



The Delineation of Watersheds in the Dhenkanal District, Odisha, India; Using Arc-GIS

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The watersheds of the Dhenkanal district of Odisha, India with the centrally flowing, river Brahmani identified and explored. The watersheds added with anthropogenic stresses are unattended that affect the land, hydrology, ecology, vegetation, and fertility of the soil. Population growth, migration to cities, challenges, continuous disasters, and anthropogenic stresses block the growth. The Arc GIS software and its Hydrology toolset were utilized. The Digital Elevation Model is used to scale various maps like flow direction, stream order, flow accumulation, Stream features, Pour points, and watershed maps of the district. The Rengali Dam, and Samal barrage of the Brahmani system and its left and right canal system have a positive impact on watersheds on both sides of the river Brahmani but the surface and groundwater are polluted by industrial effluents. The watersheds in transition ridges of the Mahanadi and the Baitarani basin of the Brahmani basin have been poorly attended in Dhenkanal. Construction of farm ponds, groundwater recharge units, soil conservation activities, renovation, and new construction of waterbodies can cater to and care

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for the land, water, and vegetation of the district. It is high time to prepare large-scale maps by modern survey techniques (UAV, drones, GIS, and GPS) and the observed data used to identify, delineate, prioritize, and plan for sustainable environment management considering availability v/s demand of water through Integrated Watershed Management in the district.

Keywords: Anthropocene; digital elevation model; farm pond; geographical information system; morphometry; delineation of watershed.

1. INTRODUCTION

A watershed is an area of land within a basin or a Doab (a hydrological unit) where it decants through naturally housed common drainage channels like larger waterbody, swamps, lakes, rivers, or streams (with micro units and sub-units). Sustainable watershed planning is to protect inland water bodies, users, and habitats. There is a need to support the water resources (WR) for future cohorts outfitting to the present demand. Science & Technology, planning, and educational outreach are the three pillars of sustainable watershed management (WSM). It recognizes the judicious planning, implementation, and management of the three elementary inland resources such as soil, water, and plants. The ecology and environment of the watershed must attain specific objectives for its stakeholder's sustainability.

Last four to five decades watershed development (WSD) programs have brought a paradigm shift through the cutting-edge solution of the green revolution in the holistic natural resources of rain-fed agriculture. The WSM has stabilized assured irrigation through the implementation of innovative technology missions. India is thickly populated with a diverse tropical Savanna climate (extreme, moderate, and sober) and the glaciers of the Himalayas. The nation has 7500 km of coastline with about 3% of mangroves. India sustains nearly 16% of forest coverage housed in the land mass of 329 M ha, Thar That desert, and large rivers and large deltas are also part of India.

The Anthropogenic epoch period (1950 onwards) has increased land degradation that has exhausted the natural resources due to population growth. Urbanization, salinity intrusion, industrialization, desertification, soil and coastal erosion, deforestation, and dwindling GWT (Ground water table). A paradigm shift in agricultural practices, erratic climate change, meteorological extremes, and frequent disasters have reduced Water resources, grazing areas for bovines, and even better-yielding fields and have

invited 6th mass extinction and energy crisis [1], Van bal et al. [2].

The district Dhenkanal in Odisha, India was a mountainous hill in its periphery without scarce water sheds in the peripheral blocks. Agriculture was rai fed with uncertain yields from the crops before 30 years. Meanwhile, major canals are passing parallel to the mid-flowing Brahmani River. The hilly boundaries have two medium irrigation projects that could not cater to the needs of the rich biodiversity and remote villagers' demand. The present study is an attempt to identify, delineate, prioritize, and plan for a green Dhenkanal district using the commonly used geographic Information and Remote Sensing technology (GIS/RS).

1.1 Study Area

Dhenkanal is a small rain-fed agricultural district adjacent to the central Mahanadi delta. The district lies between 20° 29'00" and 21° 11'00" lat. N. and east 85° 58'00" and 86° 02'00" long. E.), at 249 m above MSL elevation and comprising an area of 4452 sq. km.

The district comprises eight blocks enlisted under the agro-climatic zone of eastern deltaic plains bounded by hillocks in the northern and southern periphery. The peripheral blocks often reel under austere water scarcity, especially in summer. The watersheds in those blocks need identification, delineation, and prioritization by the line departments of the district using GIS and RS technology. These watersheds need to include in an integrated management scheme by prioritizing various parameters as the people to thrive over an agrarian economy, [3,4,5] (Fig. 1).

2. REVIEW OF LITERATURE

A watershed is a fluvial-lacustrine landform in the terrestrial environment. Water scarcity is the result of erratic climate change at present with the proliferation of *Escherichia coli* (E-coli) effluent discharge and basin runoff of a watershed that threatens human health and

security, [6], Bunch et al. [7], Sharifi et al. [8]. Water-shed management for an integrated water resource (WR) supervision strategy warrants upcoming water use for drinking, portability, and irrigation requirement declines in dry periods with physiochemical parameters having high ranges of pH, Total dissolved Solids (TDS), and DO enabling the watershed ecology deteriorated, Kellner et al. 2017, Rajaein et al. 2021 [9]. Submission of Integrated Watershed Management (IWSM) Curtails the Land Use (LU) alteration Influences, [10]. Proper enactment of IWSM is a good indicator of public health in remote and tribal areas, [11-13]. The geographical Information Sys. (GIS) and remote sensing technology (RS) is modern, and innovative environmental monitoring tool and effective in integrated watershed management (IWSM), [14-16]. Land use and land cover changes are interrelated with watershed development, soil erosion, quality of water, vegetation, and yield of the area [17,18].

IWSM Programme in India was framed to provide the expansion of the DPAP (Drought Prone Areas Program), and DDP (Desert Development Plan) and rectifies the 1994 formulations, identifying the drawbacks, capacity-building strategies, and suggesting precisions, [19,20]. Investigation through Morphometry of an ungauged watershed, its prioritization, and delineation is usually done for the expansion of the district hydrological model using GIS/RS, [21-24,20]. In a multifaceted watershed, the groundwater (GW) should not be neglected. They must be planned by using GIS and AHP techniques based on the delineation of the

groundwater potential zones, [25,26]. IWSM a part of the Sustainable development goal (SDG - 6) and climate change impact takes care of the various watersheds for its stakeholder's health, [27].

Arc GIS software along with RS and modern high-speed computers, cloud technology, and the use of big data can help in the analysis and planning of geo, hydro, oceanic, ecology, and environment. For all these purposes, a digital elevation model (DEM) is necessary, [28].

The review of the past works reveals that the watershed sector in the basin-wise division, the macroscale, and the microscale partitioning were ignored. The Geo-bio-hydro terrestrial ecosystem and socioeconomic status of the stakeholders were not considered. The present study envisages the investigation of a major rain-fed district Dhenkanal in Odisha with fewer medium/minor irrigation projects, allowing the arterial river through the Rengali right/left canals yet to be operative full-fledged.

2.1 Methods and Methodology

AS per SDG- 6; there is a need for Land, WR planning, and eco-friendly sustainable development management goals for the district are warranted by evaluating the source availability and demand for both the present and future. This strategy can be smoothed by people's participation through the PPP (Public-Private Partnership) mode added with an integrated approach with regular monitoring of the concurrent development.

