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Watershed Management of Joda-Barbil Mining Area, Odisha, India: A Geospatial Approach

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Authors' contributions

This work was carried out in collaboration among all authors. Author SRP designed the study, performed the statistical analysis, Authors KKB and SPM managed the analyses of the study and wrote the protocol and wrote the first draft of the manuscript. Author SPM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Geological Information System plays vital protagonist in watershed management particularly in mining areas in hilly terrain .Though GIS cannot be a resource for analytical resources but can be efficiently used for mapping and related engineering activities within the watershed. Present study is based on watershed management Geospatial Technology with spatial reference to mining area in order to suggest the best possible management strategies to protect crop field, degraded forest cover and maintain the energy balance. The software employed are Arc GIS 10.1 and ERDAS Imagine 9.2 for the analysis. The slope, flow direction, flow accumulation and the contour maps have been constructed to search for the ground water potential zone and analyzed for searching lacking hydraulic structures beyond the existing one. Proposal for adequate numbers of new check dams, percolating boulder bundhs, vegetative barriers and gulley bundhs are found out as ameliorative measures to develop backward tribal mining areas of Odisha.

Keywords: Watershed; GIS & RS; mining areas; DEM; contour map.

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1. INTRODUCTION

Human life without a watershed is challenging and dreadful. A watershed is the upland between hydraulic boundaries, where excess water from the land area is drained to the rivers/streams/ drainage channels. The Watershed (WS) is sourced from rainfalls, irrigation water, water bodies and snow melting. The run off or recharged underground (UG) water from fields, hills, forests, rooftops, lawns, parking lots, and streets flows towards a waterbody through the existing anastomosed drainage channels and later through the hydraulic boundaries within the watershed. Small drainage basins are the sub-watersheds and congregation of a cluster of sub-watersheds constitutes a large watershed.

Terrestrial anthropogenic activities have direct stress on the water bodies within a watershed. Upstream basin runoff influences the downstream discharge and sediment river. Embanking drainage channels (D/C) for channelizing deprives the watersheds its riparian vegetation of the flooding zone adjacent to the watercourses. Paving recharge areas, filling in wetlands, and overexploiting groundwater failing synchronous with replenishment pose severe and even irreversible effects on natural systems. These effects in turn usually impair water quality, degrade aquatic and terrestrial habitat, contribute to a loss of biodiversity, contaminate underground aquifers, and increase risks of flooding and erosion damage [1,2].

In a mines area the Water resources managers have to handle three types of water i.e. surface water, underground (UG) water and mines water. Considering the paucity in water availability for Barbil and Joda Township and the 48 villages in the area, it is evident to investigate the topographic parameters like Slope, drainage, outlining the watershed. Mining and appurtenant activities like open cast mining excavation, crusher yards, pellet plants, minor steel industries and many other sister concern clusters have developed within the mining area. The area is dust polluted with high SPM values due to running of mills and vehicles. Further, the water demand of the area is due to surface water, UG water and Mines water.

The geo-spatial facts and the data of a terrain and its pertinent attributes as obligatory for a watershed improvement is acquired efficiently by using other mathematical and physical models along with geographic information system (GIS) data acquisition from satellites and Remote sensing (RS) data or air based techniques or many others; [3,4,5]. [6,7,8] and [9], Mines areas in hilly terrain has acute water problem and land use and land cover issues which has been investigated by very few numbers of researchers [10,11,12,13] but not in watershed management in Mines areas . So it became pertinent to study watershed management by GIS/RS method in mines areas.

2. MATERIALS AND METHODS

This study is focused on a watershed in the hilly mining terrain; Barabil, (lat. 22.12°N, Long. 85.40°E and alt. 477m above MSL) is in Keonjhar district, Odisha, India (Fig. 1). The Barbil area is a Municipality and adjoining 48villages having geographical area of 318 km The mining area is the fifth largest deposit of Iron and manganese ores in India generating huge revenue for both the Central and the State government. Mining area wise, the % of mines in different districts are Keonjhar (31.28%), Sundergarh (20.03%), Angul (10.24%), Jharsuguda (8.87%), Koraput (6.3%) and Mayurbhanj (6%). Keonjhar district has occupied 12076 km^2 area iron ore mines [14]. The Barbil lies in the Joda - Barbil plateau spreads in north up to Singhbhum and Bonai in the west as an extension of Singhbhum rock in south at an altitude 477m (Wikipedia). The Barbil town lies in the slope of Saranda Hills in the EGB hills range and in the upper basin of the Baitarani River. Several hilly rivulets and d/c's drains to the river Baitarani via the rivulets are Suna and south Karo (a tributary of the South Koel River) emerging from Saranda hills and forest areas. These rivulets are highly polluted by mining effluents and mining wastes along with the liquid waste realized from Bibakundi, Baro and Kemp Hutting in Joda area, which is within 10km from Barbil. The Area is of red lateritic soil with absence of grazing cattle's, thick forests, grazing ground and large vegetation appearing as if the earth is aging here (Fig. 2).

