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

Abstract: The watersheds of the Dhenkanal district of Odisha, India with the centrally flowing, river Brahmani identified and explored. Thewatersheds 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.

TheArc 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 pollutedby 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 newconstruction of waterbodies can cater to and carefor 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, FarmPond, Geographical Information System, Morphometry, delineation of Watershed.

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 waterbodies, 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 elementaryinland resources such as soil, water, and plants. The ecology and environmentof the watershed must attainspecific 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 7500km of coastline with about 3% of mangroves. Indiasustains 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 (Mishra, 2017[1], Van bal et al, 2023[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 30years. 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)

Study area

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

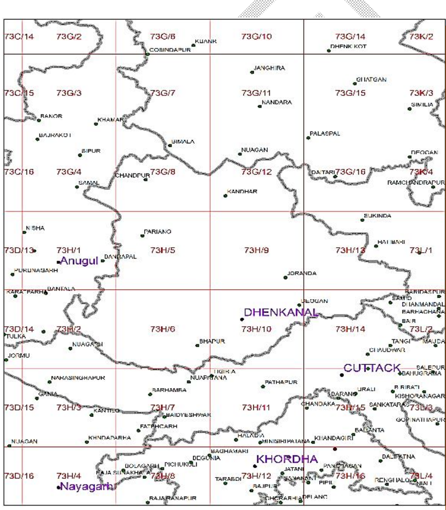


Fig 1: The Topo-sheets Catalog and Index map of the Dhenkanal district, Odisha, India(Source: modified: Mahalik et al, 2015[3])

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, (Dash et al, 2018[4], Naik et al, 2022[5]) (Fig 1).

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 threats human health and security, **(**Whiteman et al, 2006[6], Bunch et al., 2011[7], Sharifi et al., 2023[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, Rajaeinet al, 2021[9]). Submission of Integrated Watershed Management (IWSM) Curtails the Land Use (LU) alteration Influences, (Sharifi et al, 2023[10]). Proper enactment of IWSM is a good indicator of public health in remote and tribal areas, (Nerkar et al., 2013[11], Herrera et al 2017[12], Mishra et al, 2022[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), (Shrestha et al, 2016[14], Anil et al, 2021[15], Gene et al., 2022[16]). Land use and land cover changes are interrelated with watershed development, soil erosion, quality of water, vegetation, and yield of the area (Umawali et al., 2021[17], Usman et al., 2023[18]).

IWSMProgramme 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, identifyingthe drawbacks, capacity-building strategies, and suggestingprecisions, (Hanumantha Rao Committee, 1994[19], Pandey et al., 2023[20]). Investigation throughMorphometry of an ungauged watershed, its prioritization, and delineation is usually done for the expansion of the district hydrological model using GIS/RS, (Chandiha et al 2017[21], Sharma et al., 2020[22], Mishra et al, 2022,[23]Sekhar PR,et al., 2022[24], Pandey et al, 2023[20]). In a multifaceted watershed, the groundwater (GW) should not be neglected. They must be planned by using GIS and AHP techniques based onthe delineation of the groundwater potential zones, (Arubalaji et al., 2019[25], Mirchooli et al., 2021[26]). IWSM a part ofthe Sustainable development goal (SDG - 6) and climate change impact takes care of the various watersheds for its stakeholder's health, (Narendra et al., 2021[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, (Mishra et al 2022[28]).

The review of the past works reveals that the watershed sector in the basin-wise division, the macroscale, andthe 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.

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 smoothened by people's participation through the PPP (Public-Private Partnership) mode added with an integrated approach with regular monitoring of the concurrent development.

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

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. TheGIS, 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 theirapplicability, (**Table 2.)**

Table 2: The attribute information and remote sensing applications using GIS/RS in Watersheds (IIRS activities) (Dr. YVN Krishna Murty[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 run-off; soil erosion in the USLE or RUSSLE 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; Riguosity coefficient	Geomorosis maps
Delineation & prioritisation	Rainfall, runoff, wind, soil, slope, vegetation; geomorphology; usual practices; Quantity. method – USLE/ RUSSLE;Qual. method - Sediment Yield Index using Runoff Rate, Vegetation Status;Socio-economic conditions	Calculation NDVI, SBI, PC; Sediment Yield index

Demography: The demographic growth of the district is very fast (From 300thousand 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 Km^2 area with an inhabitants density of 268per/km^2, www.indiacensus.net/states/orissa/density, (Fig 2: a & b).

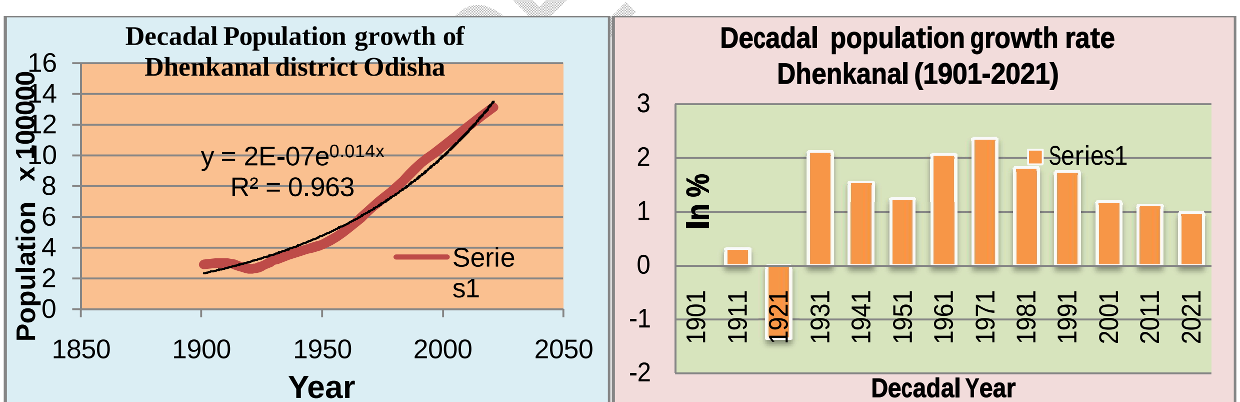


Fig 2: (a) The decadal population change and (b) % of the growth rate of Dhenkanal District Odisha (1901-2021); Source data: https://www.census2011.co.in/census/district/407-dhenkanal.html

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**.