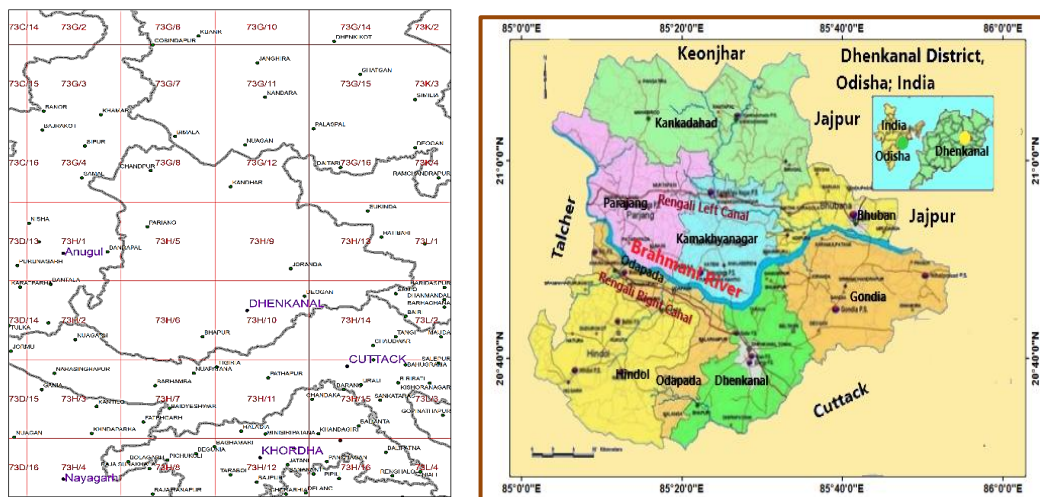


Fig. 1. The Topo-sheets Catalog and Index map of the Dhenkanal district, Odisha, India (Source: modified: Mahalik et al. [3])

Table 1. The methodology applied for generating the watershed map of Dhenkanal


Extract Basin	Basin Fill	Flow Accumulation	Flow Direction	Flow Path	Snap Pour Pt.	Strem Order	Stream to feature	Water Shade map
								

Table 2. The attribute information and remote sensing applications using GIS/RS in Watersheds (IIRS activities) [29]

DEM real field Applications	Parameters obtained for various studies	Thematic Maps Showing Attributes
Runoff, Sedimentation studies	Length, area; rainfall, runoff; geometry; shape index; Drainage pattern form factor; av. Elevation, av. Slope, aspect, altitude relief, & density.	Size, shape; Physio-graphy; slope; drainage; stream order
Geology; geo-technology, and geomorphology	Soil Texture, moisture, the capability of land squalor, Production potential, Wasteland; surface water runoff; soil erosion in the USLE or RUSLE process.	Contour ; LULC; land erosion; geographic/ geomorphologic
Groundwater	Groundwater Potential Recharge & irrigation; GW contamination; and Salinity intrusion maps	Zoning Na ⁺ , Ca ⁺⁺ , K ⁺ , Mg ⁺⁺ , Cl ⁻ , SO ₄ ⁻
Geomatics	Social, demographic; cultural, and economic data; surveying, mapping, remote sensing (LiDAR or HDS Scanning), photogrammetry, hydrography, global positioning systems (GPS), and geographic information systems (GIS).to deliver delivering spatially referenced information	Using small-scale maps gathering data, storing, processing, and analyzing the data using Q-GIS & geomatics tools.
Geomorosis	Watershed characterization, delineation, appending the adjacent WS; stream parameter analysis; aerial length; Relief parameters; Rigosity coefficient	Geomorosis maps
Delineation & prioritisation	Rainfall, runoff, wind, soil, slope, vegetation; geomorphology; usual practices; Quantity. method – USLE/ RUSLE;Qual. method - Sediment Yield Index using Runoff Rate, Vegetation Status; Socio-economic conditions	Calculation NDVI, SBI, PC; Sediment Yield index

The investigations of various constituents of a watershed consist of drainage pattern, the order of anastomosed drains, delineating WS boundaries, length, and area. The analysis of the morphology, prevailing federal laws, characters, and delineation of the WS is essential. The GIS, and RS technology are the instruments that should be prioritized to conduct the small-scaled survey by the UAV methodology the various attributes, their parameters, and their applicability, (Table 2).

2.1.1 Demography

The demographic growth of the district is very fast (From 300 thousand population in 1900 the district has risen to 1310th population in 2011). The trend in population growth declined in the decade 1911-1921 due to the Pandemic H1N1

virus and reached optimum in the decade 1971-1981 then the growth rate is declining slowly. It is estimated that the population of Dhenkanal in 2023 was 1,192,811 housed in an area of 4,452 Km² area with an inhabitants density of 268per/km², www.indiacensus.net/states/orissa/density, (Fig. 2. a & b).

2.1.2 Climate

The climate of the region is characterized as Humid to semi-humid housing in the Eastern/South Eastern Upland (as per ICAR), or Agro Climatic Zone (noted by NARP), or it is Mid central table land (OR-10),. The Dhenkanal relishes (Aw Koppen Hazen) moderate climate, average annual rainfall of 142.9 cm, (Oct 2020 it was 164.49cm), Fig. 3.

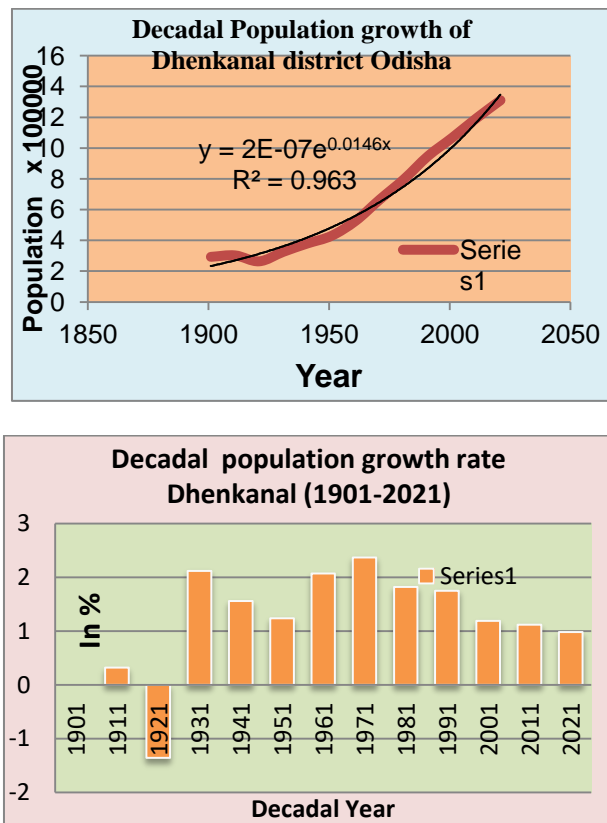


Fig. 2. (a) The decadal population change and (b) % of the growth rate of Dhenkanal District Odisha (1901-2021)