To enhance productivity of the area from the shrinking and skinned land resources to arrest forest degradation, and waste disposal it is imperative to adopt best watershed management strategies. For meeting these needs, a comprehensive study on watershed and hydrological parameters with special reference to mining area is indispensable [15,16,17].

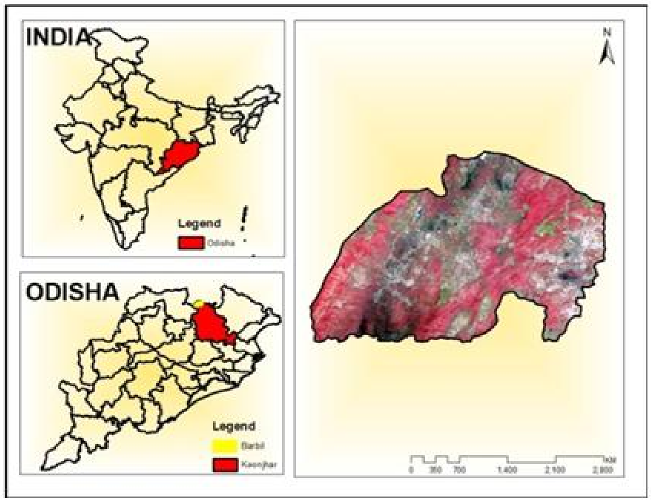

Fig. 1. Location map depict the study area

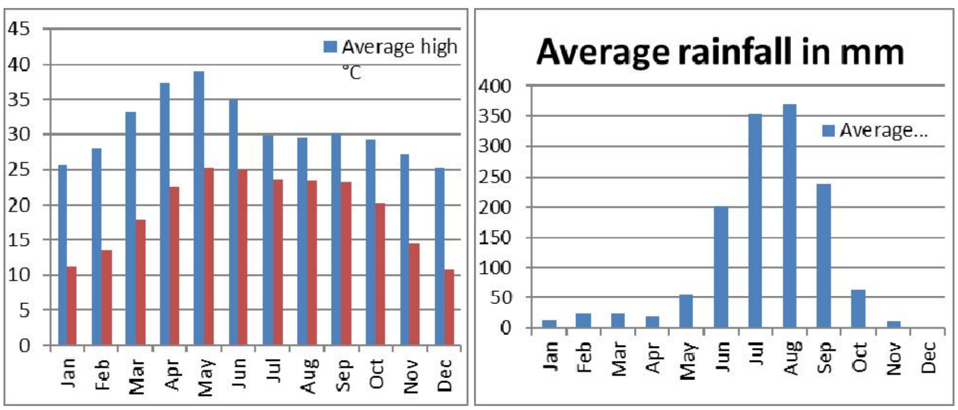

Fig. 2. Graph shows average temperature and rainfall of the study area

The data were collected from the USGS websites, which is an open source for data collection such as SRTM and CARTO DEM (30 m spatial resolution). Later the data is used for the terrain and anastomosed drainage pattern analysis. The results of the analysis can be used for slope and elevation determination like existing geographical features i.e. contour and datum. Satellite data is used suitably for the proposed watershed management for change detection through various multi spectral images using LISS III, which is collected from NRSC BHUBAN website. The utmost efficiency in energy balance in watershed management will be helpful for WS managers to face natural calamities and suggest the best suitable structure for water harvesting like gulley-bunds and check dams. In this present study, multi date Satellites used, are the LISS III - IV), LANDSAT series (Landsat 5 & 8) and CARTO DEM. The Landsat Program, a joint effort of the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA). The data are useful in assessing agriculture geology, forestry education, regional planning and mapping and global research. The analysis can be done by using software Arc GIS 10.1 and ERDAS Imagine 9.2

2.1 Climate Joda-Barbil WS

The WS is influenced by typical hard hit summer climate with lightening activities (Nor westers with thunderstorms) because of excessive mining activity. The area experiences winter westerlies and cold wave with at times, intensely hot. The average high temperature of study area is 30.77°C (pre-monsoon) and low 19.29°C (Post monsoon) maximum rail fall.

