Water resources planning for Alanda micro watershed using geospatial techniques

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ABSTRACT

Groundwater is a vital natural resource, especially in areas lacking surface water bodies. About one-third of the global population relies on it for drinking, irrigation and industrial purposes. However, excessive and unregulated exploitation has led to a rapid decline in water tables, emphasizing the need for sustainable groundwater management. The Alanda micro watershed in Barshitakli Taluka, Akola District, Maharashtra, spans 11.39 km², with a sub-humid climate and uneven monsoon rainfall averaging 780 mm. The region faces high water stress in summer, with dried bore wells and farmers relying on rain and groundwater for irrigation. The water resource development plan for Alanda micro watersheds integrates GIS, remote sensing, and AHP to identify groundwater potential zones. The survey of the study area identified existing soil and water conservation structures, including 3 farm ponds, 1 check dam and a contour bund. Additional recommendations include 5 farm ponds, 4 check dams, contour trenches and bunding measures, along with agronomic practices for effective surface and groundwater management.

Keywords: Groundwater, Watershed, GIS, Remote sensing, Soil and water conservation

1. INTRODUCTION

Groundwater is one of the important natural resources that are essential to life and ecological diversity, especially in regions that are devoid of major surfaces of water bodies in the vicinity. The significance of groundwater is evident considering that roughly one-third of the global population relies on it for drinking, irrigation and various domestic and industrial uses [1,8]. Groundwater is a renewable natural resource, but unregulated and excessive use can result in its depletion [4]. The water table is steadily declining at an extremely rapid rate with time because of the non-scientific exploitation of groundwater for various purposes, particularly in regions with fresh groundwater reserves [2]. Hence, the accurate delineation and sustainable management of groundwater are essential to meet growing demands, ensuring its availability not only for the present generation but also for future ones [4]. Water resource management planning considers the various competing demands for water and aims to distribute it equitably to meet all needs and requirements. Agriculture is the backbone of Maharashtra's economy, which is primarily based on this sector. It is the main livelihood for the state's population, with both food and cash crops cultivated. The total irrigated area utilized for crop cultivation in Maharashtra covers 33,500 Sq. Km. [3]. The study area has experienced a rise in water demand, primarily met through the exploitation of groundwater resources. Also, the groundwater quality is deteriorating all over the regions in India [9]. Therefore, creating a sustainable groundwater management plan is essential to ensure the efficient use of these critical resources. This requires the delineation of groundwater potential zones using remote sensing data [5]. Surface water bodies such as streams, tanks, check dams, and ponds act as groundwater recharge zones within the study area [7,10].

1.2 STUDY AREA

The watershed chosen for the research work is the Alanda micro watershed which lies in Barshitakli Taluka of Akola District in Maharashtra. The watershed is located between 20°36’ to 20°38’ N latitude and 77°03’ to 77°05’ E longitude. The total geographic area of the watershed is 11.39 km2. The watershed is characterized by sub humid to humid climate with rainfall received mostly during the monsoon months of June to September. The area receives an average rainfall of about 780mm. The temperature of the area ranges between 30°C to 42°C during summer while the temperature ranges between 13°C to 28°C during the winter season. The distribution of the rainfall in the monsoon season is uneven and erratic marked by prolonged rainless days. The study area location map is shown in Fig 1. Alanda micro watershed faced high water stress during the summer season. The villages accompanying the micro watershed rely on bore wells which were dried out. Farmers mainly depend on rain, groundwater and other sources of water for irrigation.