Source data: <https://www.census2011.co.in/census/district/407-dhenkanal.html>

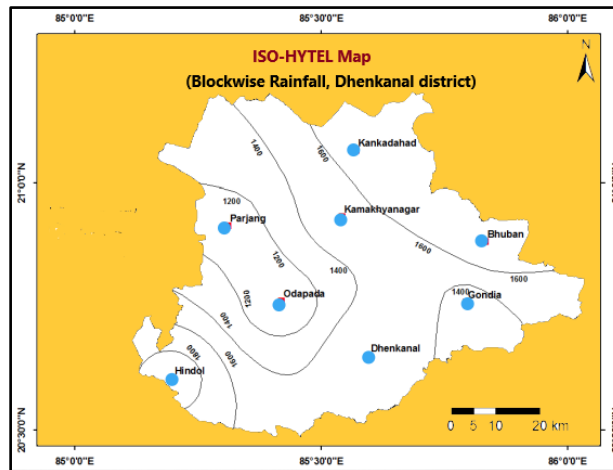


Fig. 3. Blockwise Isohytel map of Dhenkanal district, Odisha

(Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Odisha/DHENKANAL)

The average temperature ranges from as high as about 38.6° c in summer to as low as about 9.6° c during winter. The pattern of rainfall is highly erratic & maximum water goes as runoff. Relative humidity (RH) observed is about 26-82% throughout the year. The district gets an average

of 72 days of rainfall out of which 1109mm in 54days during SW-monsoon (June-mid Oct;), NE-monsoon (Oct-Dec; 14.3cm in 7 days), in winter (Jan –March; 6.6cm in 4 days), and in summer (APR to May; 11.1cm in 7days). (Agriculture Handbook 2022 of Dhenkanal [30]).

2.1.3 Geology

The Moula-Bhanja Mountains ranges are in the Dhenkanal district. The mountainous range has underlain by the Precambrian rocks of granite, granite gneiss, and Khondalite. They intersect by gabbroic dykes and stocks. Solid rocks have primary porosity. On weathering and fracturing, secondary porosity forms discreetly better aquifers. The district is partitioned into four physiographic units such as Southern Mountainous (Hindol Region, part of Gondia, Odapada, and Dhenkanal block), Eastern Valley and Plain (Kamakhyanager part), Central Undulating Plain (part of Parajang block), and Northern Mountainous Region (Kankadahad part), Bhuban and Kamakhyanager block (part). Dhenkanal is housed centrally in the flood Plains

of the Bramhani River and its drainage system with the sporadic hill ranges in the southern corner indicating Dhenkanal district is suitable for watershed management. https://cgwb.gov.in/District_Profile/Orissa/Dhenkanal.pdf

2.2 Geomorphology

The district has four geomorphic subdivisions (i) the Northern Mountainous Region (ii) the Eastern Valley and Plain,(iii) the Southern Mountainous Region, and (iii) the Central Undulating Plain. The Southern Mountains trends in NNW-ESE and bifurcate the Mahanadi and Bramhani Basin (60 m to 971 m above) mean sea level (MSL) with deep vegetation (Fig. 4).

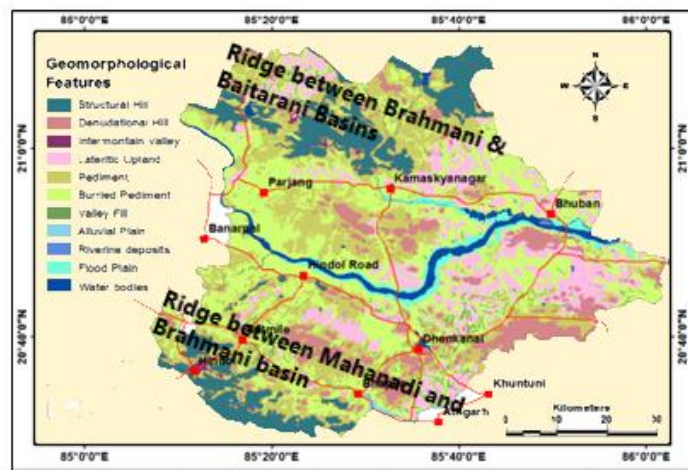


Fig. 4. The geomorphology of the Dhenkanal area FY 2022 (Source: CGWB modified)



Fig. 5a. The drainage map of the Dhenkanal district (Source: CGWB modified)



Fig. 5(b). The main rivers and canals in Dhenkanal district
(source: <http://www.msmedicuttack.gov.in/annualreport/DIPS-DHENKANAL.pdf>)

The eastern valley and plains are a small strip of land of the Brahmani River and its drainage system within the stretch comprising ridges and residual hills (40m to 60m above MSL) with lateritic soil with scrub jungles. The central undulating plain spreads over the Panjang block. It needs to have broad flat topography with hillocks with a flat top. The Northern Mountains have terrain covered with Broad valleys, isolated hill locks, and dense forests.

2.3 River/Drainage System

The river Brahmani flows (initially north (N) to the south (S) and later NW to SE) in its mid-reach of the river within the districts. It controls the anastomosed drains like *Dadaraghati*, *Sapua*, and *Ramial*, the medium irrigation projects of Dhenkanal.

The tributaries flowing within the district are Ramiala, Nigre, Purajhor Nadi, etc with subparallel drainage patterns. The seven minor irrigation projects in the district are at *Bedapada*, *Gundurposi*, *Jodabadia*, *Kalijodi*, *Kankadajhar*, *Panaspal*, *Bainsidihi (new)*, and *Sarapa* only. Kisinda nallah and its tributary to Tikira River are the causes of drainage pollution through sludge discharge from Bhusan, GITPL, GMR (TPPs), Nababharat, and BRG steels. As the 2nd largest river of the state the NW and NE parts of the district, it is heavily contaminated due to the toxic effluent of the Rourkela steel plant and various industries getting in the way. The water of the rivers is highly contaminated with all toxic heavy metals viz. Cr and Ni, Mn, etc. which possess concern and warrant immediate environmental response, and societal purposes [31] (Fig. 5a).

2.4 Land Use

The total geographical area of the Dhenkanal district is 445200 Ha They comprise command areas, forests, and land use beyond agriculture, pastures, waste, and fallow. Urbans, Industries, and anthropogenic activities have deteriorated the land use pattern. The area under forest is **192699Ha** of land, where the watershed area is **4473Ha** only [32].

2.5 Major Soils

The major portion of the soil of the district is in plain land consisting of soils like Red sandy loam medium textured soils 152.0 Th Ha, Light surfaced laterite soils 159.0 Th Ha, old alluvium sandy loam soils 67.0 Th Ha, Clayey soils 55.0 Th Ha, and Black soils 12.0 Th Ha respectively. The soil of the district is acidic and warrants reclamation by using lime. As a substitute retrieval is possible through Paper Mill waste generated at Chaudwar @ one to two MT/Ha, as proposed by Mishra et al. [33].

2.6 Agriculture

As per Deputy Director Agriculture, Dhenkanal, out of the total area of 445200 Ha, the gross cropped area is 281668Ha, Fig. 5(b).

In 2021, the net sown area was 186286Ha with a cropping intensity of 153%. During the calendar year 2019-20, the district has net area sown area was 86 Th. Ha. Paddy is the major crop cultivated, along with added harvests yielded from Mung (green gram), Biri (black gram), Groundnut, horse gram, mustards, and vegetables.

2.7 Irrigation

Agriculture in Dhenkanal in Odisha was mostly rain-fed until the operation of Samal Barrage. The stabilization of agriculture started after the construction of the Rengali left and the right canal system. In the year 2019-20, the DAO (District Agricultural Officer), Dhenkanal, reported that the potential created during Kharif and Rabi are 85871 hectares (911888 qtl/yr) and 29795 hectares (349526 qtl/yr) respectively with average annual productivity is 56.059 qtl/ha. The years 2019 to 2022 were the year of little irrigation infrastructural activities due to the pandemic COVID-19. The net irrigation potential created by the district was 51.7 Th Ha, the gross irrigated area was 74.7 Th Ha, and the Rainfed area was 134.2 Th Ha respectively. The Rengali right/left canals are on the verge of completion that will irrigate the Dhenkanal Sadar, Gondia, and Parjang blocks.

