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Watershed and Dam Analysis Report for Brahmani River

1. Introduction

This report presents the detailed analysis of watershed delineation, dam layout, and land use/land cover (LULC) classification for the Brahmani River basin using QGIS and Google Earth Engine (GEE). The primary objective is to delineate the catchment area of the Brahmani River, analyze the dam location, and classify the LULC types to understand the basin characteristics and estimate hydrological parameters such as area and volume.

Understanding the dynamics of watersheds and the role of dams is crucial in managing water resources, especially in a country like India where agriculture and local livelihoods heavily depend on seasonal rainfall. This report focuses on the Brahmani River Basin, aiming to provide a comprehensive analysis of its watershed using modern GIS tools like QGIS and remote sensing data from Google Earth Engine (GEE). The purpose of this study is to delineate the watershed, assess the land use and land cover (LULC), and evaluate the potential of the existing dam structure for water storage and management.

By combining elevation models, satellite imagery, and spatial analysis tools, we attempt to extract key parameters such as the watershed boundary, drainage patterns, reservoir area, and volume. Additionally, this report serves as a guide to performing similar analyses for other basins and can help policymakers, engineers, and environmental planners in making informed decisions related to irrigation, flood control, and sustainable land development.

2. Study Area Description

• Location: Brahmani River Basin, India
• Latitude: 22.5 – 23.5° N (approx.)
• Longitude: 83.5 - 85° E (approx.)
• Elevation Range: Approximately 90 m to 150m above mean sea level
• Administrative Region: Odisha, India
• Climate: Tropical with a pronounced monsoon season (June to September)

3. Data and Software Used

3.1 Data Sources

• Digital Elevation Model (DEM): SRTM 30m resolution from GEE
• Land Use Land Cover (LULC): Dynamic World Dataset (Google Earth Engine)

3.2 Software and Tools

• QGIS 3.42.1
• Google Earth Engine (GEE) Code Editor
• GRASS Tools
• SAGA Tools for basin analysis

4. Methodology

4.1 Watershed Delineation (QGIS & GRASS Tools)

1. DEM Preprocessing: Imported DEM into QGIS and filled sinks
2. Flow Direction and Accumulation: Computed using GRASS
3. Stream Network and Pour Point: Manually selected pour point near dam location
4. Watershed Boundary Extraction: Generated using r.water.outlet and exported

- Main Drainage Direction: SE → NW

4.2 Dam Layout Mapping

• Imported dam location from satellite imagery
• Marked reservoir extent and dam toe line
• Overlaid on the DEM and LULC layers
• Created vector layout of the dam and storage area

4.3 LULC Classification Using GEE

Used Dynamic World data from GEE to classify:

BUILT-UP(RURAL)
BUILT-UP(URBAN)
Water Bodies
WASTELAND
WETLANDS
Scrubland
TRANSPORT
Industrial Area
AGRICULTURAL LAND
Forest
FALLOW LAND
BARREN LAND
MINING AREA

📌 LULC Distribution (% within basin):

TYPE	CODE	COUNT	SUM	PERCENTAGE
BUILT-UP(RURAL)	112	3	50378.186	0.011
BUILT-UP(URBAN)	111	10	327473.031	0.037
Water Bodies	80	22	2832309.64	0.082
WASTELAND	60	92	1750062.69	0.343
WETLANDS	90	125	1715065.17	0.466
Scrubland	50	208	5938553.09	0.776
TRANSPORT	116	363	4378070.36	1.353
Industrial Area	114	1124	737366962	4.191
AGRICULTURAL LAND	20	2838	86777751.4	10.581
Forest	40	3232	1393406797	12.05
FALLOW LAND	30	3649	78772800.4	13.605
BARREN LAND	126	7358	642518490	27.434
MINING AREA	124	7797	322662610	29.071
TOTAL	**13**	**26821**	**3278497323**	**100**

Steps involved to solve these assignment

Stream and Catchment Delineation in QGIS using SAGA Tools

Prepare the Digital Elevation Model (DEM):

- Import the DEM data into QGIS.
- Ensure the DEM is projected correctly to maintain accuracy in analysis.

Fill Sinks in the DEM:

- Utilize the **'Fill sinks (wang & liu)'** tool from SAGA to remove depressions in the DEM, ensuring proper flow direction calculations.

