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Integrated Models for Sustainable Watershed Management Structures in Upper Kundalika River Basin

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Abstract:

The Upper Kundalika River Basin, situated in the ecologically sensitive Western Ghats of Maharashtra, faces challenges related to soil erosion, water scarcity, and land degradation. This study focuses on developing Integrated Models for Sustainable Watershed Management Structures tailored to the unique morphometric and hydrological characteristics of the basin. By employing geospatial technologies, field data, and hydrological model, the research identifies priority areas for intervention and designs effective structural measures such as check dams, contour bunds, and percolation tanks. The integrated model emphasizes a systems-based approach, combining physical, environmental, and socio-economic parameters to enhance water conservation, reduce runoff, and improve groundwater recharge. Results suggest that such models can significantly improve watershed resilience, ensure long-term sustainability of water resources, and support rural livelihoods in the Upper Kundalika basin. The study provides a scalable framework for watershed management in similar mountainous and semi-arid regions.

Keywords: Check Dams, Contour Bunds, and Percolation Tanks.

Introduction:

Watershed management plays a crucial role in ensuring the sustainable use of water and land resources, particularly in ecologically sensitive and rainfall-dependent regions like the Western Ghats of India. The Upper Kundalika River Basin, located in Maharashtra, is a sub-basin originating in the Sahyadri ranges and flowing westward into the Arabian Sea. This region is characterized by steep slopes, high rainfall, and lateritic soils, making it highly susceptible to soil erosion, surface runoff, and seasonal water scarcity. Traditional water conservation methods have been partially effective but lack integration with modern tools and a scientific planning framework.

In this context, the concept of *integrated models for sustainable watershed management structures* emerges as a transformative approach. These models bring together hydrological data, topographical analysis, land use patterns, and socio-economic factors to design appropriate site-specific structures such as check dams, percolation tanks, farm ponds, and contour bunds. The integration of remote sensing (RS), geographic information systems (GIS), and watershed simulation models enables precise identification of critical zones, prioritization of interventions, and monitoring of outcomes.

In hilly, plateau, and lower reaches watersheds, various watershed management structures, such as continuous contour trenches, farm ponds, check dams, and percolation tanks, are proposed to address the water scarcity of the study area. For the purpose of locating potential locations for watershed management structures, the government of Maharashtra's Soil Conservation and Agriculture Department (Govt. of Maharashtra, 2006) and India's

Ministry of Rural Development (Govt. of India, 2007) technical watershed development guidelines are followed.

The Objective:

This study intends to create an integrated model for the Upper Kundalika River Basin that,

1. To sustain water resources, recharges groundwater, mitigates land degradation, and meets local agricultural and domestic water needs. Morphometric analysis, hydrological modelling, and participative planning are used to create a holistic and repeatable watershed development model.
2. The study supports regional environmental conservation and national goals like water security, climate adaption, and sustainable rural development through this strategy.

Research Methodology:

The research on *Integrated Models for Sustainable Watershed Management Structures in the Upper Kundalika River Basin* adopts a multidisciplinary and geospatial approach, combining morphometric analysis, hydrological modeling, GIS-based mapping, and field validation. The methodology is structured into the following key phases:

1. Study Area Delineation and Data Collection:

- **Study Area:** Upper Kundalika River Basin, located in the Raigad district of Maharashtra, covering the upstream portion from its origin in the Western Ghats.
- **Data Sources:**
  - Topographic maps (SOI, 1:50,000 scale)
  - ASTER/DEM or SRTM data for elevation and slope analysis
  - Satellite imagery (Landsat, Sentinel-2) for LULC classification
  - Soil and rainfall data from IMD and NBSS&LUP
  - Groundwater and surface water data from GSDA and WRD, Maharashtra

2. Morphometric and Terrain Analysis

- **Tools Used:** GIS software (ArcGIS/QGIS), Remote Sensing software (ERDAS Imagine)
- **Parameters Assessed:**
  - Linear aspects (stream order, bifurcation ratio)
  - Areal aspects (drainage density, stream frequency, form factor)
  - Relief aspects (basin relief, slope, ruggedness number)
- **Purpose:** To understand runoff potential, erosion-prone zones, and watershed behavior.