2.8 Groundwater

Both the surface water and the groundwater of Dhenkanal district are in transition of pollution. The river and the drains polluted by industrial wastes discharged to the Brahmani river system from the conjoint point at Vedavyasa to the delta head at Jenapur. There are two types of aquifers Aquifer – I (Phreatic, depth 0-30m) and Aquifer II (Semiconfined to confined, depth 30-200m). The decadal trend of fluctuations in the Groundwater table (GWT) has a 0.03 m to 0.30 m upswing in 68% of bores and 32% of wells 0.02 to 0.16 m falls in March, April, and May months. However, in the monsoon period (June to October), the GWT rises by 0.03m to 0.30 m in one-third well, and 0.02 to 0.58 m falls in the rest of the wells. The district has replenishable

groundwater (GW) resources of 44264 Ha m, whereas the GW draft for use is 2745 Ha m. As per CGWB, the quality of GW, (both shallow and deep) aquifers is within the allowable limit for both portability, drinking, and irrigation, Table 3.

An overview analysis of the soil texture of (the Kadalipal watershed, Dhenkanal, Odisha) has the samples revealed that sandy clay loam texture constituted about 60% of all samples in different cropping systems and at different depths. Clay loam, sandy loam, and loamy texture represented 20, 15, and 5%, respectively, [34].

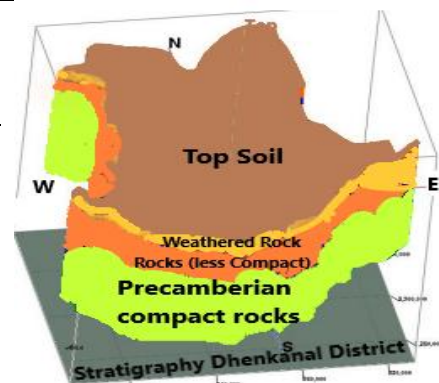
Continuous tillage and cultivation of nutrient-exhaustive crops might have favored a rapid rate of mineralization over that of accumulation of soil organic carbon (SOC) in these fields. Among crop fields, legumes (groundnut, cowpea) hold promise for greater accumulation of SOC in long term [34].

2.9 Prelude of Study

Most of the major reservoirs in Odisha are at a stage of losing their water-retaining capacity due to sedimentation. Rengali dam across the Brahmani River is suffering from sedimentation though started operating in 1984 [35]. The alternative to reservoir sources and plenty of availability of coal, several coal-based thermal power plants, and the direct discharge of effluent to the tributaries of the Brahmani River contaminating both the surface and groundwater. The major agricultural lands in the district are deprived of irrigation. Particularly the blocks are Kankadahad, Parjang, part of Dhenkanal, and Hindol. The poor maintenance of water

Table 3. Dynamic Ground Water Resources of Aquifer-I in Dhenkanal district. (2020):
(http://cgwb.gov.in/AQM/NAQUIM_REPORT/Odisha/DHENKANAL)

Total groundwater reserve Dhenkanal	Dynamic Resource (Ham)	Storage Resource (Ham)	Total Ground Water (Ham)
Aquifer-I (0-30m)	28166.89	51685.549	79852.44
Aquifer-II (30m-200m)			106449.15
			186301.59



conductors and pipelines in lift systems is compelling the farmers to stopover cultivation as water intended botched before reaching the field. The alternate choice, the waterbodies in the watershed are depleting as an outcrop of the exploitation of the GW and the catchment. The farmers running through a tough time with their livelihood. India demands Water Harvesting structures, WS development plans and implementations, CADA (Command Area Development applications), and GWR (Ground Water recharge) targets to reduce decontamination and stresses from industries, inter-basin links, and river basin developments. The watershed development projects: Pradhan-Mantri Krishi Sanchaya Yojana, has projected for Dhenkanal an area of 5896Ha out of which 1161.98ha as rain-fed in the year 2021-2022 and targeted to generate 4.56 million INR, <https://wdc.pmkysy.dolr.gov.in/blsrptproj?>

2.10 The Middle Mountainous and Highlands Region

Dhenkanal district is one of the centrally located districts in Odisha. It lies between Longitude: 85° 58' to 86° 2' East and Latitude: 20° 29' to 21° 11' North has bordered districts Keonjhar to the north, Jajpur to the east, Cuttack to the south and Angul to the west. Dhenkanal is at 20.67°N 85.6°E., with an average elevation of 80m. The district comprises mainly plains; however, there are several discontinuous hills in the district and along its southern border. The Brahmani River is the main river of the district, centrally located map of Odisha. Dhenkanal District housed in a 4452 Sq Km area houses beautiful wild lives and forests. The District headquarters bisects the Cuttack-Sambalpur road (NH 55) and the Cuttack-Sambalpur or Baranga-Sambalpur railway line. It has a vast area covered with dense forests (192.7 Th Ha) and a long range of hills. The District is the 'Home of Elephants and Tigers' of the Country.

2.11 Integrated Watershed Management (IWSM)

IWSM planning aims at a multidirectional approach to exploit the natural resources optimally, which should be Deterrent, Liberal, Corrective, and Curative. The main objective of the study should stress upon conservation of the land, Soil, Water, and vegetative growth escorted by harvesting rainwater and recharging the groundwater. The WSM should stress the yield,

ecology, flora, and fauna promoting the overall development of the economic and societal status of the people.

2.12 The Delineation Plan of Water Sheds in Dhenkanal

A watershed (WS) is an upslope area that contributes water flow as concentrated drainage. The delineation of various watersheds in various WSs is the largest to the mini watershed as per IIRS, India. They are; Regions (1500-12000 Th Km²); Basins (300 to 3000 Th Km²); Catchment (10 to 5.0 Th Km²); Sub catchment (2000 - 10000 km²); Watershed (500 - 2000 km²); Sub-watershed (50 - 500 km²), Mini Watershed (10 - 50 km²) and Micro watershed of area (5 - 10km²), https://www.iirs.gov.in/iirs/sites/default/files/pdf/Watershed_Director_IIRS.pdf.

2.13 Why the GIS Approach

GIS technology has become an authentic, very powerful tool that links the upstream (U/S) and Downstream (D/S) areas of a drainage network. The growth of the WS area picturizes the natural growth, and perspective socio-economic facades for healthier management in multi-faceted sectors like planning, accomplishment, and monitoring. This delineation of the WS area is possible from a digital elevation model (DEM) using the GIS technology endeavoring the Hydrology tools from the Spatial Analyst toolbox.

The advantages of the application of GIS/RS technology, GPS (Global Positioning System), GPR (Ground -penetrating radar), unmanned-aircraft vehicle system (UAVS), and remotely piloted aircraft system (RPAS) and drone survey methodology are the recent technology to access the watershed of an area geospatially, the environmental parameters. The method is economical, prompt, and unbiased. The WSM is only possible by collecting primary data, analyzing properly, and basing it on social indicators with accuracy. The spatial distribution of LULC (Land use and land cover), soil erosion, and vegetation index are geomorphology features, and water resources delineate using the GIS technology. RS provides collateral data such as ridgelines, erosion-prone areas, etc., [35]. The necessary maps that can do all these jobs are attribute parameters and their relevance. They are the size and shape of the study area, slopes, drainage, geography, soil erosion, LULC, salinity intrusion, GW, and many attributes [36].