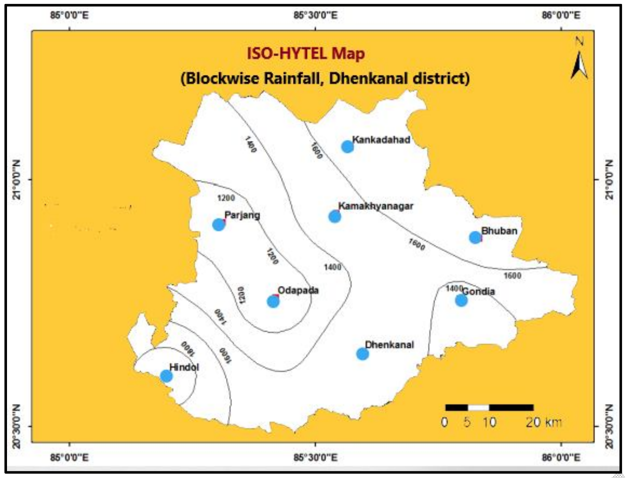


Fig 3: Blockwise Isohytel map of Dhenkanal district, Odisha
(Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Odisha/DHENKANAL)

The average temperature ranges from as high as about 38.6^{0} c in summer to as low as about 9.6^{0}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]).

Geology: The Moula-Bhanja Mountainsranges are in the Dhenkanal district. The mountainous rangehasunderlain by the Precambrian rocks of granite, granite gneiss, andKhondalite. 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 (Kamakhyanagar part), Central Undulating Plain (part of Parajang block), and Northern Mountainous Region (Kankadahad (part), Bhuban and Kamakhyanagar 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

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**).

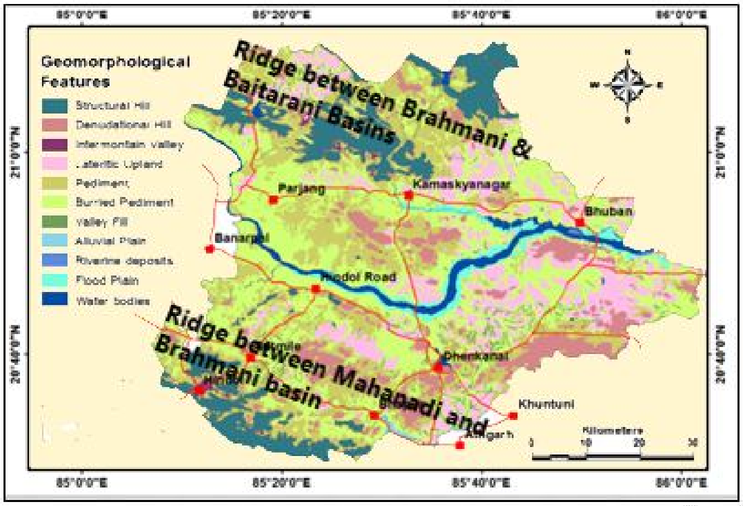


Fig 4: The geomorphology of the Dhenkanal area FY 2022 (Source: CGWB modified)

The eastern valley and plains area 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 needsto 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.

River/Drainage System

The river Brahmaniflows (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 drainslike *Dadaraghati, Sapua, and Ramial*, the medium irrigation projectsof Dhenkanal.

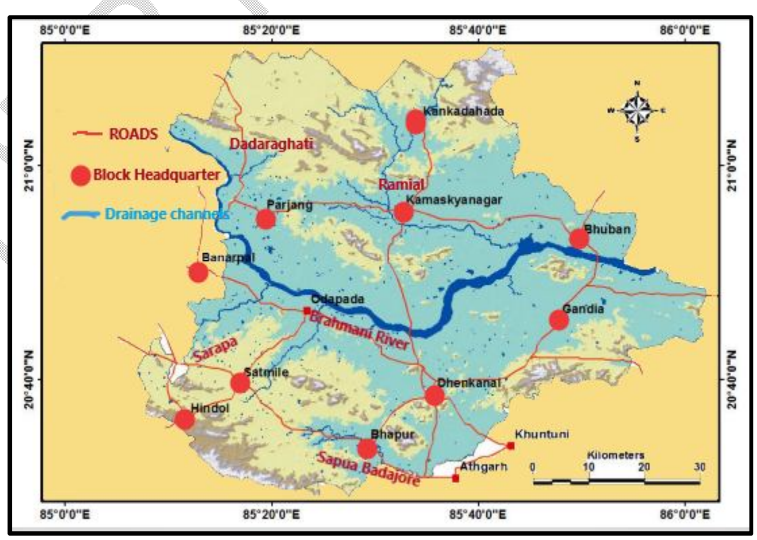


Fig 5a: The drainage map of the Dhenkanal district (Source: CGWB modified)

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 (Sahoo et al, 2018[31]) (**Fig 5a).**

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 **4473**Ha only (DD agriculture Dhenkanal[32])

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 asubstituteretrievalis possible through Paper Mill waste generated at Chaudwar @ one to two MT/Ha, as proposed by (Mishra et al, 2014[33]).