Calculate Flow Accumulation:

- Apply the **'Flow accumulation (Top Down)'** tool to compute the accumulation of flow for each cell in the DEM.

Generate Stream Network:

- Use the **'Channel network and drainage basins'** tool:

- Set an appropriate threshold value to define the minimum size of the catchment area for stream initiation.
- This process will delineate the stream network and identify drainage basins.

Extract Stream Segments:

- Utilize the **'Vectorising grid classes'** tool to convert the raster stream network into vector format for better visualization and analysis.

Define Catchment Area for a Specific Point:

- Identify the point of interest (e.g., a gauging station or outlet).
- Use the **'Upslope area'** tool to delineate the catchment area upstream of the selected point.

Visualize and Analyze Results:

- Overlay the generated stream network and catchment area on the original DEM.
- Apply appropriate symbology to distinguish between different features for clear interpretation.

Estimate different LULC type percentage present in the delineated watershed.

Step 1: Load Data into QGIS

- Open QGIS.
- Load your **LULC raster layer**.
- Load your **watershed boundary shapefile** (polygon).

Step 2: Clip the LULC Raster by Watershed Boundary

This ensures you only analyze LULC within the watershed.

1. Go to **Raster → Extraction → Clip Raster by Mask Layer**.
2. Input Layer: Select your **LULC raster**.
3. Mask Layer: Select your **watershed boundary**.
4. Choose an output file path.
5. Click **Run**.

Step 3: Convert Clipped Raster to Vector (Optional but useful)

Helps you calculate areas of each class.

1. Go to **Raster → Conversion → Polygonize (Raster to Vector)**.
2. Input Layer: Select your **clipped LULC raster**.
3. Field name: Keep as default (e.g., "DN" or "class").
4. Run the tool. This creates a polygon layer of different LULC classes.

Step 4: Calculate Area for Each LULC Class

1. Open the **Attribute Table** of the polygonized layer.
2. Click on the **Field Calculator** (abacus icon).
3. Create a new field, name it areaM2.
4. Use this expression to calculate area in hectares:

   $area / 10000

5. Click OK.

Step 5: Group and Summarize by LULC Class

1. Go to **Processing → Toolbox → Vector analysis → Statistics by categories**.
2. Input Layer: Polygonized LULC layer.
3. Category Field: The LULC class field (e.g., "DN" or "class").
4. Numeric Field: Select areaM2.
5. Click **Run**.

You'll get a new layer/table showing **total area of each LULC class**.

Step 6: Calculate Percentages

1. Open the statistics result table.
2. Export it to Excel or use **Field Calculator** to compute:

   (area_of_class / total_area) * 100

Now you'll have the **percentage of each LULC class** inside your watershed.

Steps to Calculate Inundated Area and Dam Capacity in QGIS

A. Calculate Inundated Area (Area under water)

1. **Load the DEM** and the **dam reservoir polygon shapefile** in QGIS.

2. Go to **Raster → Extraction → Clip Raster by Mask Layer** to clip the DEM using the reservoir polygon.
3. Use **Raster Calculator** to create a binary raster:

    "clipped_dem@1" <= water_level

(Replace water_level with your actual reservoir water level, e.g., 500)

4. This creates a raster where:
    - Value 1 = submerged area
    - Value 0 = non-submerged area
5. Go to **Raster → Conversion → Polygonize** to convert this raster into a vector layer.
6. Open the attribute table, filter only the polygons where value = 1 (submerged).
7. Use **Field Calculator** to add a new field area:

    $area / 10000

8. Sum all area values → this gives you the **inundated area in m^2**.

B. Calculate Dam Volume (Capacity)

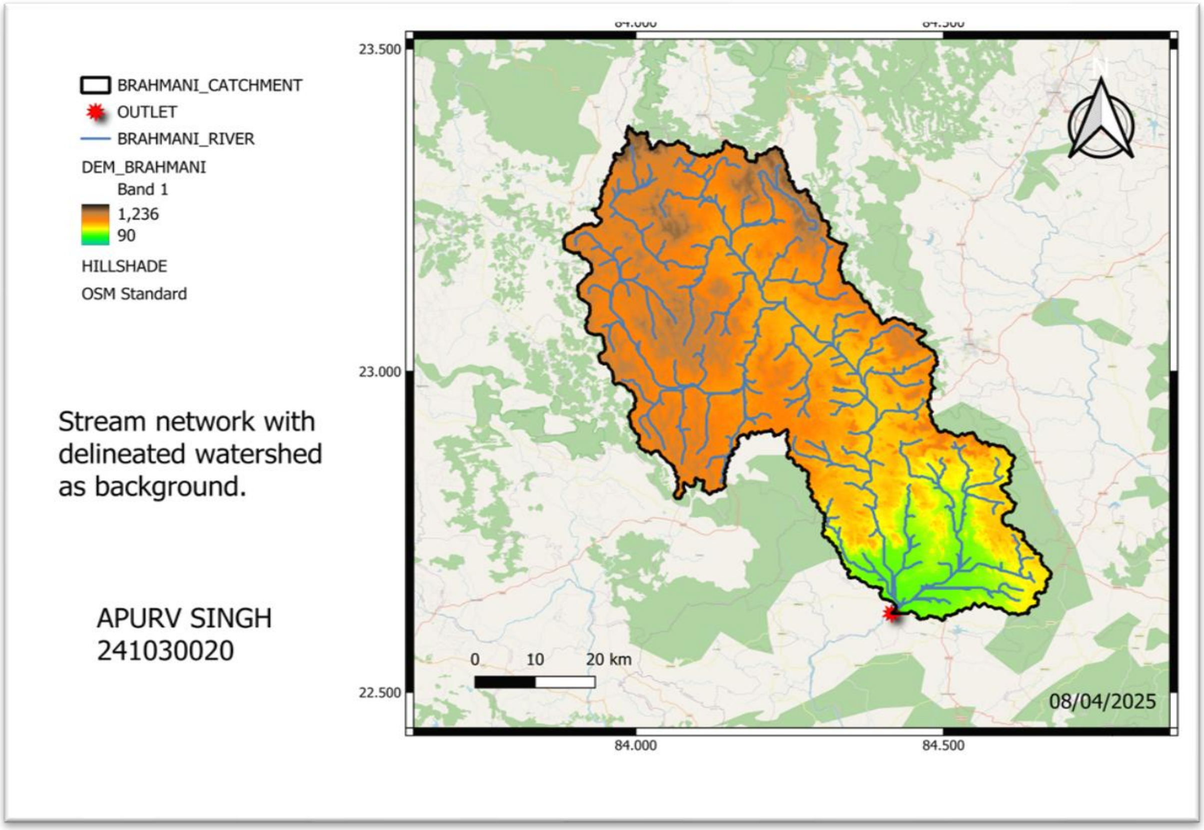
9. Open **Raster Calculator** again, and subtract DEM from water level:
10. Mask this depth raster using the binary (submerged) raster so you only keep submerged values.
11. Multiply this depth raster with **pixel area** to get volume per pixel.
12. Use **Raster → Zonal Statistics** or **Raster layer histogram** to sum all pixel volumes.
13. The total value gives you **volume of the dam in cubic meters (m^3)**.

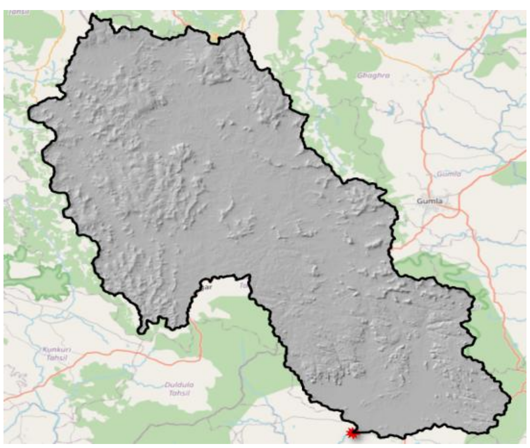
5. Results and Analysis

• The delineated watershed covers, primarily composed of agricultural and forest land.
• The Brahmani Dam is located centrally within the watershed, capturing runoff from upstream.
• LULC analysis reveals significant forest and agricultural land, indicating good water retention.
• Reservoir volume estimated from DEM and elevation-area relationship.
• Useful for irrigation planning, flood control, and watershed management.