2.14 DEM File

Digital Elevation Model (DEM) is a representation of the topographic surface of the earth excluding trees, buildings, and any other surface objects. USGS DEMs are used to derive primarily from topographic maps. Those could systematically replace with DEMs derived from high-resolution LIDAR and IFSAR (Alaska only) data.

The creation of a watershed model is possible by using the Hydrology tools from the Spatial Analyst toolbox. They can convert the model to watershed bounding polygons. The function allows us to add a file to the ArcMap blank document, be it a DEM file, or a shape file.

2.14.1 Run the fill, flow direction, and flow accumulation

The Fill tool fills sinks to remove imperfections from the DEM. A Z-limit affects the result of the

tool. It is recommended to state the Z-limit if the depths of the sinks are known. The Sink (Spatial Analyst) tool can be used to identify the sinks and their depths before using the Fill tool. The Flow Direction tool determines the direction of flow from each cell to its steepest downslope neighbor. The Flow Accumulation tool calculates the accumulated flow to each cell, as determined by the accumulated weight of all cells that flow into each downslope cell (Fig. 6a, b, c, d).

2.15 Stream Feature

The Stream Feature is vectorizing of stream networks, or other raster signifying known directionality. It alters a raster demonstrating a linear network of features. It converts the input stream, and input flow direction in raster and gives output in polyline features (Fig. 7 a & b).

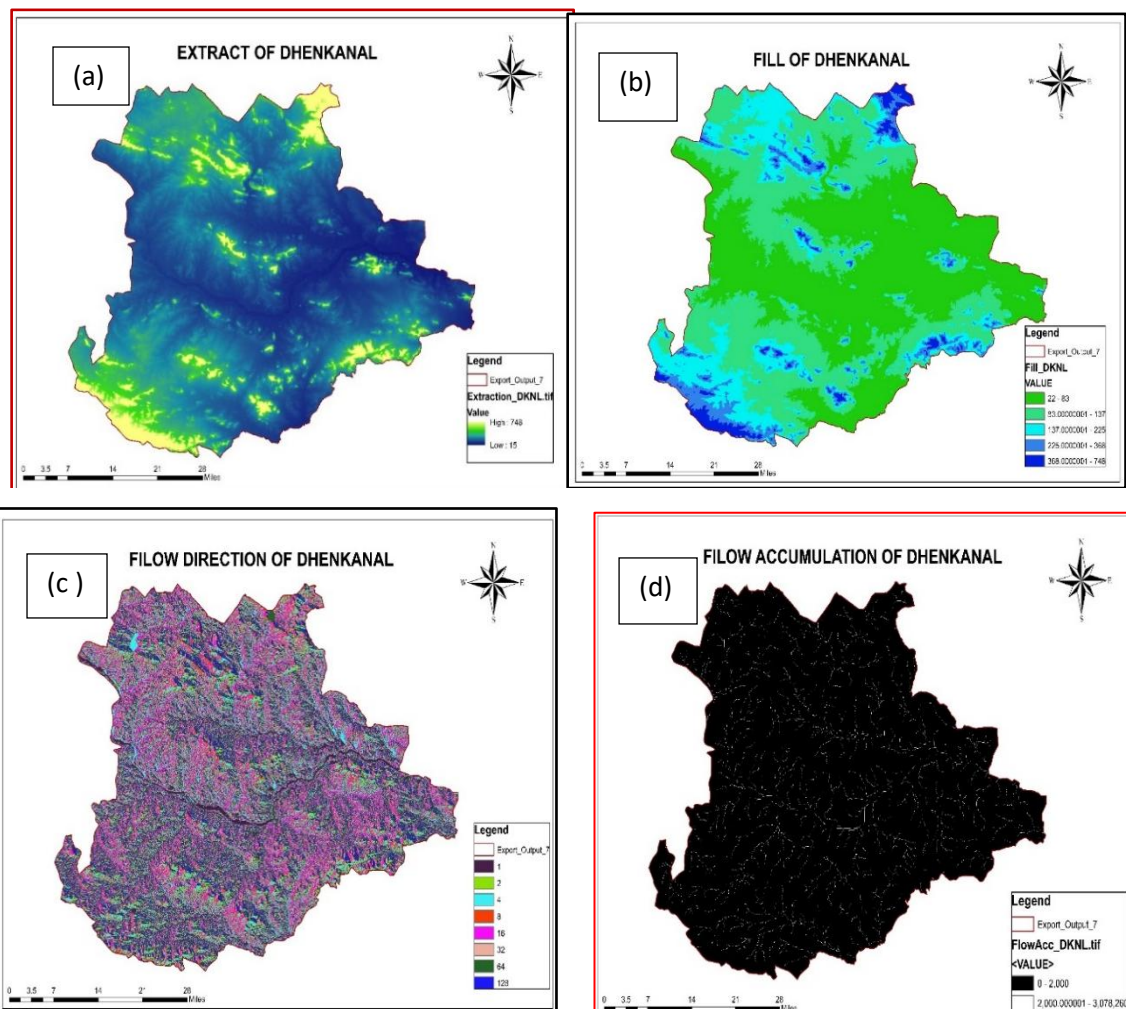


Fig. 6(a). Extracted DEM file, Fig 6 (b): Fill the DEM of Dhenkanal, Fig 6(c). Flow direction Fig. 6(d). Flow accumulation of Dhenkanal

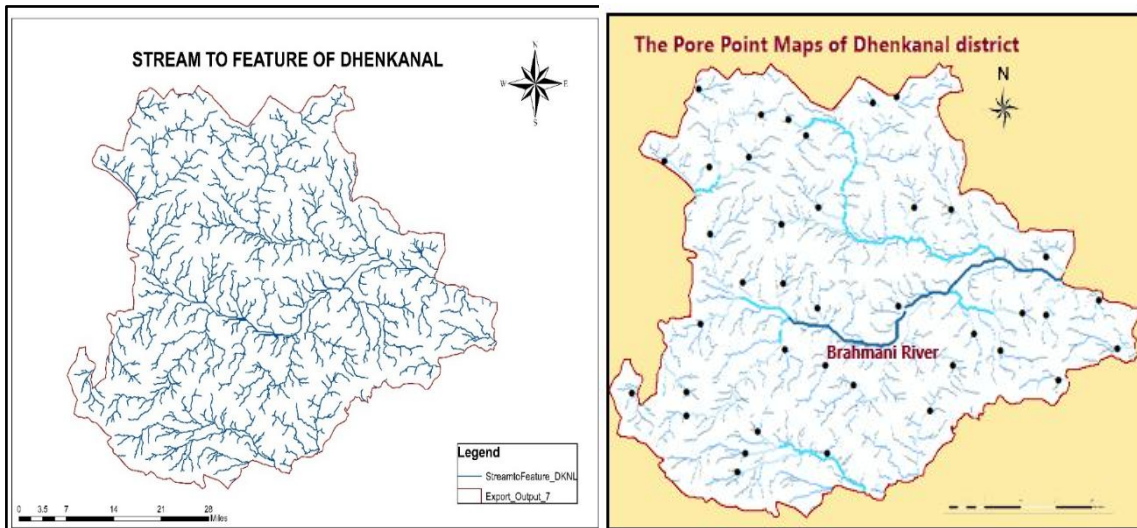


Fig. 7 (a). Stream features and (b) drainage pour points in the Dhenkanal district

2.16 Snap Pour Point and Watershed Tool

Pour points, where water pours out, are points at which water flows out of an area, usually the outlet or re-entrant locations from the flow accumulation. The Snap Pour Point tool snaps these points to the cell of the highest flow accumulation within a specified distance. Cells that have no data (cells with values) are considered pour points.