Agriculture

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

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

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.

Irrigation:

Agriculture in Dhenkanal in Odisha was mostly rain-fed untilthe 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 85871hectares (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 potentialcreated 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 canalsareon the verge of completion that will irrigate the Dhenkanal Sadar, Gondia, and Parjang blocks.

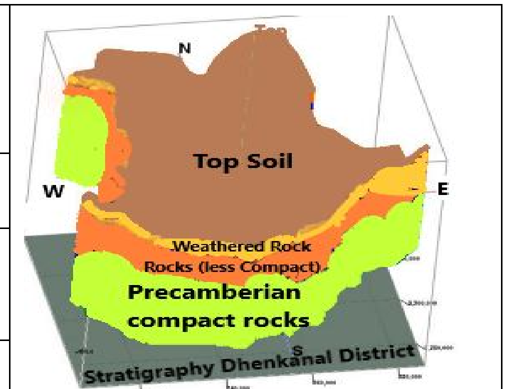
Groundwater:

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 riversystem 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) hasa 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 hasreplenishable groundwater(GW) resources of 44264 Ha m, whereasthe GW draft for use is 2745 Ha m. As per CGWB, the quality of GW, (both shallow and deep) aquifersis 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, (Panigrahi et al, 2017[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[GoO, Aquifer handbook 2022, [34]].

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	

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 (Mishra et al, 2022[35]). The alternative to reservoir sources and plenty of availability of coal, several coal-based thermalpower 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 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 througha 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 2021-2022andtargeted to generate 4.56 million INR, https: //wdc pmksy.dolr.gov.in/blsrptproj?

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 bordereddistricts 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.

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.

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 watershedsin various WSs isthe largest to the mini watershed as per IIRS, India. They are; Regions (1500-12000 Th Km^2); Basins (300 to 3000 Th Km2) ; Catchment (10 to 5.0 Th Km^2); Sub catchment(2000 - 10000 km^2); Watershed (500 - 2000 km^2); Sub-watershed (50 - 500 km^2), Mini Watershed (10 - 50 km^2) and Micro watershed of area (5 – 10km^2), https://www.iirs.gov.in/ iirs/sites/ default/files/pdf/Watershed_Director_IIRS.pdf,

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., (Mishra et al, 2017[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 (Mishra et al, 2017[36]).

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 shapefile.