3. Land Use and Land Cover (LULC) Classification

- **Method:** Supervised classification using satellite imagery
- **Categories Identified:** Forest, agriculture, built-up, wasteland, water bodies
- **Application:** To evaluate land degradation, vegetation cover, and anthropogenic impacts

4. Hydrological and Watershed Modeling

- **Model Used:** Universal Soil Loss Equation (USLE) Analysis.
- **Data Inputs:** DEM, soil type, LULC, precipitation, temperature.
- **Outcome:** Identify critical watersheds and prioritize areas for interventions.

5. Structural Intervention Planning

- **Approach:** GIS-based site suitability analysis for structures like:
  - Check dams
  - Percolation tanks
  - Farm ponds
  - Contour trenches
- **Criteria:** Slope, soil type, land use, stream proximity, runoff potential

6. Community Participation and Ground Validation

- **Method:** Field surveys, stakeholder interviews, and participatory rural appraisal (PRA)
- **Purpose:** Incorporating local knowledge and ensuring practical feasibility.

7. Impact Assessment and Model Validation

- **Indicators:** Pre- and post-intervention changes in groundwater level, soil moisture, crop yield.
- **Tools:** Time series analysis, field monitoring, GIS overlay comparisons.

8. Recommendations and Scalability

- Framework for replicating the model in other sub-basins of the Western Ghats.
- Policy suggestions for convergence with government schemes like MGNREGA, PMKSY, and Watershed Development Program.

This integrated methodology ensures scientific planning, effective implementation, and sustainability of watershed management structures, aiming to enhance the hydrological health and rural livelihood resilience of the Upper Kundalika River Basin.