The basins and the drains formed knowing the pour points by identifying the causative area above the identified pour point. The GIS tool generates a raster outlining all drainage watersheds. By integration, the basin map is obtained by considering the direction of flow as input, Fig. 8 (a, b, c, and d). The basin map indicates that the major basin that controls watershed parameters is the Brahmani basin before the apex at Jenapur and the southern edge shelter partly by the Mahanadi Basin (Fig. 9).

The southern edge is full of hills and forests of Athagarh and Hindol block that shelters large numbers of elephants, tigers, and forest animals. Similarly, the northern fringe of the hills and forests of Kankadahad and Parajang blocks houses a large number of animals like bears, tigers, and many carnivorous animals.

2.17 Creating 2D and 3D Hill Shade Map

The 2D hill shade is shown in grayscale. That represents the terrain surface, washed by the sun's rays with the relative position for shading.

Hill shading is the modus operandi to visualize the terrain washed by the sun as a light source, the aspect of the elevation surface, and the slope. After preparing the hill shade map, the next procedure is to convert the hill shade map from RASTER to TIN to prepare a 3D hill shade map (Fig. 10 (a, b, c, and d).

3D mapping allows using the profile objects in three dimensions. That provides the latest technical methods for visualization and information acquisition. The 3D map provides a realistic view of a location that can utilize by local authorities and planners. The 3D map shows the hill shade in 3D view by using the 3D analysis tool from the Arc toolbox and opens in Arc Scene, which converts the hill shade to a 3d view showing the elevations.

2.18 Slope

The slope signifies the steepness of the slope of the terrain. The lesser the value of the slope, the flatness of the terrain topography. Alternately the larger the value of the slope, the steeper the terrain. The pattern of the slope identifies the gradient type. After preparing a slope map in ArcGIS map the next procedure is to convert the map from raster to tin by using the 3D analysis tool from the ArcGIS toolbox.

2.19 Raster to Tin Conversion

The Triangular irregular network (TIN) converts the raster surface for use in surface modeling or simplifying the surface model for visualization. The Raster to TIN geoprocessing tool is used to

create a TIN map with a specified z-tolerance. In the present case, the hilly terrains and mountains are seen in the northern and southern parts of

the district. The TIN specifies the Brahmani River is the river flowing from SW to dipping down and moving northeast towards Jenapur.

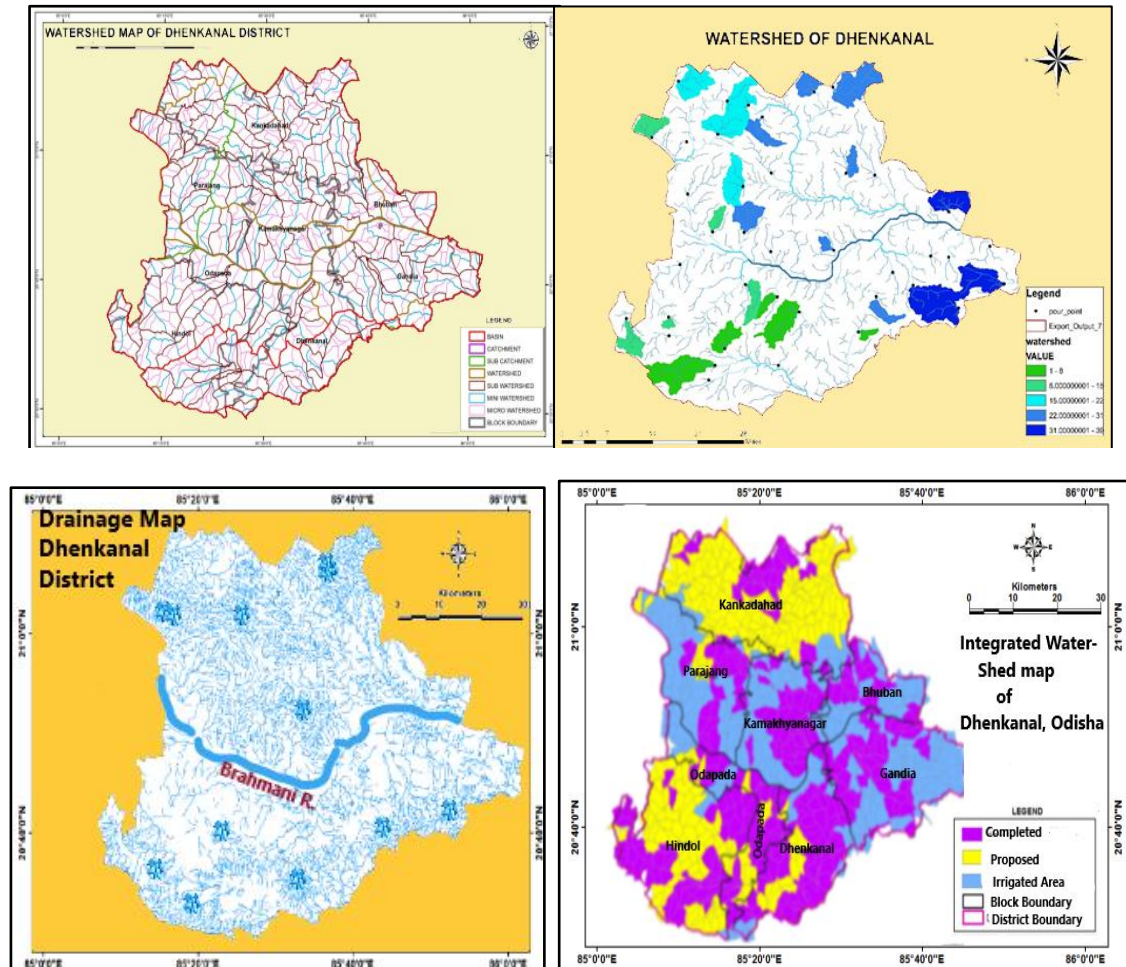


Fig. 8. (a) Watershed Map (b) feasibility for development WSM (c) Drainage map (d) the GoO's watershed map of the Dhenkanal district
(Source: WR DeptGoO)