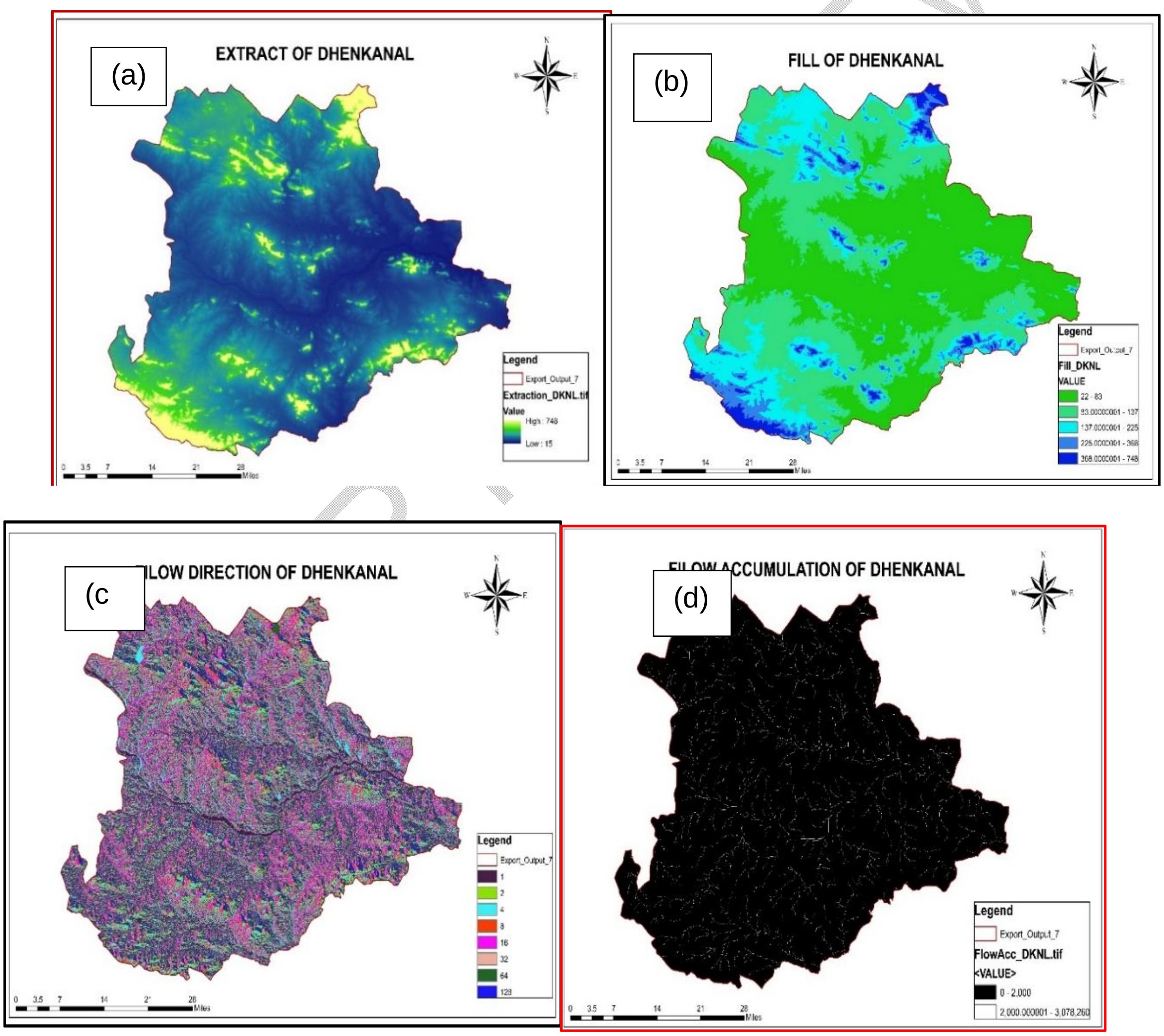


Fig 6(a): Extracted DEM file Fig 6 (b): Fill the DEM of DhenkanalFig 6(c): Flow direction Fig 6(d): Flow accumulation of Dhenkanal

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 6 (a, b, c, d**.).

Stream Feature:

The Stream Feature is vectorizing of stream networks, or other raster signifyingknown 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)).

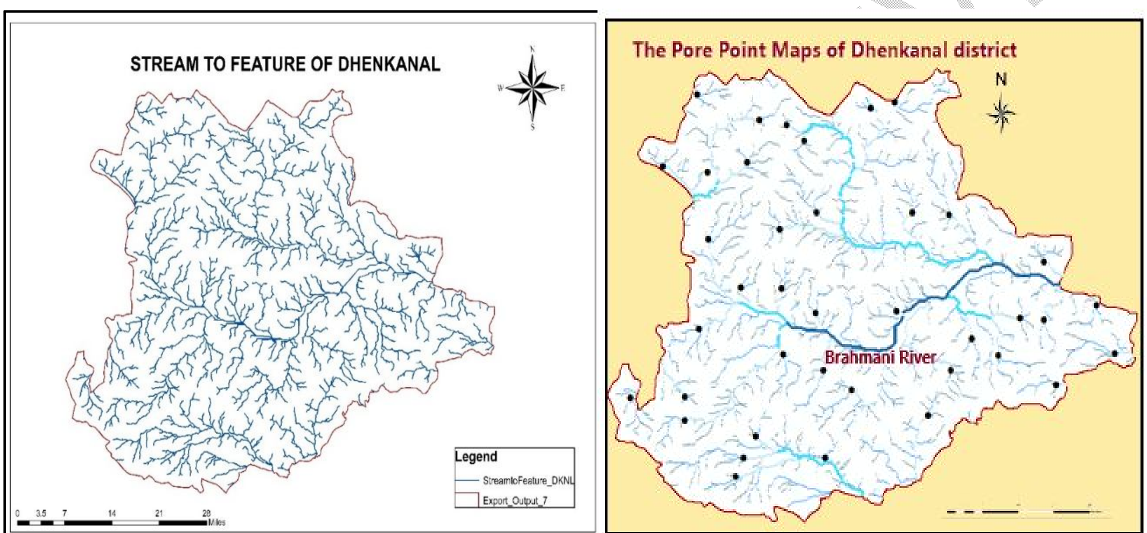


Fig 7 (a). Stream features and (b) drainage pour points in the Dhenkanal district

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 drainsformed 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.