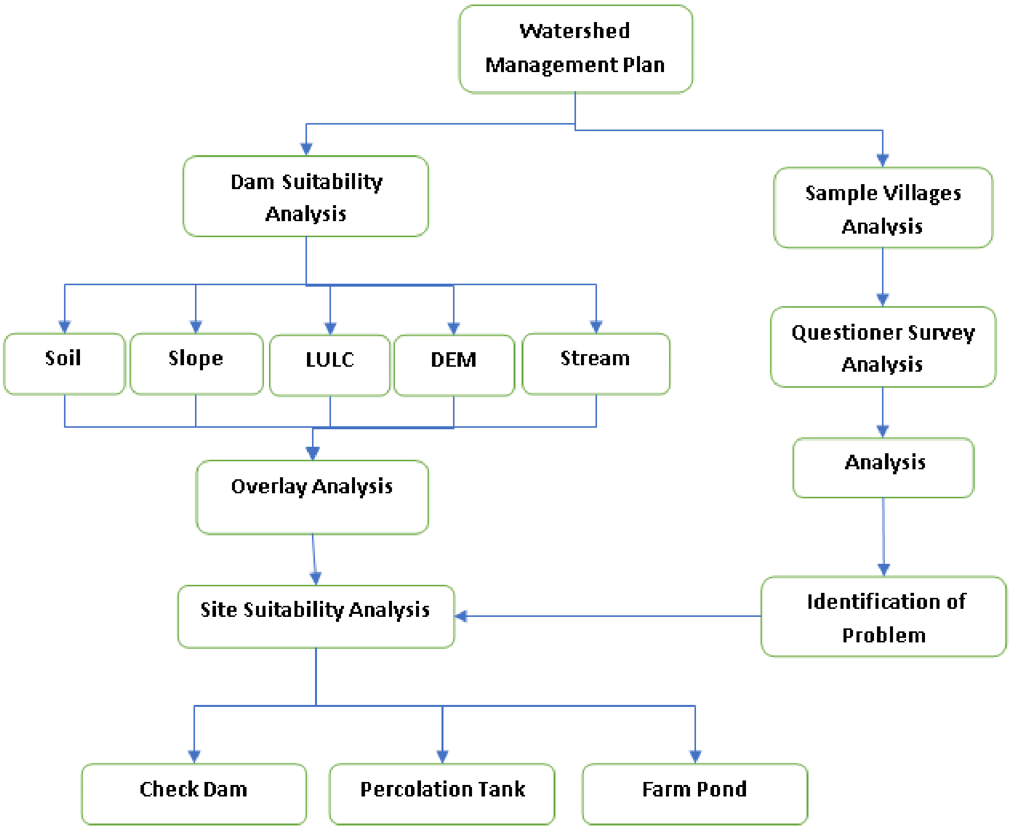

Figure 1.1 The figure shows that Methodology for Models of watershed Managements

1.1.1 Check Dams

i. The slope should be less than 15% (percent)
ii. The land cover may be barren, shrub land and riverbed
iii. The infiltration rate of the soil should be less
iv. The type of soil should be sandy clay loam
v. The stream of order first or second

Small, low, fixed dam which has been constructed of brush, logs, timber, loose rock masonry or concrete, in an eroded channel, for reducing the slope of the water flowing there and also the resulting velocity, thereby preventing excessive scour and erosion and inducing deposition.

Check dam work consists of constructing bunds of suitable dimensions across the Nala or gullies to hold the maximum runoff water to create flooding of upstream area temporally for some day or weeks, with surpluses arrangements at suitable interval to drain to water. (Tideman, 1990) Check dam is constructed across small stream having gentle slope and is feasible both in hard rock as well as alluvial formation. The site selected for check dams should have sufficient thickness have permeable bed or weathered formation to facilitate recharge of store water within short period of time.

Rajora R. (1998), “the structure helps in water harvesting, moisture control and ground water recharge. It may not be advisable to construct nala bund to stream with high gradient slope and where runoff of water flow is very high.

For selecting a site for check dams following condition may be observed including the check dams perfectly located in area where contour and graded bunding of land have been carried out. Dam should be built site that can produce a relatively high depth to surface area so as to minimize evaporation losses. Check dam is generally a small earthen dam with a cutoff core wall of brick. Rocky surface should not be fracture or cracked which cause water leak away to deeper zones or beneath the dam. The location of check dams should be convenient for user groups. Dam should site along the edge of depression or directly across the lower end of deep gullies in to the rock.