Table 1. The spatial resolution of the type of satellite and date of acquisition

S. no.	Spatial resolution	Satellite data	Date of acquisition
1	30m	CARTO DEM	23rd Jan 2016
2	23m	LISS III	10th May 2014
3	30m	Landsat 5	22nd Jan 2007
4	30m	Landsat 8	15th Dec 2018

2.2 Triangulated Irregular Network (TIN)

TIN tool create the vector-based digital geographic data to a triangulated irregular network (TIN) whose surface does not deviate from the input raster by more than a specified Z tolerance. Raster to TIN is frequently used to convert a raster derived from a U.S. Geological Survey (USGS) DEM model to a TIN surface model. The TIN is used by GIS community for many years and are a digital means to represent surface morphology. The vertices are connected with a series of edges to form a network of triangles. The other practice is interpolation to form these triangles, such as Delaunay triangulation or distance ordering. ArcGIS supports the Delaunay triangulation method. TIN is generated from the contours using Arc map 3D analyst function.

2.3 Digital Elevation Model (DEM)

A DEM is a raster representation of a continuous surface, usually referring to the surface of the earth. The DEM is used to refer specifically to a regular grid of spot heights. It is the simplest and most common form of digital representation of topography. Tin is converted to DEM (Elevation raster) raster form by surface analysis tools under spatial analyst function.

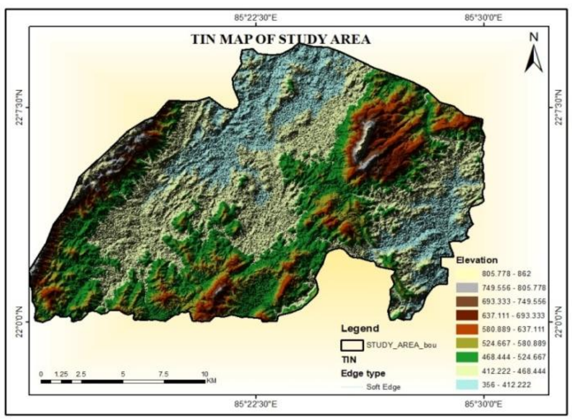

Fig. 3. The TIN map of the Joda- Barbil watershed area

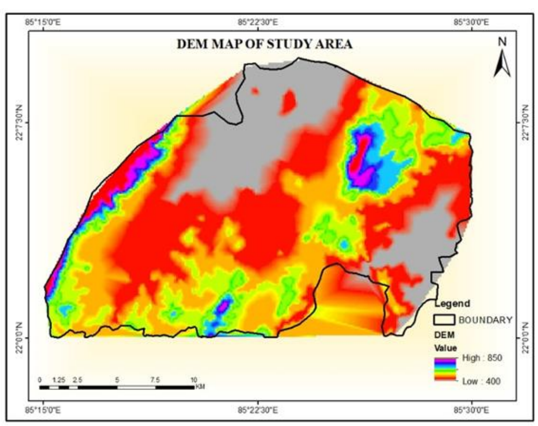

Fig. 4. The DEM map of the Joda-Barbil Watershed

2.4 Slope

Slope is a major terrain parameter which can be explained by horizontal contour spacing. The *Slope tool* is used to calculate the maximum rate of change in value from the cell to its neighbors to assess land resources. Basically, the maximum change in elevation over the distance between the cell and its eight neighbors identifies the steepest downhill descent from the cell. The vector form of closely spaced contours represents steeper slopes and sparse contours exhibit gentle slope whereas the elevation output raster every cell has a slope value. The slope values are calculated either in percentage or degrees in both vector and raster forms. Slope map can be prepared manually as per AIS&LUS (All India Soil and Use Survey) or by using 'Slope' option under Surface analysis function in ArcMap [18].

2.5 Flow Direction

To know about a watershed and its surface gradient and direction of runoff flow can be determined with the Flow Direction tool. Flow direction is an integer raster value ranging from 1 to 255. In an elevation raster if a cell is lower than its neighboring cells, the direction of the flow will be towards that cell. In some elevation raster when multiple neighbors have the lowest values then the flow will be defined by filtering out one-cell sinks. In some cases if a cell has the same change in 'Z' value in multiple directions, the resulting flow will be sum of those directions. The flow direction can be determined by finding steepest descent from each cell, which is calculated using the equation.