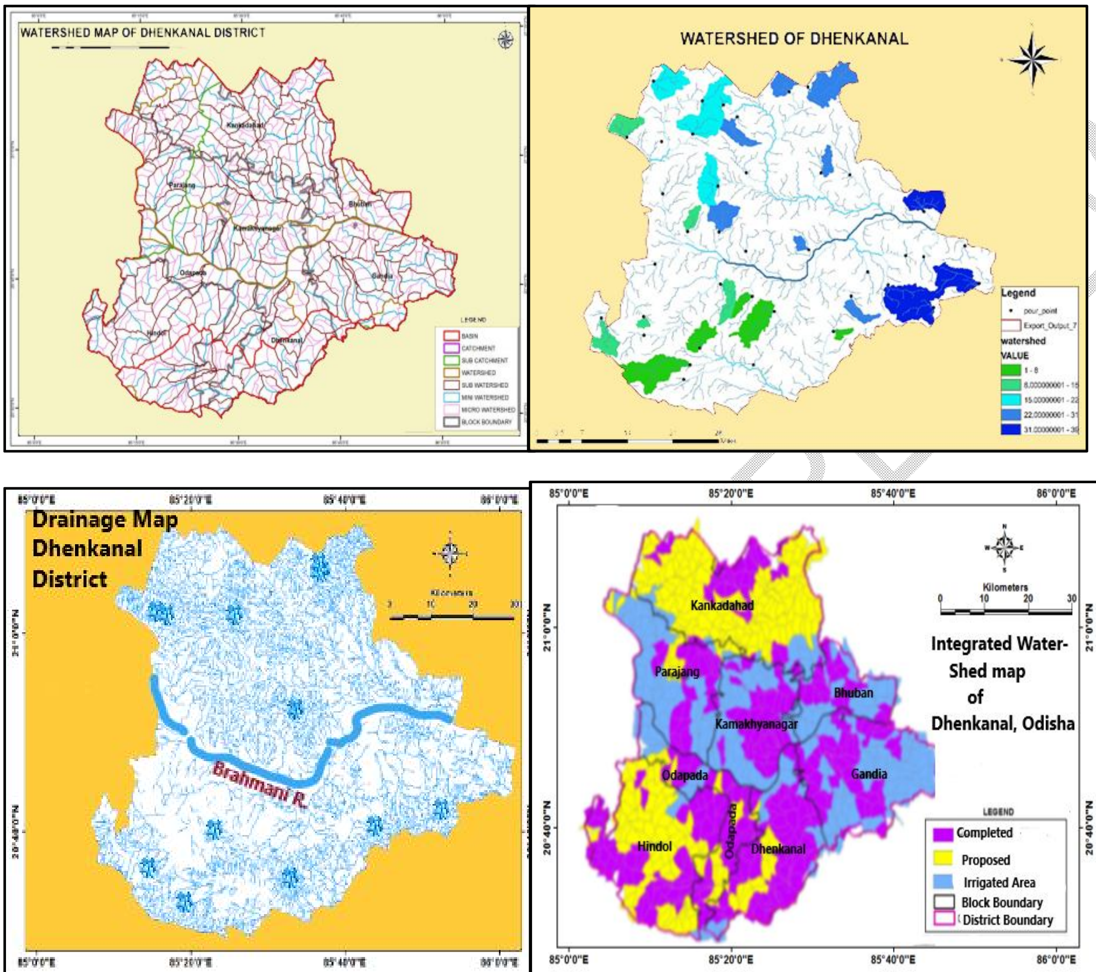


Fig 8. (a) Watershed Map (b) feasibility for development WSM (c) Drainage map (d) the GoO's watershed map of the Dhenkanal district (Source: WR DeptGoO)

Fig 9. The Basinshoused in the Dhenkanal district

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 themodus operandito visualize the terrain washed by the sun asa 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 ArcScene, whichconverts the hill shade to a 3d view showing the elevations.

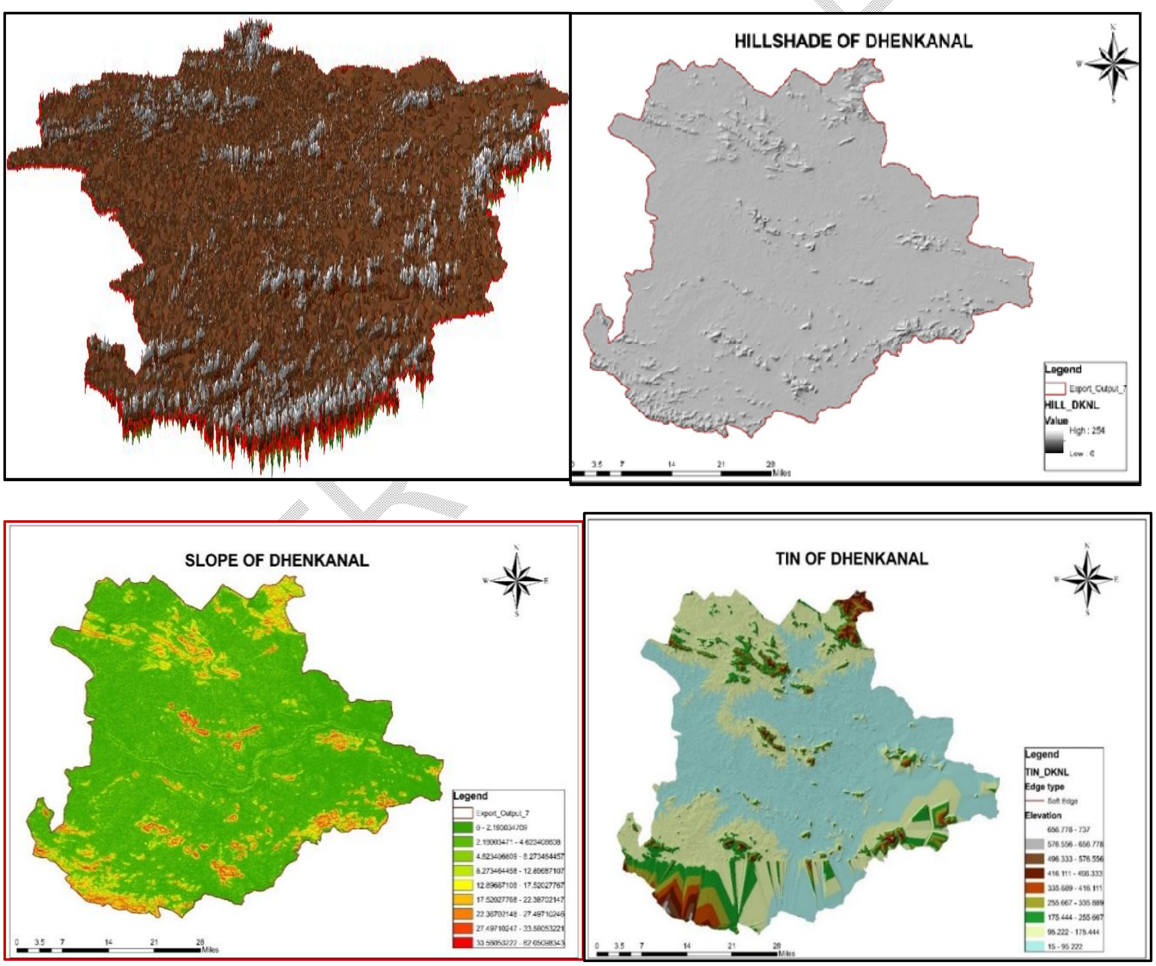


Fig 10 (a and b) The 2D, and 3D Hill shade Map; Fig 8 (c&d): The slope map and the TIN map of the district Dhenkanal

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.

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.

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), 90^0 (east), 180^0 (south), and270^0 (west). Flat areas have no downslope direction (value taken as -1).