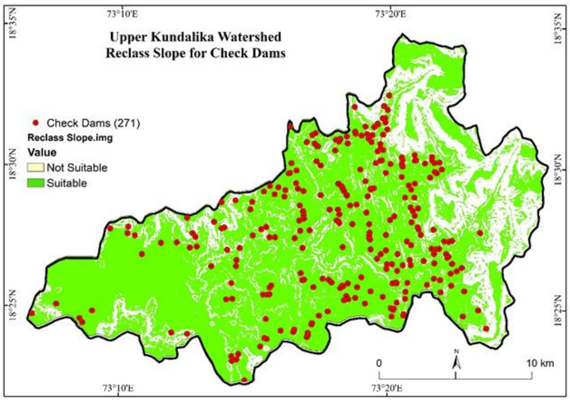

Figure 1.2 The figure shows that reclassified Slope

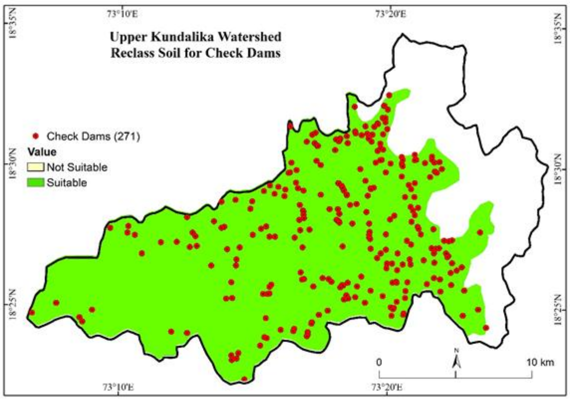

Figure 1.3 The figure shows that reclassified Soil

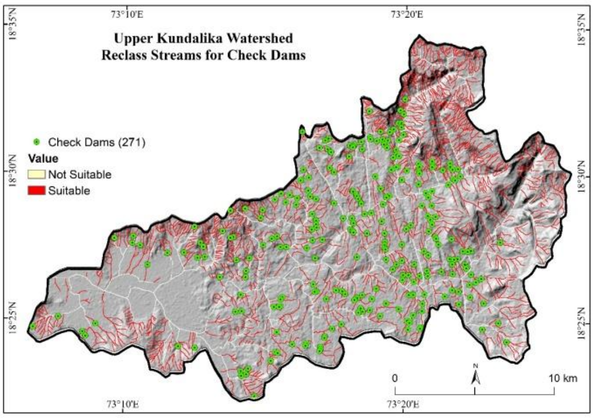

Figure 1.4 The figure shows that reclassified Stream of First and Second Order

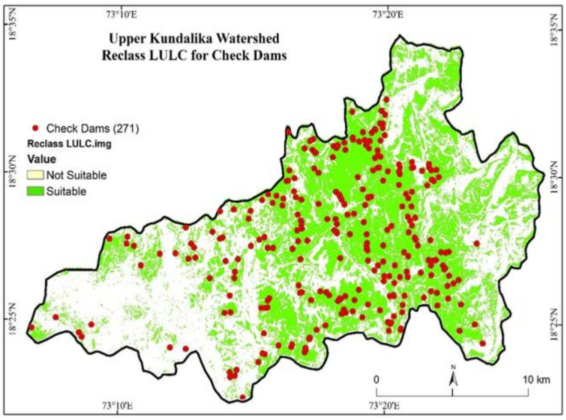

Figure 1.5 The figure shows that reclassified LULC

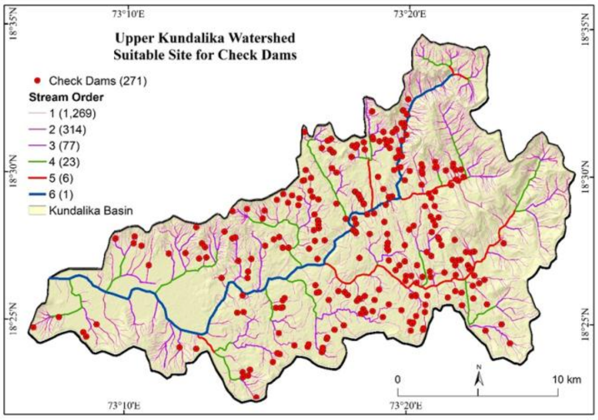

Figure 1.6 The figure shows that Suitable Sites for Check Dams

The result shows that there were 271 suitable sites for the construction of Check dam in the region. Due to stream order limitation the first and second order streams mostly found in source region. The concentration of check dam was found in middle upper part of the basin. Figure 1.6 shows spatial distribution of check dam in study region the villages like Ninavali, Nagaon, Atone, koshinbale, Pinploli and vitthalvadi etc were highly suitable for the construction of Check dams. (Table1.1)

Table 1.1the table Shows village wise suitable site for check dams

Sr. No.	**Name of Village**	**Suitable Site for Check Dam**	**Sr. No.**	**Name of Village**	**Suitable Site for Check Dam**
1	Adiwasiwadi [Dhankanhe]	3	29	Khad Sambale	7
2	Adiwasiwadi [Kolad]	2	30	Khamb	5
3	Adulse	5	31	Koshimbale	8
4	Ainwahal	3	32	Kudali	5
5	Ambewadi	1	33	Ladhar	1
6	Ambivali	6	34	Nadawali	1
7	Atone	13	35	Nagaon	1
8	Balhe	2	36	Nagshet	9
9	Bedgaon	3	37	Nandgaon	6
10	Borghar	1	38	Neharunagar	1
11	Chilhe	1	39	Nenavali	15
12	Chinchawali Tarf Atone	5	40	Nivi	2
13	Chinchawali Tarf Diwali	2	41	Pachhapur	7
14	Daryagaon (N.V.)	6	42	Pahoor	3
15	Devakanhe	1	43	Pale Bk.	1
16	Dhagadwadi	4	44	Patnus	19
17	Dighewadi	5	45	Pimploli	5
18	Dolavahal	1	46	Potlaj Bk.	1
19	Durtoli	8	47	Potlaj Kh.	7
20	Gaulwadi	5	48	Rawalje	9
21	Ghera Sudhagad	17	49	Saje	15