2.6 Flow Accumulation

The Flow direction operation determines the natural drainage direction for every pixel in a DEM and generated from the error free elevation raster data. Based on the output Flow direction map, the flow accumulation operation counts the total number of pixels that will drain into outlets. The cells of indeterminate flow directions other than (1 to 8) will only receive flow accumulation. The accumulated flow in the raster output is calculated based upon the number of cells flowing towards each cell. The high flow areas in the output raster are the areas of concentrated flow, which are important to identify possible stream channels. Topographically high like ridges has flow accumulation value zero. A drainage network is created by using the results of the high-accumulated flow. The stream network is used as input to generate stream order, stream line and stream link. The Flow Accumulation tool calculates accumulated flow as the accumulated weight of all cells flowing into each down slope cell in the output raster. If no weight raster is provided, a weight of 1 is applied to each cell, and the value of cells in the output raster is the number of cells that flow into each cell.

2.7 Contour of the Watershed

A contour line is a curve along which the function has a constant value. It is a cross-section of the three-dimensional graph of the function $f(x, y)$ parallel to the x, y plane. A contour map is a map showing contour lines, exhibiting valleys and hills, and the steepness of slopes in the terrain. The contour interval of a contour map is

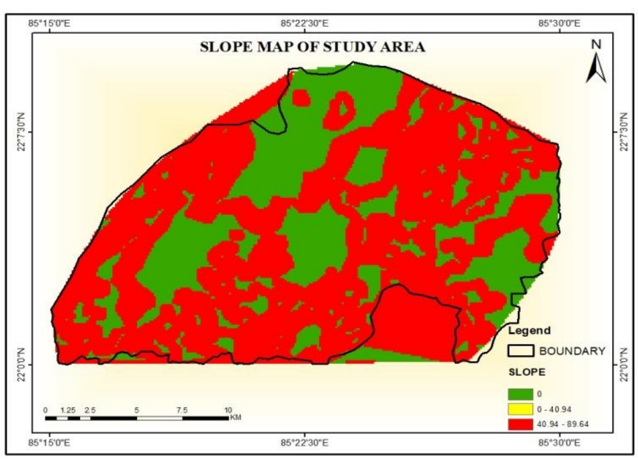

Fig. 5. The slope map of the hilly terrain Joda-Barbil watershed

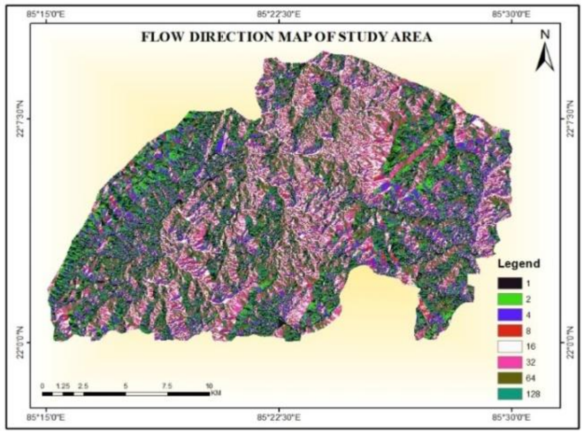

Fig. 6. The flow direction map of the Joda-Barbil watershed

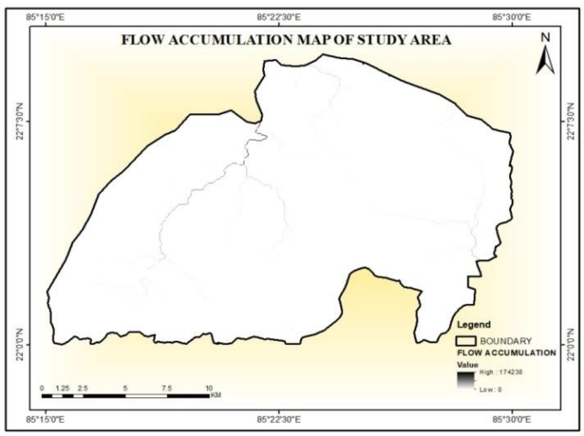

Fig. 7. The flow accumulation map of Joda-Barbil watershed

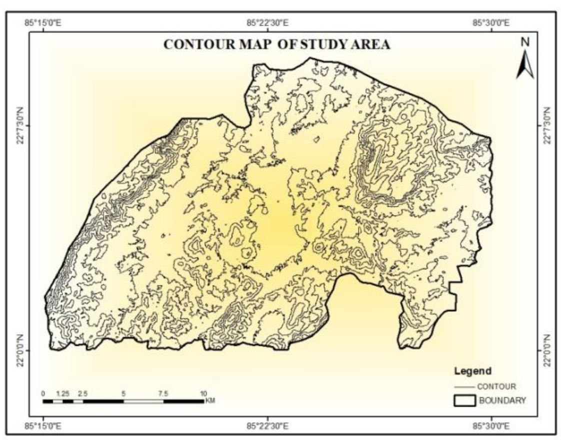

Fig. 8. The contour map of the Joda-Barbil watershed

the difference in elevation between successive contour lines. The gradient of the function is always perpendicular to the contour lines. When the lines are close together the magnitude of the gradient is large: the variation is steep [16].

2.8 Ground Water Potential Zone

Hydro geomorphologic mapping incorporates relationship of geomorphic units with their groundwater potential as interpreted from the landform characteristics (nature of landform occurrence, lithology, structure, inter-relationship with other units etc.) as well as sub-surface geology. The Hydro geomorphologic interpretation of the investigated area has been carried out on 1:50,000 scale with the help of Indian Remote Sensing (IRS) 1C, False Color Composite (FCC) imageries and Survey of India topographical sheet. Based on image characteristics of landforms (tone, texture, drainage, size, association etc.), their genesis, occurrence and composition, the hydro geomorphic units of the area are classified under alluvial plains, Buried Pedi plains, highly dissected hilly region. Ground Water Potential Map is prepared from the Hydro geomorphology structures [19].

