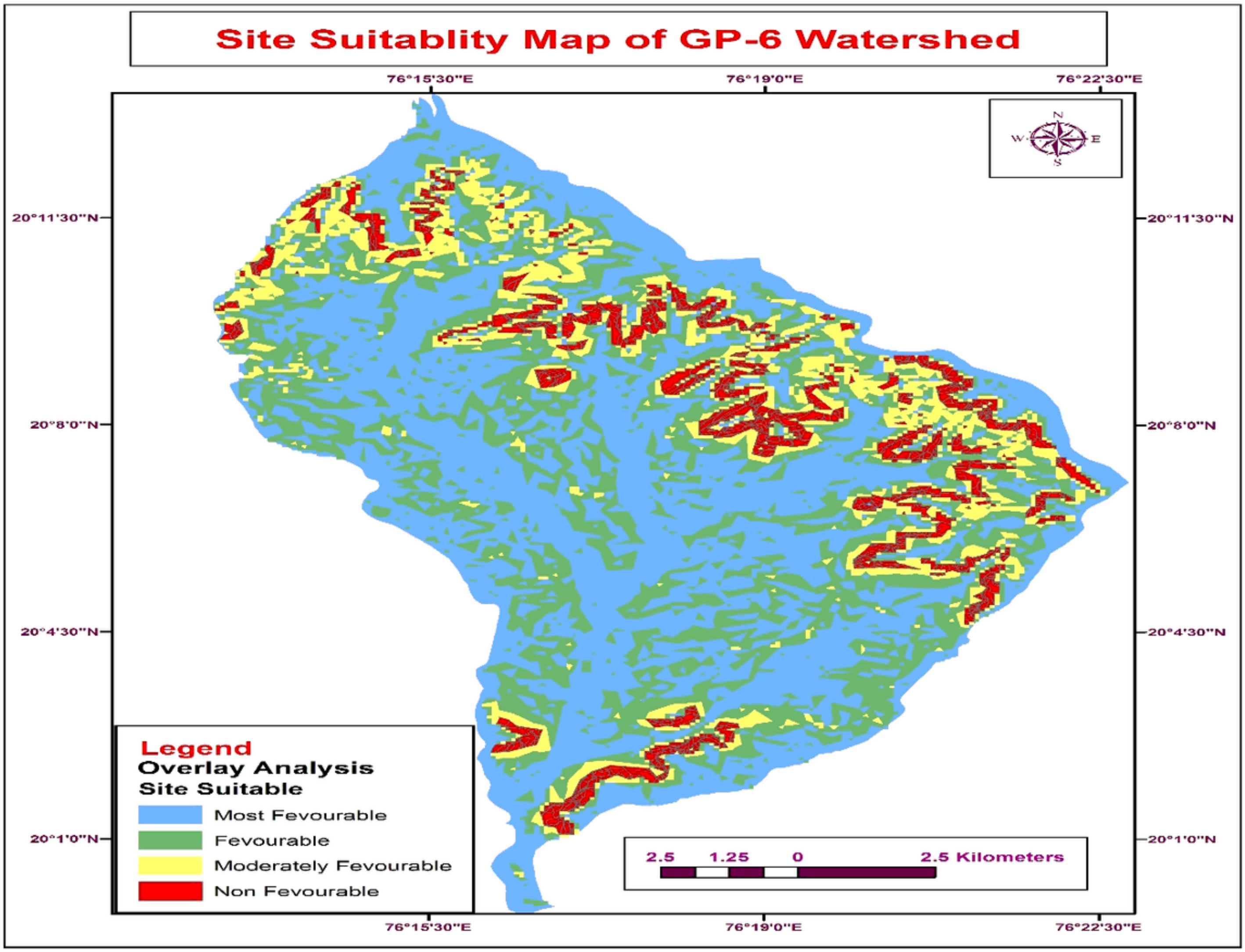

Figure 7

Final Site Suitability Map. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

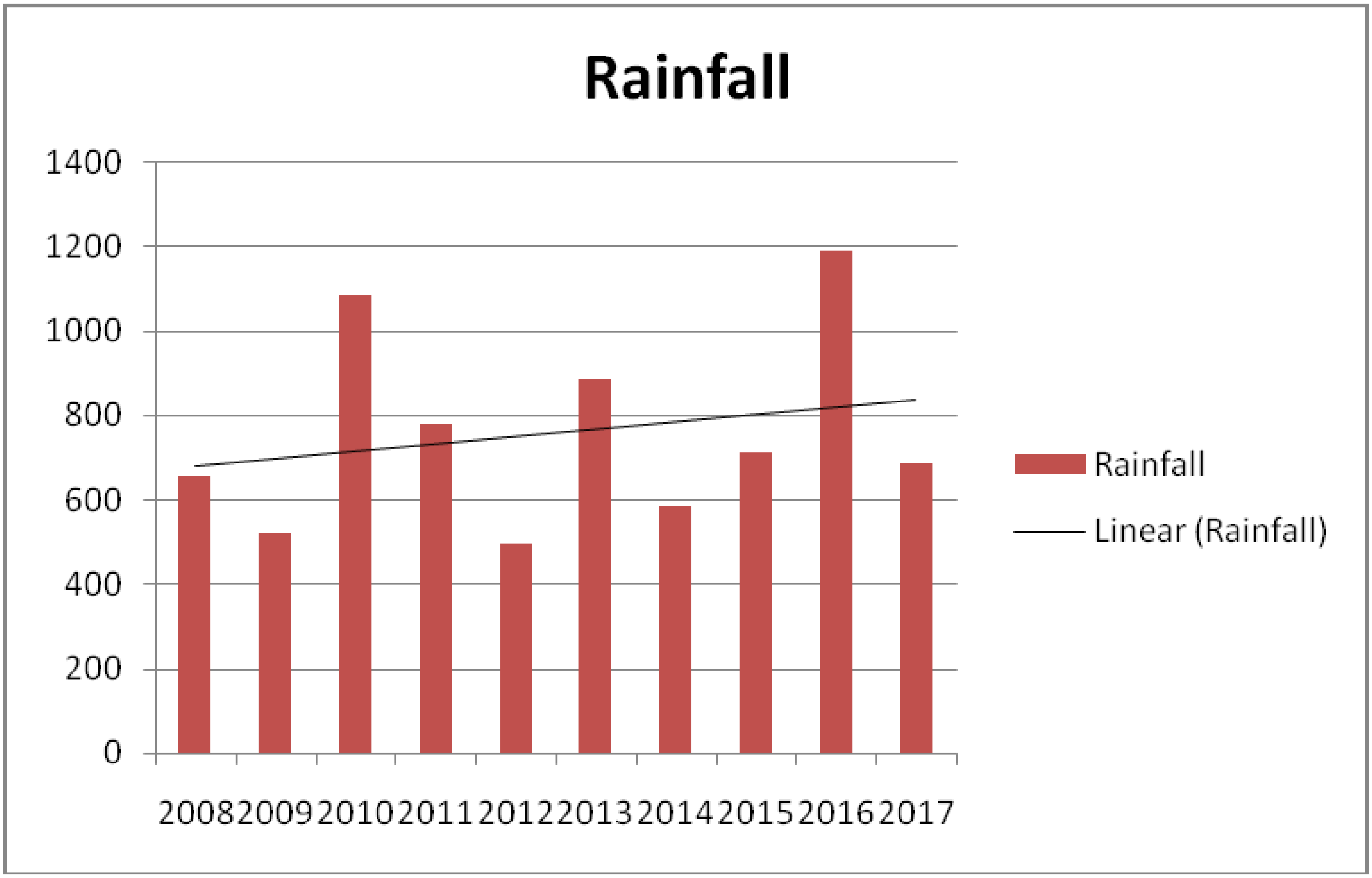

Figure 8

Rainfall chart