22	Gherasurgad	4
23	Gomashi	8
24	Gondale	8
25	Jamgaon	3
26	Kalamboshi	1
27	Kamath	1
28	Kandale	6
50	Tise	3
51	Vaijnath	1
52	Vile	4
53	Vitthalwadi	6
54	Washi	1
55	Yeral	3
Grand Total		**271**

Source: Primary data

1.4.2 Percolation Tanks

Percolation tanks are commonly used for large-scale artificial recharge. Runoff from 10- to 15-km catchments is collected in percolation tanks. The tank dries out in summer after four months of water percolation from October to February. Percolation tanks recharge groundwater by submerging a permeable land area to allow impounded surface runoff to percolate. These are built across streams and larger gullies to impound runoff. This improves downstream well recovery. Percolation tanks raise the water table in command areas and enhance well yield per day. The well has water until March, allowing for additional wells. Pawar (1989, 2013). The following guideline will adopt this conservation method. Lower basin has percolation tanks. There is no percolation tank at the Ghod river source. Percolation tanks supply drinking and agricultural water. Percolation tanks raise groundwater levels in the area. This water source is ideal for well irrigation. Farmers can manually build percolation tanks in our field. The Ghod river basin has 52 possible percolation tank locations. The sites are in the lower basins of the left and right Ghod river channels. Lower basin sites are evenly distributed. The showing potential sites are to check dam and percolation tank together. This plane will be useful for increasing ground water table as well as productivity of agriculture. Also useful for water, soil, vegetation, conservation. Following criteria is used for the constriction of percolation tank.

i. The slope should be less than 10 percent
ii. The infiltration rate of the soil should be moderately high
iii. The land cover may be barren or scrub land
iv. The type of soil should be silting loam
v. The stream of third order