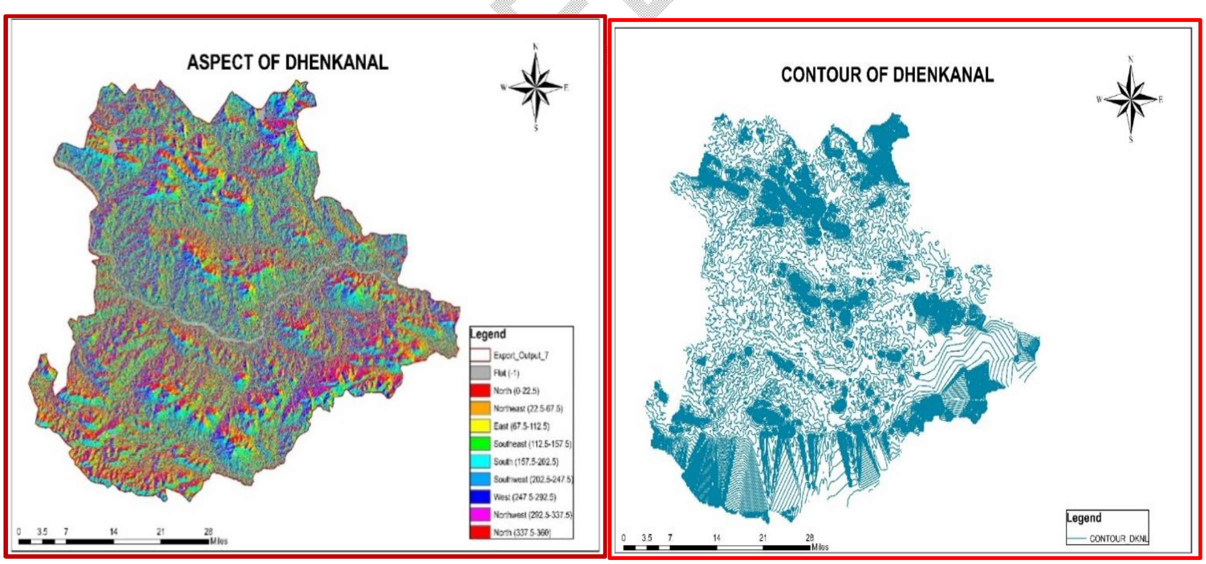


Fig 11.(Left) Aspect Map; (Right) the contour mapof Dhenkanal District Odisha

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).

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 indicatesa 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.

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 2817Km^2 and 1863Km^2. Having a cropping intensity of 153% (both Rabi and Khariff), The forest area is 1927 km^2 whereas the wasteland is 44.73 km^2.Hence,a new development in water bodies is hard not to crack.

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).**

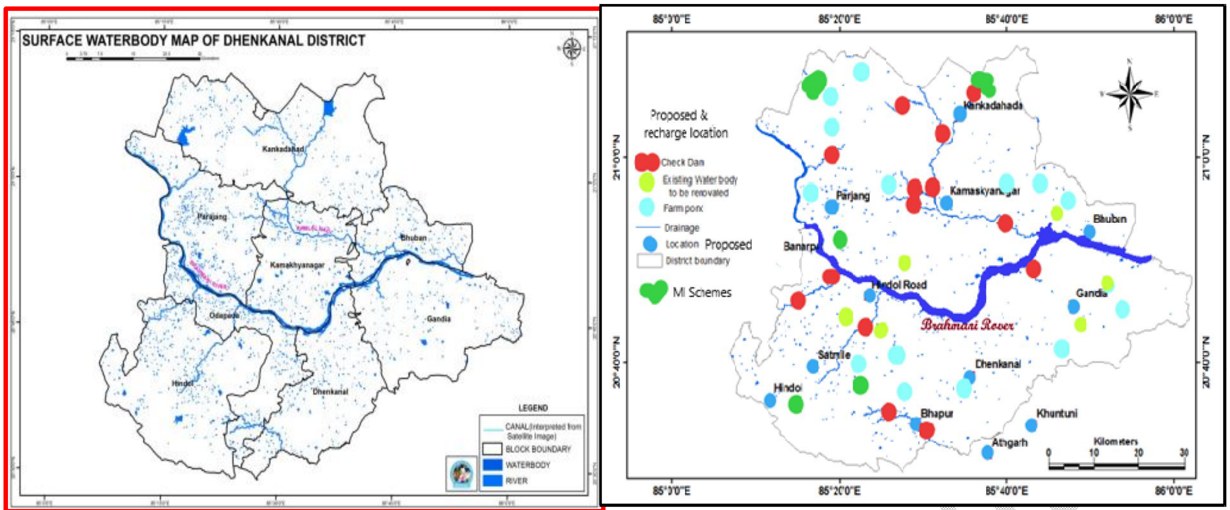


Fig 12 : (a) The existing waterbodies, (b) proposed and recharge points in Dhenkanal district 2022

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, (GoO 2023[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 increaseurban 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.

