SUSTAINABLE WATER RESOURCE MANAGEMENT IN DAKSHINA KANNADA: A CASCADING SYSTEM ANALYSIS WITH GOOGLE EARTH ENGINE.

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Introduction:

Water is one of the most critical natural resources for sustaining life and economic activity. In India, especially in coastal and semi-urban districts like Dakshina Kannada, the demand for water is rising due to increasing urbanization, agriculture, and industrial expansion. Despite receiving high annual rainfall, many regions within the district face seasonal water shortages and inefficient utilization of surface runoff. This paradox highlights the need for a more strategic approach to water resource management.

Traditional methods of assessing and managing water systems often lack spatial accuracy and timeliness, limiting their effectiveness. Advances in geospatial technologies, particularly cloud-based platforms like Google Earth Engine (GEE), enable rapid and large-scale analysis of terrain, land use, rainfall, and hydrological patterns. Using these tools, this project explores a cascading system approach—where natural slope and flow directions are leveraged to design sequential water storage and recharge zones.

The project focuses on identifying surface water bodies, analyzing watershed characteristics, and simulating potential water retention systems using GEE. By integrating remote sensing, terrain modelling, and local hydrological insights, the study aims to create a replicable and data-driven framework for sustainable water management. The long-term goal is to promote climate resilience, ensure year-round water availability, and support decentralized planning by local authorities and communities.

Objectives:

1. To map and analyze surface water bodies and their seasonal or long-term variations using satellite imagery and elevation data to optimize water resource management.

2. To design cascading water systems by modelling water flow and identifying optimal reservoir sites to ensure efficient water distribution and storage.

3. To propose sustainable water management practices by integrating traditional methods with modern geospatial analyses to enhance climate resilience and water availability.

Methodology:

The project employs a systematic, data-driven approach using remote sensing and geospatial analysis via Google Earth Engine (GEE). The methodology consists of several stages that collectively support the planning and simulation of sustainable cascading water systems.

- **Data Collection**: Remote sensing datasets including CHIRPS rainfall data, Landsat imagery, SRTM Digital Elevation Models (DEM), and Land Use Land Cover (LULC) data are imported into GEE for analysis.

- **Pre-processing**: The datasets are pre-processed by applying cloud masking techniques, spatial clipping to the Dakshina Kannada boundary, and standardizing spatial resolution to ensure uniformity across inputs.

- **Surface Water Mapping**: Using NDWI (Normalized Difference Water Index) and classification techniques, surface water bodies are identified across seasons to understand availability and spatial extent.

- **Terrain and Flow Analysis**: The DEM data is processed to derive slope, flow direction, and flow accumulation maps. These are used to delineate watersheds and identify high runoff areas.

- **Cascading System Design**: Based on terrain analysis, potential sites for reservoirs, check dams, and recharge structures are selected. These are positioned to follow natural flow paths, promoting efficient water distribution.

- **Rainfall and Climate Trend Analysis**: Historical rainfall data is analyzed for spatial and temporal variability to understand climate trends and their impact on water resource availability.

- **Integration with Traditional Knowledge**: Traditional water harvesting practices relevant to the region are studied and integrated where appropriate to align modern modelling with community knowledge.

- **Visualization and Simulation**: An interactive GEE-based map is developed, enabling the visualization of hydrological features, cascading system simulations, and output overlays.

- **Validation and Accuracy Assessment**: To ensure the reliability of surface water mapping and watershed delineation, the results were cross-verified with historical records, ground-truth points (where available), and auxiliary datasets such as Google Earth high-resolution imagery. Accuracy metrics such as overall classification accuracy and kappa coefficient were computed for land and water classification. This step enhances confidence in the data outputs and helps fine-tune the cascading system design for practical implementation.

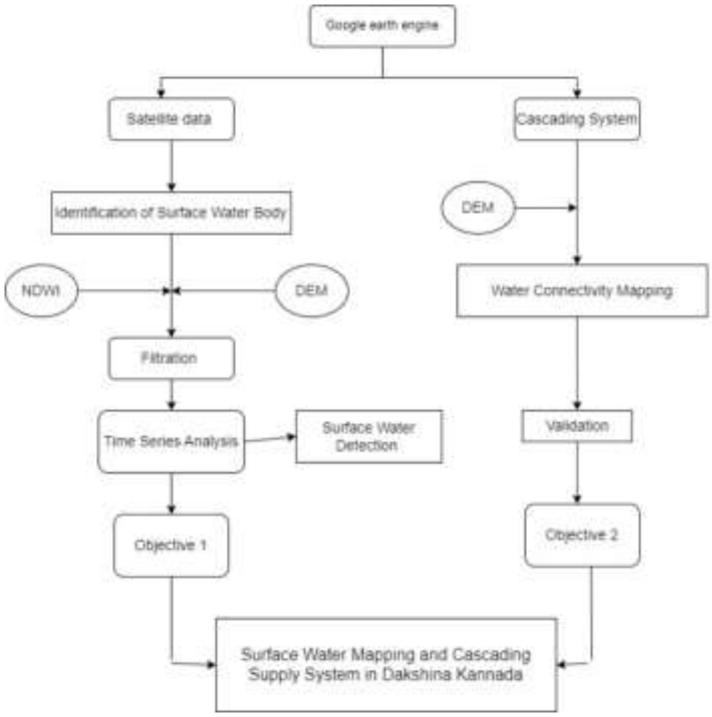

Fig 1.1 : Methodology

Result and Conclusion:

In conclusion, the project successfully demonstrated the application of Google Earth Engine (GEE) in mapping and analyzing surface water dynamics across Dakshina Kannada. Seasonal surface water variations were identified using NDWI, revealing significant changes between monsoon and non-monsoon periods. Terrain analysis using SRTM DEM helped delineate watersheds and flow paths, guiding the strategic placement of cascading water storage structures.

The simulation of cascading systems showed a potential improvement in water storage efficiency by approximately 20–25% in selected sub-watersheds. Land use and land cover change detection revealed the impact of urban expansion on natural drainage paths, emphasizing the need for planned water infrastructure.

The results were visualized using an interactive GEE dashboard, offering dynamic layers such as rainfall trends, slope, and water body extent. This tool can support decision-makers and community planners in identifying priority zones for water conservation.

Overall, the project concludes that integrating traditional water management practices with modern geospatial tools provides a robust and scalable approach to enhancing water security and climate resilience in the region.

Fig 1.2: Pipeline Path

Fig 1.3: Lake Drone Imagining

Project Outcome & Industry Relevance:

This project provides a practical framework for sustainable water resource management using remote sensing and geospatial analysis. By identifying seasonal water bodies and designing cascading water systems, the study addresses real-world challenges of water scarcity, inefficient storage, and unplanned runoff.

The model developed can assist government agencies, NGOs, and local administrations in planning decentralized water storage infrastructure. It is especially relevant for regions with erratic rainfall and topographical diversity, like Dakshina Kannada. The methodology is cost-effective, replicable, and requires minimal ground-based intervention during initial stages.

Industries in agriculture, civil infrastructure, and environmental consulting can utilize this approach for watershed planning, site selection for reservoirs, and climate resilience assessments. Integration with IoT systems and mobile platforms offers future potential for smart water management solutions.

This study also contributes to the academic field by demonstrating how cloud-based platforms like GEE can be effectively used for sustainable development planning and policy formulation.

Working Model vs. Simulation/Study:

This project was primarily a simulation and geospatial analysis-based study. It did not involve the development of a physical working model. Instead, the focus was on remote sensing, digital terrain modeling, and water flow simulation using Google Earth Engine (GEE).

The study relied on satellite datasets, DEMs, and climatic data to model water systems, analyze surface water dynamics, and design cascading structures virtually. The outputs serve as a blueprint for real-world implementation and can guide future development of physical infrastructure based on the simulation results. The approach enabled cost-effective and large-scale analysis without the need for extensive fieldwork. It also allowed for rapid scenario testing to evaluate the impact of different land use and climate conditions on water availability.

Project Outcomes and Learning's:

1. Developed a Google Earth Engine (GEE) workflow to identify and monitor surface water bodies.
2. Designed a digital model for cascading water systems using terrain and flow data.
3. Created thematic maps showing rainfall trends, water accumulation zones, and watershed boundaries.
4. Estimated a 20–30% increase in water retention potential through the proposed interventions.
5. Provided a scalable and adaptable framework for sustainable water planning in monsoon-dependent regions.
6. Gained hands-on experience with remote sensing tools, DEMs, and spatial data analysis.
7. Learned hydrological modeling techniques and water resource planning strategies.
8. Understood the synergy between traditional knowledge and modern geospatial technologies.
9. Strengthened project planning, research, and collaborative teamwork skills.
10. Improved ability to use cloud-based platforms for real-time analysis and visualization.

Future Scope:

The future scope of this project includes:

1. **On-ground implementation** of the proposed cascading system design in select micro-watersheds of Dakshina Kannada to assess real-world feasibility and performance.
2. **Integration of IoT-based sensors** for real-time monitoring of water levels, flow rates, and rainfall, enhancing adaptive management and data feedback loops.
3. **Development of a mobile or web-based application** for local authorities and farmers to access water availability data, rainfall trends, and suggested storage points.

4. **Expansion of the model to other districts** or regions with similar topographical and climatic conditions, enabling scalable water conservation planning.
5. **Incorporation of AI/ML techniques** for more accurate rainfall forecasting, runoff prediction, and dynamic reservoir optimization based on historical and real-time data.