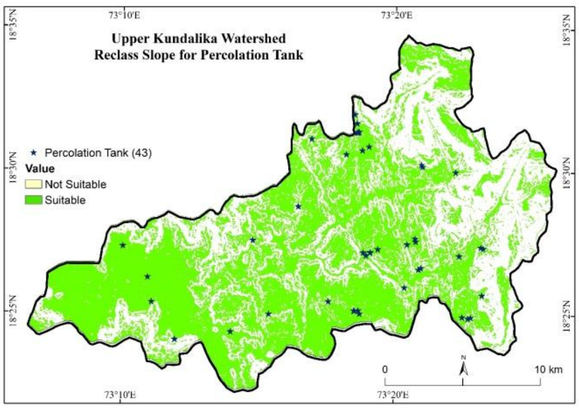

Figure 1.7 The figure shows that Reclass Slope for Percolation Tank

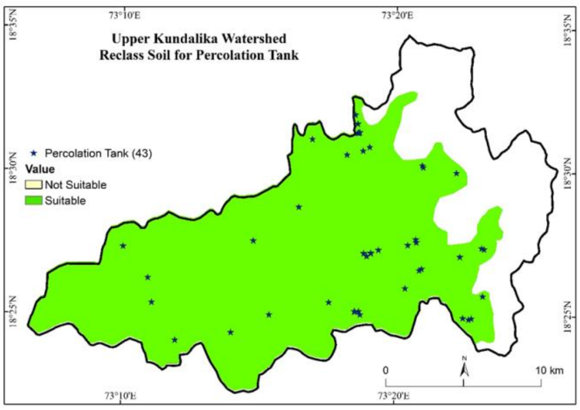

Figure 1.8 The figure shows that Reclass Soil for Percolation Tank

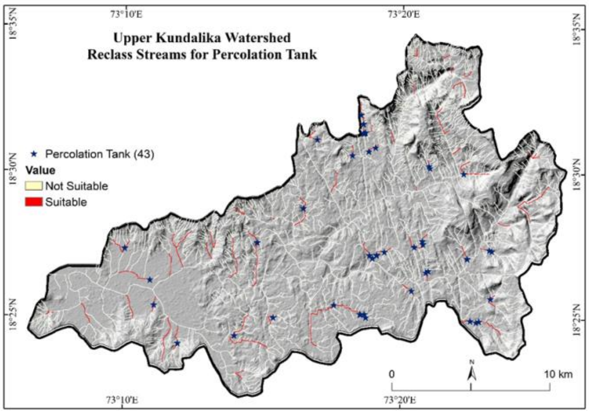

Figure 1.9 The figure shows that Reclass Streams for Percolation Tank

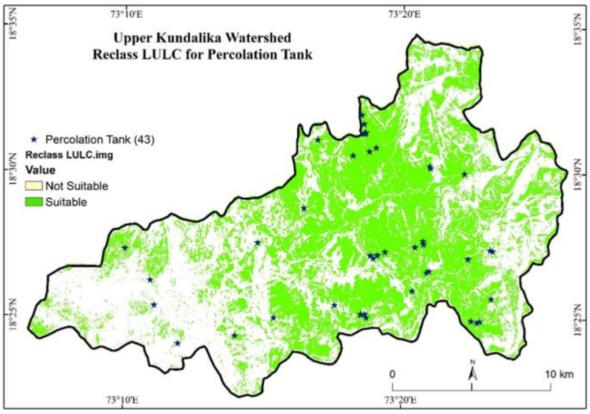

Figure 1.10 The figure shows that Reclass LULC for Percolation Tank

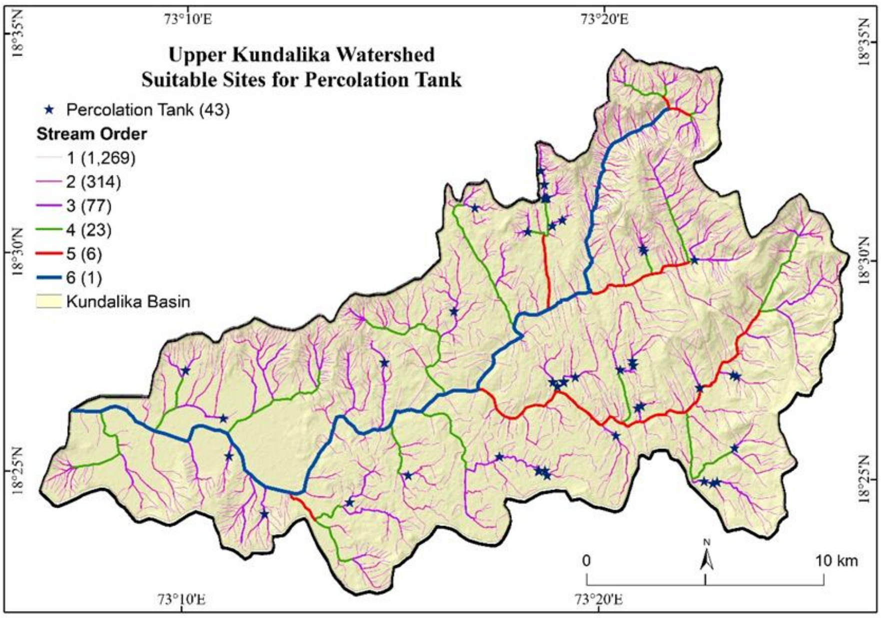

Figure 1.11 The figure shows that Suitable Sites for Percolation Tank

In upper Kundalika river basin having 43 suitable sites for construction of percolation tank. These sites may distribute majorly 23 village of the study region. The figure 1.11 shows that spatial distribution of percolation tank. As like check dams' percolation tank suitable site also in middle part of the basin. the following villages have mainly suitable for percolation tank namely Adulse, Atone, Bedgaon, Daryagaon (N.V.), Dhankanhe Durtoli, Gondale, Kalamboshi, Killa, Kolad, Koshimbale, Kudali, Nagshet, Nenavali, Pachhapur, Pale Bk., Patnus, Potlaj Bk., Rawalje, Saje, Talawali Tarf Ashtami, Vile, Vitthalwadi.