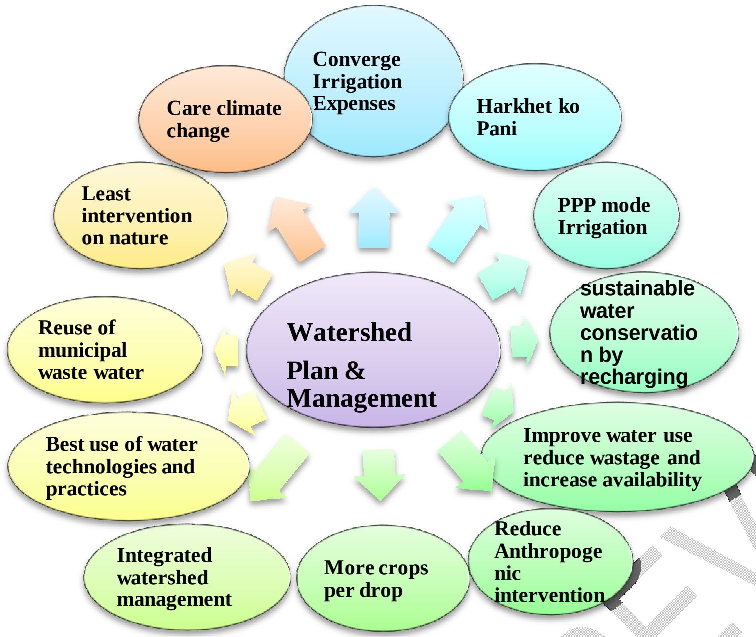


Fig 13: Major Watershed Management Strategies and Approaches

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. 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.

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 playa 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.

Reference:

1. Mishra S. P., 2017, The apocalyptic Anthropocene epoch and its management in India, Int. Jour. Adv. Research, Vol. 5(3), pp. 645-663; DOI: 10.21474/IJAR01/3555
2. van Baal K, Stiel S, Schulte P. Public Perceptions of Climate Change and Health-A Cross-Sectional Survey Study. Int J Environ Res Public Health. 2023 Jan 13;20(2):1464. doi 10.3390/ijerph20021464
3. Mahalik G, Sahoo S., Satapathy KB., 2015, Ethnobotanical Survey of Plants used in Treatment of Urinarydisorders in Dhenkanal district of Odisha, India, IOSR Journal of Environmental Science, Toxicology and Food Technology,9(8), 58-63
4. Dash, PK., Mishra, A., Saren, S., Revathi, B., Sethy, SK. Preparation of GPS and GIS-based soil fertility maps and identification of soil-related crop production constraints of RRTTS and KVK farm, Dhenkanal located in the mid-central table land agro-climatic zone of Odisha, India. Int J Chem Stud, 2018; 6(5):934-943
5. Naik, M.R., Barik, M., Prasad, K.V. et al. Hydro-geochemical analysis based on entropy and geostatistics model for delineation of anthropogenic groundwater pollution for health risks assessment of Dhenkanal district, India. Ecotoxicology 31, 549–564 (2022). https://doi.org/10.1007/s10646-021-02442-1
6. Whitman, RL., Nevers, M.B., Byappanahalli MN.,2006. Examination of the watershed-wide distribution of Escherichia coli along southern Lake Michigan: an Integrated Approach. Applied and env. microbiology, ASM Journal, 72(11), DOI: https://doi.org/10.1128/AEM.00454-06
7. Bunch, MJ. Morrison, KE, Parkes, MW, Venema, HD., (2011). Promoting Health and Well-Being by Managing for socio–Ecological Resilience: the Potential of Integrating Eco-Health and Water Resources Management Approaches. Ecology and Society 16(1): 6. 2014, Environmental Management 54(2), DOI: 10.1007/s00267-014-0301-3
8. Sharifi ME, Sadeghi SH, Zarghami M, Delavar M., Developing sustainable land-use patterns at watershed scale using nexus of soil, water, energy, and food. Sci Total Environ. 2023 Jan 15;856(Pt 1):158935. doi: 10.1016/j.scitotenv.2022.158935.
9. Rajaei F, Dahmardeh Behrooz R, Ahmadisharaf E, Galalizadeh S, Dudic B, Spalevic V, Novicevic R. Application of Integrated Watershed Management Measures to Minimize

the Land Use Change Impacts. Water. 2021; 13(15):2039. https://doi.org/10.3390/w13152039

10. Sharifi ME, Sadeghi SH, Zarghami M, Delavar M. Developing sustainable land-use patterns at watershed scale using nexus of soil, water, energy, and food. Sci Total Environ. 2023 Jan 15;856(Pt 1):158935. doi: 10.1016/j.scitotenv.2022.158935.
11. Nerkar, S.S., Tamhankar, A.J., Johansson, E. et al. Improvement in health and empowerment of families as a result of watershed management in a tribal area in India - a qualitative study. BMC Int Health Hum Rights 13, 42 (2013). https://doi.org/10.1186/1472-698X-13-42
12. Herrera, D., Ellis, A., Fisher, B. et al. Upstream watershed condition predicts rural children's health across 35 developing countries. Nat Commun 8, 811 (2017). https://doi.org/10.1038/s41467-017-00775-2
13. Mishra SP., Patel, A., Mishra, A. Chandan Ku., (2022). Geomorphologic Change in Nagavali River Basin: Geospatial Approach, Int. J. of Environment and Climate Change 11(12):235-250, DOI: 10.9734/IJECC/2021/v11i1230574
14. Shrestha, F., Uddin, K,. Maharjan, SB., Bajracharya, SR.,. Application of remote sensing and GIS in environmental monitoring in the Hindu Kush Himalayan region. AIMS Environmental Science, 2016, 3(4): 646-662. doi: 10.3934/environsci.2016.4.646F
15. Anil, S.S., Arun Das, S. Ascertaining Erosion Potential of Watersheds using Morphometric and Fuzzy-Analytical Hierarchy Processes: A Case Study of Agrani River Watershed, India. J Geol Soc India 97, 951–958 (2021). https://doi.org/10.1007/s12594-021-1796-x
16. Gene T. Señeris. Nabaoy River Watershed potential impact to flooding using Geographic Information System remote sensing. AIMS Environmental Science, 2022, 9(3): 381-402. doi: 10.3934/environsci.2022024
17. Umwali ED, Kurban A, Isabwe A, Mind'je R, Azadi H, Guo Z, Udahogora M, Nyirarwasa A, Umuhoza J, Nzabarinda V, Gasirabo A, Sabirhazi G. Spatio-seasonal variation of water quality influenced by land use and land cover in Lake Muhazi. Sci Rep. 2021 Aug 30;11(1):17376. doi 10.1038/s41598-021-96633-9.
18. Usman K, Deribew KT, Alemu G, Hailu S. Spatial modeling of soil loss as a response to the land use land cover change in Didessa sub-basin, the agricultural watershed of Ethiopia. Heliyon. 2023 Mar 13;9(3):e14590. doi: 10.1016/j.heliyon.2023.e14590.
19. Hanumantha Rao Committee, A report of the Committee appointed for the review of rural development programs in India, GoI, 1994, p. 65; https://dolr.gov.in/sites/ default/ files/TechCommitteeReport1994.pdf
20. Pandey, A., Gupta, R.K., Gupta, R.K., Kumar S., Morphometric delineation of administrative boundaries and classification of threatened categories of small watersheds in transboundary rivers. Sci Rep 13, 1652 (2023). https://doi.org/10.1038/s41598-023-28913-5