The Ground Water Potential Depends on the landforms. By using this study area is divided in to three parts Low, Moderate and Good. The Alluvial Plain has Good water potential whereas Buried Pedi plain has moderate to poor ground water potential. Highly dissected hilly region have poor ground water potential [20].

3. RESULTS AND DISCUSSION

Limnologically the mine expanses like the Joda-Barbil area have meager ground water prospective due to interception of mines during mining activities, seepage of mines contaminants in addition to liquid water waste, sewage water due to uncivilized slum dwellings adjacent to the mining premises of Barbil. Both land air and water, are major resources pollution at Joda-Barbil area, [21]. Hence, its efficient management of the resource is a growing concern. Understanding of the hydrological behavior of a watershed is important for its effective management. The characteristics of watershed are dynamic which vary both spatially and temporally. The impacts of changing scenario such as change in land use, land management, climate variations, mining activities, and water quality has led to the development of number of simulation models. Improving infrastructure facilities is done concerning afforestation, restoration of water and transportation of stream water. Draining out excess water with safe velocity and diverting it to storage pond and recharging of UG. Ensuring suitability of afforestation location and developing the water storage structures is essential [22, 23].

To increase productivity and yield, is less subject to the effect of erratic rains if proper WS management is done by improving resource conservation (Soil and water) and land use. To create additional employment potential for the small marginal farmers and agricultural labourers; sound planning, adequate design and operation of water resources projects are essential. The modeling of runoff, soil erosion and sediment yield are indispensable for sustainable development. The reliable estimates of the various hydrological parameters for remote and inaccessible areas are tedious and time consuming by conventional methods.

3.1 Action Plan for Watershed Development

In the present watershed, water harvesting structures like check dams [22], gulley bunds, [23] percolating checks [24], and vegetative barriers [25,26], were the ameliorative measures proposed in water resources development plan for overall development. Sporadic streams can be exploited by constructing gulley bunds, check dams, percolation structures etc., can improves the ground water status and help to bring additional lands under assured irrigation. This water harvesting structure can help in impounding water, arresting flow of sediments, recharge GW-table and helps in conservation of water. The recharged aquifers can add to the substantial water availability for agriculture.