Table 2.2 the table Shows village wise suitable site for Percolation Tank

Sr. No.	Village Name	Percolation Tank Suitable Site
1	Adulse	1
2	Atone	1
3	Bedgaon	3
4	Daryagaon (N.V.)	5
5	Dhankanhe	1
6	Durtoli	2
7	Gondale	1

8	Kalamboshi	4
9	Killa	1
10	Kolad	1
11	Koshimbale	3
12	Kudali	4
13	Nagshet	1
14	Nenavali	2
15	Pachhapur	2
16	Pale Bk.	1
17	Patnus	3
18	Potlaj Bk.	1
19	Rawalje	2
20	Saje	1
21	Talawali Tarf Ashtami	1
22	Vile	1
23	Vitthalwadi	1
Grand Total		**43**

Source: Primary data

1.4.3 Farm Pond

Farm pond useful for small farmer for preserve water for the dry period. In Konkan region during monsoon season heavy rainfall may experience but due to unproper water conservation techniques the water directly accumulated to the Arabian sea. Hence the summer season farmer face scarcity of water. Even some time the drinking water issues also be identified in this region as per quaternaries analysis. For construction of form pond following criteria were used.

i. In the regions with low percolation, the farm pond needs to be prepared.
ii. Black cotton soil is the best type of soil for pond construction since it seems less water.
iii. A pond can be built on first-order tributaries or at a junction in the landscape. Ponds can be built on flat ground
iv. A large natural depression should be chosen as the location of the pond.
v. The pond's drainage area ought to have enough space to fill the pond.
vi. Ponds are planned in areas with slopes of up to 1.72 degrees; caution should be exercised in areas where other constructions are not.
vii. Topography influences a farm pond's length, width, and depth, which can be 20 X 20 X 3 m or 40 X 20 X 2.5 m, for example.
viii. It has a 1000 TCM storage capacity.
ix. Ponds are not suggested in areas with existing canal irrigation systems and salinization.

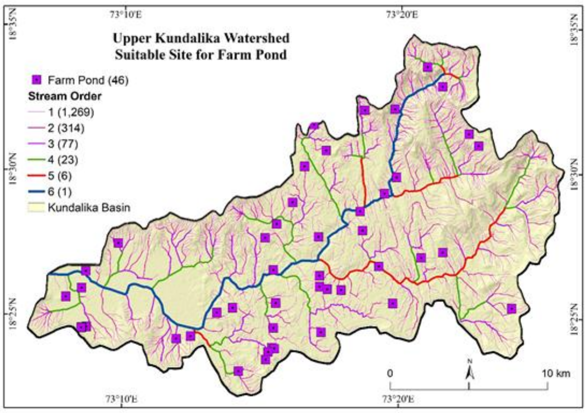

Figure 1.12 The figure shows that Suitable Sites for Farm Pond

Using the given criteria, an excessive approach was used. The analysis showed 46 agricultural pond-suitable sites. Farm ponds were absent from research region field observations. Sustainable agricultural development requires competent management. This location recommends a farm pond as a top method. Form ponds can be built on 46 sites, according to a criteria analysis. Figure 1.12 depicts the distribution of agricultural pond construction sites. Compared to previous models, this model uniformly distributes the study zone and takes less space and money. It may be more beneficial in the upper Kundalika river basin. Adiwasiwadi [Kolad], Adulse, Ambewadi, Ambivali, Balhe, Borghar, Devakanhe, Dhagadwadi, Dighewadi, Durtoli, Ekole, Gaulwadi, Ghera Sudhagad, Ghutake, Gomashi, Gondale, Kandale, Khad Sambale, Koshimbale, Pahoor, Patnus, Pimploli, Potlaj Kh., Roth Bk., Roth Kh., Saje, Sambhe, Tail