21. Chandniha, S.K., Kansal, M.L. Prioritization of sub-watersheds based on morphometric analysis using the geospatial technique in Piperiya watershed, India. Appl Water Sci 7, 329–338 (2017). https://doi.org/10.1007/s13201-014-0248-9
22. Sharma, S., Mahajan, A.K. GIS-based sub-watershed prioritization through morphometric analysis in the outer Himalayan region of India. Appl Water Sci 10, 163 (2020). https://doi.org/10.1007/s13201-020-01243-x
23. Mishra SP., Mishra, A., Chandan Ku., Mishra, S., (2022), Sedimentation in East Coast Hilly Terrain Reservoirs; Balimela, Odisha., International Journal of Environment and Climate Change; 12(5): 15-30, 2022; DOI: 10.9734/IJECC/2022/v12i530670
24. Shekar, P.R., Mathew, A. Morphometric analysis for prioritizing sub-watersheds of Murredu River basin, Telangana State, India, using a geographical information system. J. Eng. Appl. Sci. 69, 44 (2022). https://doi.org/10.1186/s44147-022-00094-4
25. Arulbalaji, P., Padmalal, D. & Sreelash, K. GIS and AHP Techniques Based Delineation of Groundwater Potential Zones: a case study from Southern Western Ghats, India. Sci Rep 9, 2082 (2019). https://doi.org/10.1038/s41598-019-38567-x
26. Mirchooli F, Sadeghi SH, Khaledi Darvishan A, Strobl J. Multi-dimensional assessment of watershed condition using a newly developed barometer of sustainability. Sci Total Environ. 2021 Oct 15;791:148389. doi: 10.1016/j.scitotenv.2021.148389.
27. Narendra BH, Siregar CA, Dharmawan IWS, Sukmana A, Pratiwi, Pramono IB, Basuki TM, Nugroho HYSH, Supangat AB, Purwanto, Setiawan O, Nandini R, Ulya NA, Arifanti VB, Yuwati TW. A Review on Sustainability of Watershed Management in Indonesia. Sustainability. 2021; 13(19):11125. https://doi.org/10.3390/su131911125
28. Mishra Siba Prasad, Chandan Kumar, Abhisek Mishra, Sasat Mishra, (2022). Estimation of Sediments in Rengali Reservoir, Odisha (India) Using Remote Sensing, January Int J. of Environment and Climate Change 11(12):205-225, DOI: 10.9734/IJECC/2021/v11i1230572
29. YVN Krishna Murty, Remote sensing & GIS applications in watershed management; iirs, India
30. Government of Odisha: (2022). Agriculture Handbook 2022 of Dhenkanal, The Ministry of Agriculture, Odisha
31. Sahoo, H.B.; Gandre, D.K.; Das, P.K.; Karim, M.A.; Bhuyan, G.C., Geochemical mapping of heavy metals around Sukinda-Bhuban area in Jajpur and Dhenkanal districts of Odisha, India. Environmental Earth Sciences 77(2): 34, 2018, DOI: 10.1007/s12665-017-7208-2
32. O/O the Dist. Agriculture Officer, 2022. Agriculture Contingency Plan for District: Dhenkanal. Deputy Dir. of Agriculture, gricoop.nic.in/sites/default/files/9.Dhenkanal.pdf
33. Mishra, A., Pattnaik, T., Das, D., & Das, M. (2014). Soil Fertility Maps Preparation Using GPS and GIS in Dhenkanal District, Odisha, India. International Journal of Plant & Soil Science, 3(8), 986–994. https://doi.org/10.9734/IJPSS/2014/9325

34. Govt of Odisha, 2022. Report on, aquifer mapping and management plan in Dhenkanal district, Odisha, Ministry of Jal Shakti, Dept of WR, River Development & Ganga Rejuvenation, May 2022.
35. Mishra S. P., 2017, Stochastic Modelling of Flow and Sediment of the Rivers at Delta head, East Coast of India, American Journal of Operation Research, Scientific Research, Vol. 7 (6), PP. 331-347, DOI: 10.4236/ajor.2017.76025
36. Mishra S. P., Das K., 2017, Management of Soil Losses in South Mahanadi Delta, India, International Journal of Earth Sciences and Engineering, 10(02), 222-232, 2017, DOI:10.21276/ijee.2017.10.0213