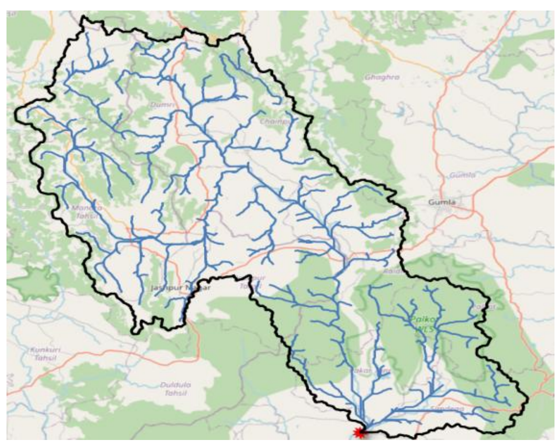
6. Screenshots and Visual Outputs

6.1 Watershed Delineation Map: Refer to 'NEW_BRAHMANI_DELINIATION_PHOTO.png'



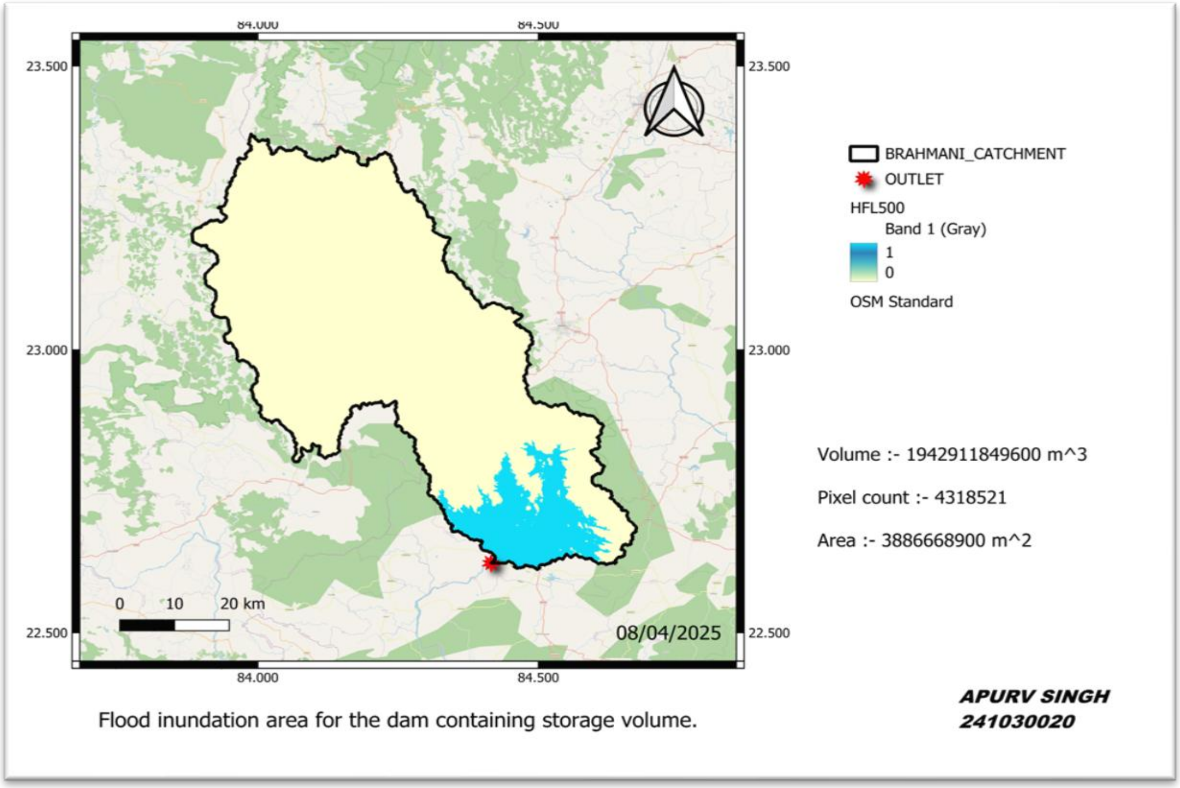


HILLSHADE IMAGE