Table 1.3 the table Shows village wise suitable site for Farm Pond

Sr. No.	Village Name	Farm Pond Suitable Site
1	Adiwasiwadi [Kolad]	2
2	Adulse	1
3	Ambewadi	1
4	Ambivali	2
5	Balhe	1
6	Borghar	3
7	Devakanhe	1
8	Dhagadwadi	2
9	Dighewadi	1
10	Durtoli	2
11	Ekole	1
12	Gaulwadi	1
13	Ghera Sudhagad	2
14	Ghutake	2
15	Gomashi	2
16	Gondale	1
17	Kandale	2
18	Khad Sambale	1
19	Koshimbale	1
20	Pahoor	4
21	Patnus	1
22	Pimploli	1
23	Potlaj Kh.	1
24	Roth Bk.	1
25	Roth Kh.	1
26	Saje	1
27	Sambhe	1
28	Tail Baila	1
29	Tamhini Bk	1
30	Tise	1
31	Vitthalwadi	1
32	Warse	1
33	Yeral	1
Grand Total		**46**

Source: Primary data

1.5 Limitations

Several limitations and difficulties are incurred during the study

1. Cross sectional survey of whole watershed cannot be completed due to many reasons.
2. In the watershed cross section are not taken because of disturbance by local people, invisibility, loose material and inconvenience.
3. Discharge data is available only at Roha station. Rainfall stations are also low in frequency in the study area.
4. Other methods of water conservation have not taken into consideration in the present study.

1.6 Measures to Be Taken

1. To eradicate water scarcity following measures should be taken
2. Besides the measures suggested in the previous discussions more parameters should be included in the analysis. So that accuracy level of measures would match.
3. Awareness program for the local people to maintain the watershed structures.
4. Plantation of native trees observed in forests.
5. Conserve scrub land for the protection of watershed structures.

1.7 Contribution to the Society

1. Drinking and domestic water scarcity will be solved in drought period.
2. Groundwater level of the region would be increased, which makes possible to take agriculture in two cropping seasons, Kharif and Rabi.
3. Socio-economic status of the local people would be increased.
4. Sustainable development of the area will be possible through present work.

1.8 Recommendation

1. Drinking water situation is very poor in the watershed. Rainwater is the prime source of water, hence there is a need of the rain water harvesting in the way of Continuous Contour Trenches, Farm Pond, Percolation Tanks and Check Dams at suitable sites as suggested
2. People participation in watershed development is essential, so awareness among people need to be increased by arranging public meetings. User community or local people should be involved in the planning, implementation, operation and maintenance of the different drinking water schemes.
3. NGOs play the vital role in integrated watershed development programs. NGOs are not found active in most of the sub watersheds, hence state and central government should work together with NGOs on various watershed development schemes to get better results.
4. The Success villages of water harvesting, suitable land use planning and sustainable socio-economic development such as Hivare Bazar (Popatrao Pawar) Ralegan Sidhi, in Ahmednagar District should be put as models before of remaining villagers of Ahmednagar District and other districts in Sina watershed and encourage them for active participation in various watershed development schemes like Integrated Watershed Development Programme (IWDP), Mahatma Gandhi National Rojagar Hami Yojana (MGNREAGA), Hariyali Project etc.
5. Village level conservation measures have been recommended for effective micro-level watershed planning. Villages at the high elevation zone are more susceptible for soil erosion and water scarcity problem. Hence these villages should be giving top priority and conservation measures.

6. Geographical information system, GPS and Remote Sensing should be applied by Local, State and Central Government for planning of natural resource management and in integrated watershed development. Geoinformatics techniques provide reliable source of information for effective and long-term planning for integrated watershed development and management.

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