3.2 Check Dam

Check dam are permanent or temporary barrier structures, usually used in concentrated flow areas, such as vegetated ditches and swales. They prevent erosion and promote slowing flow to cater filtering of concentrated flow. A check-dam intercepts the rain water from the upstream of the local catchment area and stored for direct use and / or ground water recharge of the downstream wells. Check dam with masonry spillway are constructed across 2^{nd} and 3^{rd} order streams particularly, in medium sloping areas (0-5%). To reduce the erosion of soil on the upper reaches of the catchment area; loose boulder structure is more effective. By constructing the bunds made up of boulders and cobbles across the drain of high velocity runoff can reduce erosion of soil by blocking the discharge and

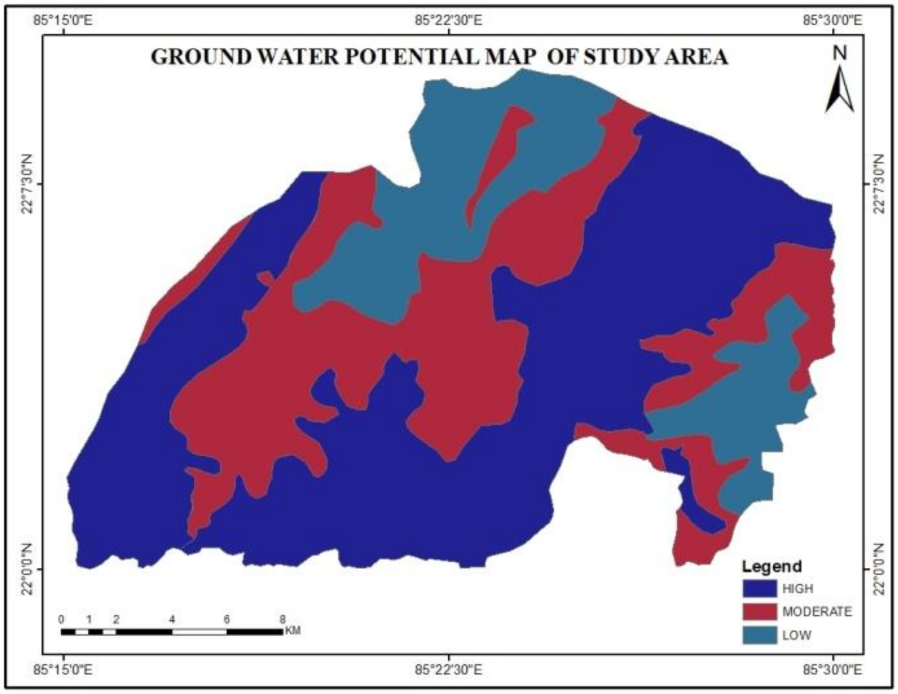

Fig. 9. Groundwater potential map of Joda-Barabil area

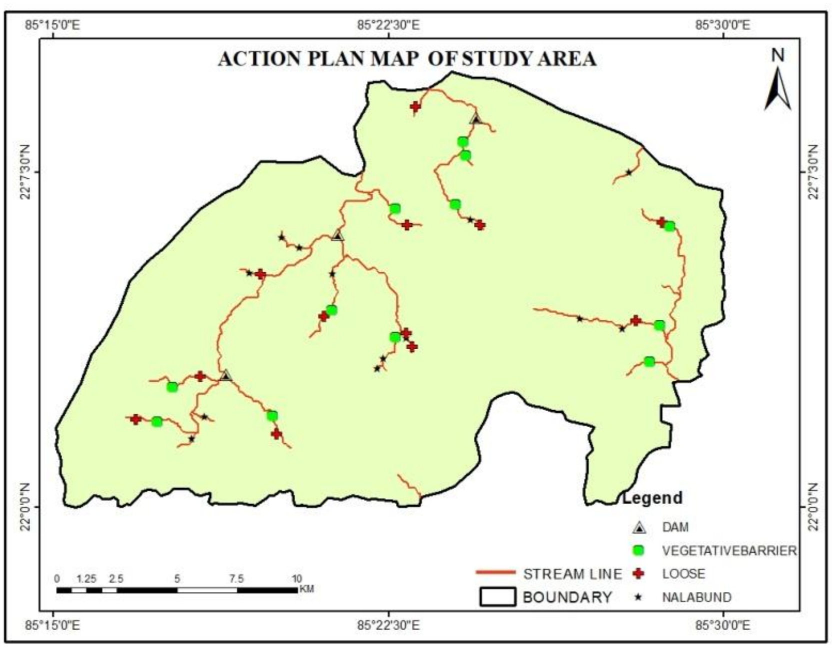

Fig. 10. Proposed additional structures within Joda-Barbil watershed

allow it to percolate to recharge the aquifers. As the silt gets accumulated between two bunds, this area can be used under afforestation, plantations or agriculture.