Fig. 9. The Basins housed in the Dhenkanal district

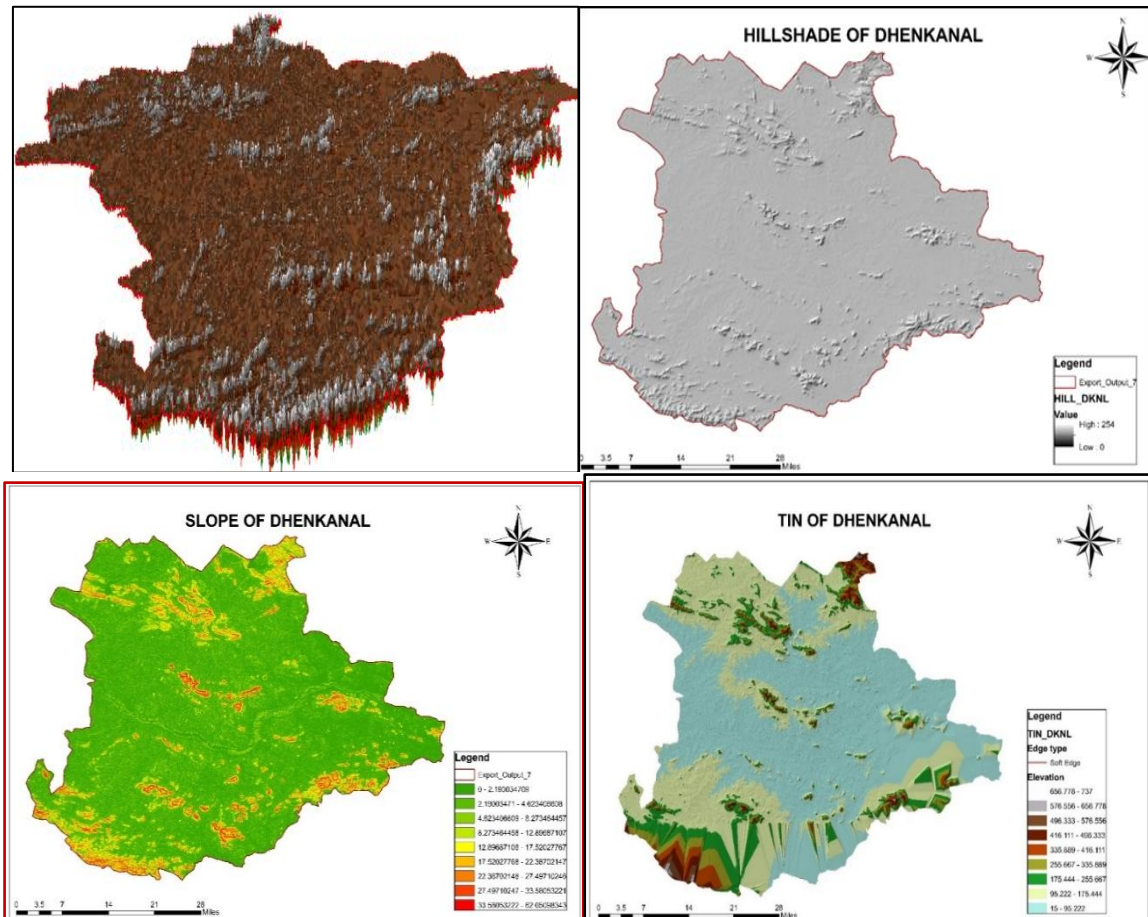


Fig. 10 (a and b) The 2D, and 3D Hill shade Map; Fig. 8 (c&d): The slope map and the TIN map of the district Dhenkanal

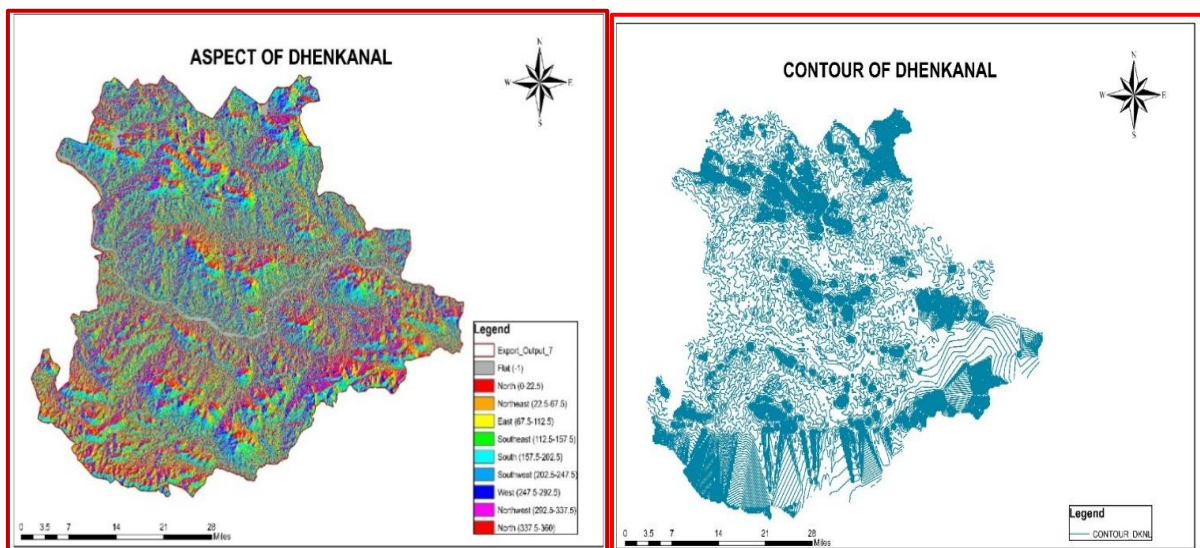


Fig. 11. (Left) Aspect Map; (Right) the contour map of Dhenkanal District Odisha

2.20 Aspect

The aspect is the slope direction that recognizes the downslope bearing of the determined rate of modification in comparison to adjacent neighbors and their location. It is measured clockwise in degrees from 0 (north), 90° (east), 180° (south), and 270° (west). Flat areas have no downslope direction (value taken as -1).

The Aspect map, in the present case most of the direction the downhill slope faces shows towards the mid of the basin of the Brahmani River (Fig. 11 left & right).

2.21 Contour

In ArcGIS Pro, the Contour function is available under Raster functions, which is accessible either on the Analysis or the Imagery tab, that creates a feature class of contours from a raster surface. The contour map shown above clearly indicates a flatter towards the delta boundary comprising blocks Bhuban, Gondia, Dhenkanal, and Odapada. Closer contours are found in Kankadahad and Parajang, and they are hilly terrain.

3. RESULTS

From the study, the following results observed are:

- i. The average yearly precipitation of the Dhenkanal is about 143cm. The southwest monsoon provides 75-80% of total rainfall. Discussion.
- ii. In the Stoney areas with hilly terrain and sloppy topography, lion's share of the rainfall contributes towards runoff to the centrally located river the Brahmani.
- iii. The southern and northern peripheral blocks are sloppy and all runoff decants to the river Brahmani over which no water harvesting mega structures are lagging.
- iv. Rainwater harvesting and conservation through water bodies and groundwater recharge are difficult. They need identification, delineation, and prioritization to finalize the integrated watershed plans.
- v. The presence of porous soil, laterite capping, the soil posse's meager moisture retention capacity, and are under heavy runoff. The erosive soil of

the sloppy terrain is poor in recharging GW.

- vi. The GCA, net sown area is 2817Km² and 1863Km². Having a cropping intensity of 153% (both Rabi and Khariff), The forest area is 1927 km² whereas the wasteland is 44.73 km². Hence, a new development in water bodies is hard not to crack.

4. DISCUSSION

Present watershed management and the identification, delineation, and prioritization uses the geographic information system (GIS) as numerous parameters involved in the selection and management process.