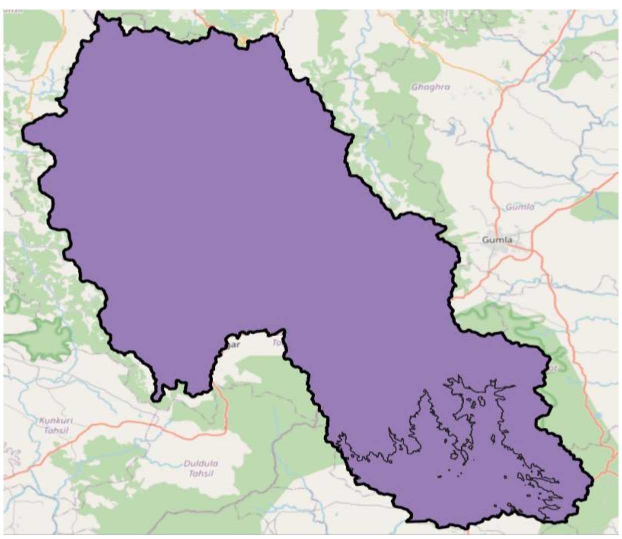


CHANNELS NETWORKS

6.2 Dam Layout Map: Refer to 'BRAHMANI_DAM_LAYOUT_PHOTO.png'

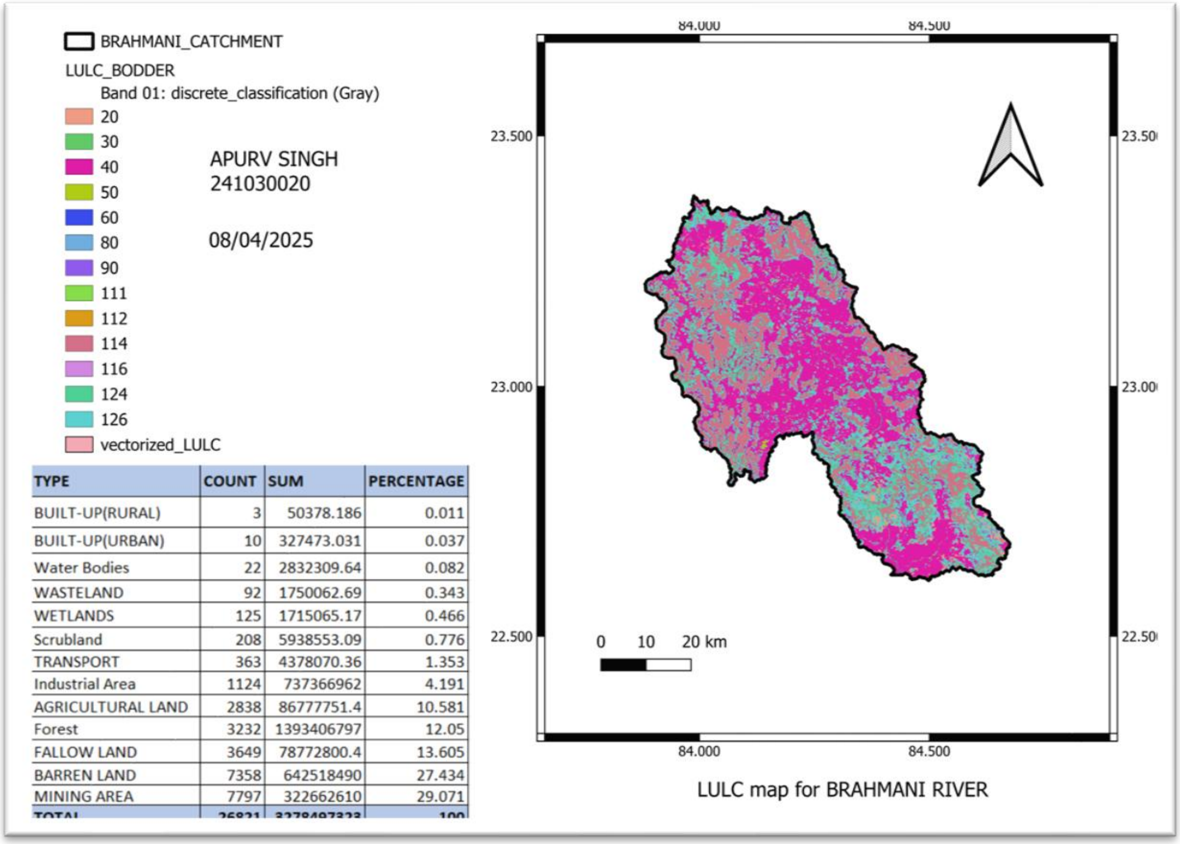


Flood inundation area for the dam containing storage volume.