3.3 Watershed Management

Gully bunds are embankments constructed across water courses in hilly region for checking velocity of runoff, increasing water percolation and improving soil moisture regime. Main objectives of gulley bundling are to impound surface runoff coming from for catchments and to facilitate percolation of stored water into soil sub strata with a view to raise ground water level and silts which would otherwise deplete the water bodies downstream. Vegetative barriers or grass hedges are currently being evaluated as an alternative contractive practice. The vegetative barriers are lined narrow strip (0.3 to 1m wide) of stiff, erect densely growing plants, usually grass to prevent soil erosion and silting of percolation tanks, check-dams and minor irrigation tanks and to allow more water to recharge the ground by properly assessing the ground water potential zones using GIS [27,28,29,24].

4. CONCLUSION

The concept of Watershed management in the watershed should be taken up such as to achieve sustained higher production without causing any descent in the resource base or causing no ecological imbalances. The aim is to prevent watershed degradation that results from the interaction of physiographic features, eliminate unscientific land use by appropriate cropping pattern, soil erosion thereby improving and sustaining productivity of resources leading to higher income and living standard for the inhabitants in the watershed area. Present study area has a number of soil and water conservation structure but still there is a need to increase the number of such water harvesting units. By considering the landmass, geomorphology of the area, hydro geomorphology, soil, ground water potential some structures are proposed which will increase the crop production and ground water availability. Here the present study recommended there are 3 check dams, 12 loose bolder structure, 15 vegetative barriers and 10 gulley bunds needed to the appropriate areas. It has been done through by using geospatial techniques. Thus, GIS and RS technology is highly suitable for watershed management and planning.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ma Yongsheng. GIS Application in Watershed Management; Nature and Science, GIS Appl^{n} in Watershed Management. 2004;2(2);1-7.
2. Pinto D, Shrestha S, Babel MS, et al. Delineation of groundwater potential zones in the Comoro watershed, Timor Leste using GIS, remote sensing and analytic hierarchy process (AHP) technique. Appl Water Sci. 2017;7:503–519. Available:https://doi.org/10.1007/s13201-015-0270-6
3. Srinivas P, Sarala CP, Chowdary P. Integrated watershed management using remote sensing and GIS techniques. Nature Environment and Pollution Technology. 2007;6(3):463-470.
4. Banukumar K, Panneerselvam A, Aruchamy S, Ganesh A. Surface water mapping for Watershed management using Geospatial techniques. Int. Jr. of Geomatics and Geosciences. 2011;2(1): 289-300
5. Srivastava VK, Giri DN, Bharadwaj P. Study and Mapping of Ground Water Prospect using Remote Sensing, GIS and Geo-electrical resistivity techniques – A case study of Dhanbad dist., Jharkhand, India. Jr. of Indian Geophysical Union. 2012;16 (2):55-63.
6. Obi Reddy GP. Geospatial Technologies in Integrated Watershed Management; book: Geospatial Technologies in Land Resources Mapping, Monitoring and Management Publisher: Springer, Switzerland; 2018. DOI: 10.1007/978-3-319-78711-4_27
7. Rajeev, Sultan Singh. Watershed management - a GIS approach; International Journal of Research in Applied, Natural and Social Sciences. 2016;4(6):109-116
8. Balasubramani K. Assessment of watershed resources for sustainable agricultural development: a case of developing an operational methodology under Indian conditions through geospatial technologies, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. 2020;XLII-3/W11:1-5. PECORA 21/ISRSE 38 Joint Meeting, 6–11 October 2019, Baltimore, Maryland, USA; 2019.
9. Balasubramani K, Veena M, Kumaraswamy K, Saravanabavan V. Estimation of soil erosion in a semiarid watershed of Tamil Nadu (India) using revised universal soil loss equation (rustle)