Rengali Multipurpose Project (RMP) over the Brahmani River cater 55550 Th cum of maximum design discharge) comprising a dam at Rengali (71m high and 1040m long)and 22km downstream the Samal barrage (530m long) is under operation along with Rengali's right and left irrigation canals. The system has contributed to both the surface and groundwater flow and watershed management of the past rain-fed agriculture of the Dhenkanal district, Fig. 12 (a & B).

The proposed mega lift Irrigation projects are Chhatia (4100Ha) and Saradeipur (4800Ha) proposed for supplementing lift irrigation and OLIC has been financed for 51 LI projects through OLIC in addition to 299 LI projects providing 13.8THa irrigation in 2021, [36], <https://agricoopnic.in/sites/default/files/9.Dhenkanal.pdf> and <https://finance.odisha.gov.in/sites/default/files/2021-05/>. Various approaches need consideration during delineating and prioritizing process. They are in Fig. 13.

1. Micro-watershed management in Hilly areas by water harvesting structures and percolation tanks by recharging shallow aquifers in hills.
2. The local village ponds, check dams and village waterbodies recharge a shallow GWT (3 to 5m) during the post-monsoon period.
3. To reduce conjunctive use of a crop, instead of flooding irrigation apply sprinklers or modern and even agri-voltaic technologies for the best use of surface and groundwater to ensure irrigation facility.

4. To increase urban water supply need to be from nearby perineal sources like rive-constructing infiltration galleries or collector wells need construction in suitable locations to harness the GW or base flow.
 5. Effluent treatment plants should be mandatory to minimalize water pollution in industrial areas as fluoride, and heavy metals (Pb, Mn, and Fe, As) are identified in some areas both in soil and water in the last few decades.
 6. Participatory Irrigation management through Water user associations can augment the quantity of irrigation area.
- Proper and sustainable watershed management (WSM), is a complex relationship between land, water, climate, and people triggered by the delineation, and prioritization of the watershed type, hydrology, and forest cover of the area. The optimization of the efficiency of water use and vegetation conservation can renovate, stabilize, and rehabilitate a deteriorated watershed.

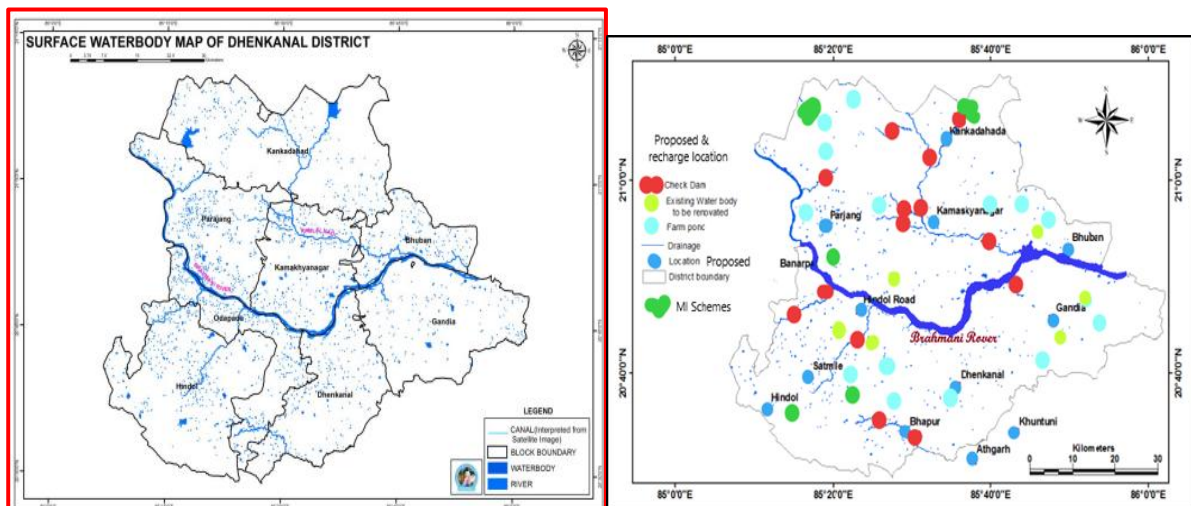


Fig. 12. (a) The existing waterbodies, (b) proposed and recharge points in Dhenkanal district 2022

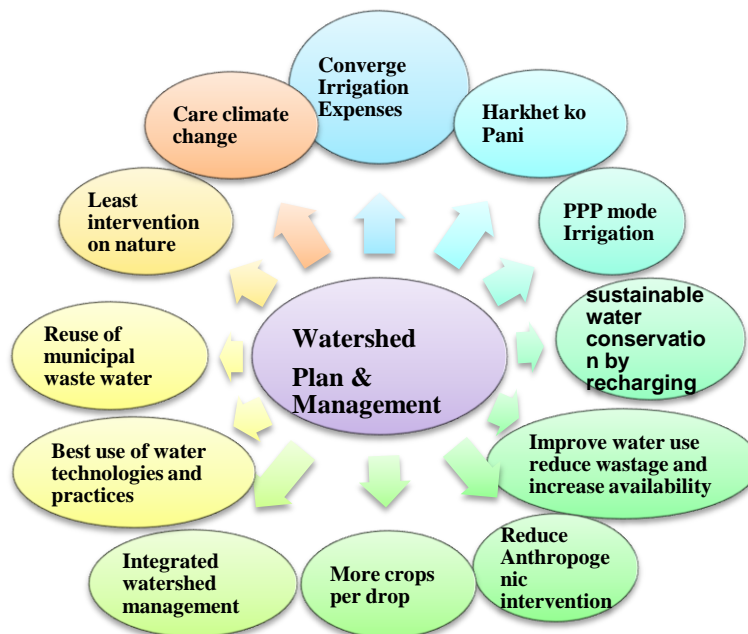


Fig. 13. Major Watershed Management Strategies and Approaches

The downstream of the watershed warrants peatland, fallow and swampy area, management of forest cover, mangroves, Socio-Economic Paybacks, and Participatory irrigation and WSM. The government initiations, continuous monitoring, and evaluation systems and the lacuna need sorting through Public private participatory mode.

5. CONCLUSION

The southern and the northern fringe of the district having blocks Kankadahad, Parajang, Hindol, and Dhenkanal Saddar is covered by hills and forests. These blocks are dwelled by poor and aboriginal communities without modern amenities, roads, education, health care, proper sanitation, and drinking water. There is the possibility of micro watersheds and ponds that provides water during the rainy season. It is high time to take care of energy, soil, water, and biomass of the study area by rejuvenating Watersheds for Agricultural Resilience through Innovative Development to cater to needs like food, water, and soil for the Dhenkanal district.

There could be multiple watersheds within a larger watershed. The hydrology toolset of ArcGIS can play a vital role in the management geo-hydro-bio sector in the environment. The hydrology tool set has multifaceted applications in assessing stream flow, floodplain management, and monitoring geologic hazards due to flooding events.

Presently the district Dhenkanal has cropped area of 281668 ha and the av. cropping intensity is 151%. WSM can assure by stabilizing irrigation from natural resources in the extreme northern and southern hills that separate the left and right basin boundaries of the Brahmani basin. The optimal increasing water potential is possible by stabilization of swamps, defunct water, promoting soil conservation, water harvesting structures, secondary and micro storage, old village ponds, and GW recharging in the district. Since the central region is providing irrigation through Rengali's left and right canals, the watershed management should focus on the basin ridge line in the Kankadahad and Hindola blocks of Dhenkanal.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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