FLOOD AREA

6.3 LULC Classification Map: Refer to 'NEW_LULC_LAYOUT_BRAHMANI_PHOTO.png'



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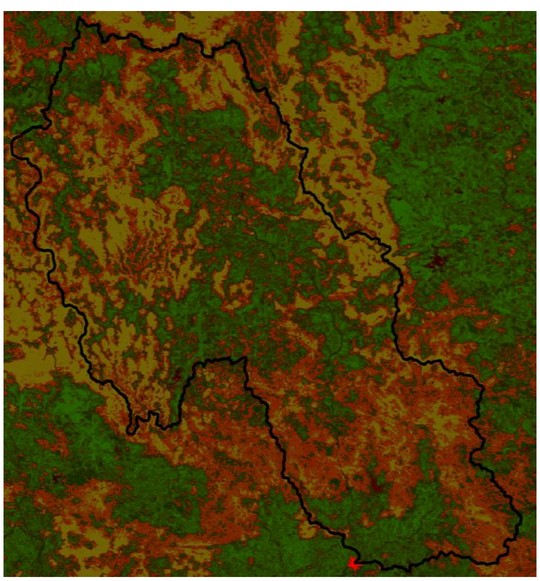
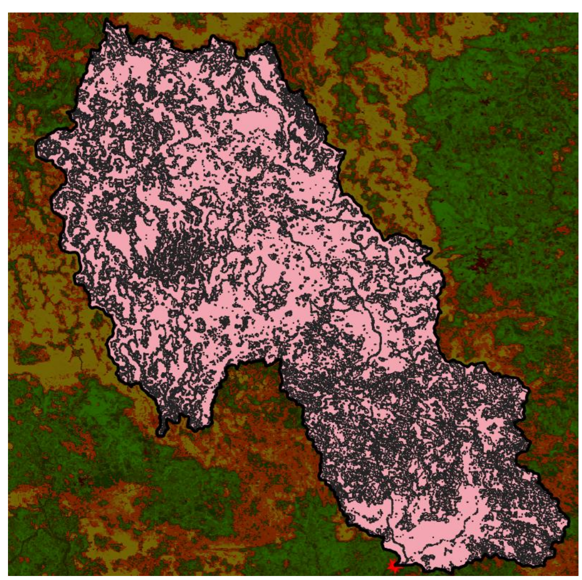


LULC FILE WITH CATCHMENT



LULC FILE MASKED WITH CATCHMENT

Question: *Identify the dominant land cover type and discuss its impact on runoff generation and infiltration.*

Answer (Point-wise):

Dominant Land Cover Type:

- Agricultural land is the most dominant, covering approximately 33.7% of the Brahmani watershed.

- Followed closely by forest land at 31.6%.

Impact on Runoff Generation and Infiltration:

1. Agricultural Land:
    - Moderate to low vegetation cover, especially between crop cycles.
    - Results in increased surface runoff during heavy rainfall.
    - Lower infiltration capacity due to compacted or bare soils.
    - Higher potential for soil erosion and sediment flow into reservoirs.
    - Farming practices (like ploughing direction, slope management) affect runoff rate.

2. Forest Land:
    - Dense canopy and leaf litter increase infiltration.
    - Forest roots stabilize soil and reduce surface runoff.
    - Act as a natural buffer zone, helping in groundwater recharge.

3. Combined Effect:

    - While agriculture increases runoff, forests balance the system by promoting infiltration.
    - Proper land management practices in farmlands can significantly reduce negative runoff impacts.

7. Conclusion

The Brahmani River basin was successfully delineated using QGIS and GEE. Spatial and land use analysis was conducted, and key hydrological parameters were estimated. This methodology can be used as a base model for other small and medium-scale watershed projects in India.

8. References

- Dynamic World (GEE) Land Cover Classification.
- QGIS 3.42.1 Documentation.
- Google Earth Engine Documentation.
- Youtube
- Friends