model through GIS. Model. Earth Syst. Environ. 2015;1:10.
Available:https://doi.org/10.1007/s40808-015-0015-4
10. Joshi PK, Kumar M, Midha N, Vijayanand, Paliwal A. Assessing areas deforested by coal mining activities through satellite remote sensing images and GIS in parts of Korba, Chhattisgarh. J. Indian Soc. Remote Sens. 2006;34:415–421.
DOI: 10.1007/BF02990926
11. Kim SM, Choi Y, Suh J, Oh S, Park HD, Yoon SH, Go WR. Armine: A GIS extension to support mine reclamation planning. Comput. Geosci. 2012;46: 84–95.
DOI: 10.1016/j.cageo.2012.04.007
12. Suh J, Kim SM, Yi H, Choi Y. An Overview of GIS-Based Modeling and Assessment of Mining-Induced Hazards: Soil, Water, and Forest. Int J Environ Res Public Health. 2017; 14(12):1463. Published 2017 Nov 27.
DOI: 10.3390/ijerph14121463
13. Choi Y, Baek J, Park S. Review of GIS-Based Applications for Mining: Planning, Operation, and Environmental Management; Appl. Sci. 2020;10(7):2266.
Available:https://doi.org/10.3390/app10072266
14. Patra HS, Sethy KM. Assessment of impact of opencast mine on surrounding forest: a case study from Keonjhar district of Odisha, India. Journal of Environmental Research and Dev. 2014;9(1):249-54.
15. Burrough, Peter A. Principles of geographical. Information Systems for Land Resource Assessment. Clarendon Press, Oxford; 1986.
16. Zhang H, Haan CT, Nofziger DL. Hydrologic modeling with GIS: An overview, Applied Eng. in Agriculture, ASAE. 1990;6(4):453–458.
17. Patra S, Pattanaik A, Venkatesh AS et al. Mineralogical and Chemical Characterization of Low Grade Iron Ore Fines from Barsua Area, Eastern India with Implications on Beneficiation and Waste Utilization. J Geol Soc India. 2019;93: 443–454.
Available:https://doi.org/10.1007/s12594-019-1199-4
18. Das, Madhumita. Ethics and mining–Moving beyond the evidence: A case study of manganese mining from Keonjhar district, India. Geoethics: Ethical challenges and case studies in earth sciences. 2015;393-407.
19. Etikala Balaji, Golla V, Lee P, Renati S, Deciphering groundwater potential zones using MIF technique and GIS: a study from Tirupati area, Chittoor District, Andhra Pradesh, India. Hydro Research. 2019;1-7.
Available:https://doi.org/10.1016/j.hydres.2019.04.001.
20. Golla V. Delineation of groundwater potential zones in Sathyavedu area, Chittoor District (Andhra Pradesh), South India, using geospatial technologies. Model. Earth Syst. Environ. 2020;6:895–905.
Available:https://doi.org/10.1007/s40808-020-00726-9
21. Goswami S, Das Madhumita Guru BC. Ethics and mining–Moving beyond the evidence: A case study of manganese mining from Keonjhar district, India. "Book; Geoethics: Ethical challenges and case studies in earth sciences. 2015;393-407.
22. De Atasi, Dheeraj Kumar, 2018, Remote sensing and GIS for assessment and prediction of environmental hazards due to mine waste: case study from Daitari iron ore mines, Odisha, India, Conference: Earth Resources and Environmental Remote Sensing/GIS Applications; 2018.
DOI: 10.1117/12.2326709.
23. Sharma AK, Shukla JP. A RS and GIS based approach to evaluate the ground Water Prospects of baghain watershed, Panna and Satna Districts of M.P., India: a Case Study, Journal of Geological Society of India. 2015;86(6).
24. Soni, Abhay Kumar. Mining of minerals and groundwater in India. Groundwater-Resource Characterisation and Management Aspects. Intech Open; 2019.
25. Chavare Subhash. Application of remote sensing and GIS in landuse and land cover mapping of sub-watershed of Wardha River Basin; Proceedings of National Conference on Development & Planning For Drought Prone Areas. 2015;221-24.
26. Choudhury M, Hasan ME, Mamun MMMA. Land use/land cover change assessment of Halda watershed using remote sensing and GIS; Sensing and Space Science. 2020;23(1):63-75.
27. Saraf AK, Choudhury PR, Roy B, Sarma B, Vijay S, Choudhury S. GIS based surface hydrological modelling in identification of

groundwater recharge zones, International. Journal of Remote Sensing. 2004;25: 5759–5770.

28. Senthil Ku GR, Shankar K. Assessment of Groundwater Potential Zones Using GIS, Frontiers in Geosciences. 2014;2(1): 1-10.

29. Siddi RR, Sudarsana RG, Ravikumar M, Raghubabu. Applications of remote sensing and GIS, for identification of ground water prospecting zones in and around Nandalur, YSR district, Indian Journal of Environmental Protection. 206;36(4):293–304.

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