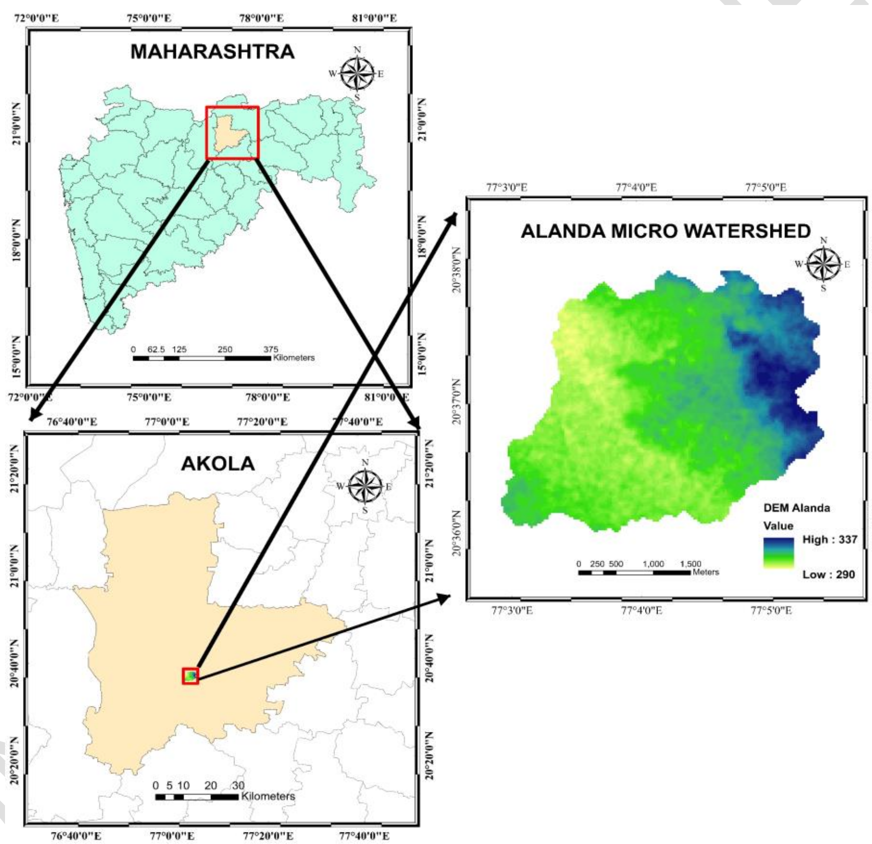

Fig. 1 Location map of the study area

2. MATERIAL AND METHODS

Soil and water conservation measures/structures plans of the Alanda micro watershed were prepared using GIS, remote sensing and the AHP method. AHP is applied by creating a pairwise comparison matrix to assign weights to these factors based on their importance to water resources. These weights are used in a weighted overlay analysis in GIS, where thematic maps (drainage density map, lineament density map, slope map, land use and land cover map, soil map, geology map, geomorphology map and rainfall map) were integrated and overlaid using Arc-GIS software to identify groundwater potential zones for water resource development. The zones are categorized into high, moderate and low potential for water resource management based on their conditions. The largest area falls under moderate groundwater potential zones, indicating significant opportunities for soil and water conservation measures/structures plans. This could be instrumental in transforming these moderate zones into areas with high groundwater potential zones. The water resources management plan ensures judicious and effective use of water resources in the micro-watershed, enhancing productivity and mitigating drought. It identifies potential sites for surface water development and groundwater exploitation, reflecting a careful approach to sustainable resource use [6]. Implementing soil and water conservation measures/structures plan strategies improves moderate groundwater potential zones, increasing groundwater availability. This improvement supports crop sustainability, ultimately benefiting residents of the micro-watershed region. Surface water resources within the micro-watershed, including the drainage network, contour bunds, ponds water harvesting structures etc. were identified. Areas appropriate for groundwater development were also suggested. A detailed description of water resources management action through surface and groundwater development is provided below.

Contour bund

Contour bund is a soil and water conservation technique used in agricultural lands to reduce soil erosion, enhance water infiltration and improve soil moisture. It involves constructing embankments along natural contour lines, which slow runoff, capture water and promote groundwater recharge. This method is particularly effective in areas with gentle slopes (0-6%) and low rainfall (below 700 mm). Typically, contour bunds are 0.3 to 0.6 meters high, 1 to 2 meters wide at the base and 0.3 to 0.5 meters wide at the top, with spacing of 10 to 30 meters depending on slope and soil type. It is highly effective in this region due to the presence of light soils and low rainfall, supporting rainfed crops by improving moisture retention.

Graded bunds

Graded bunds are soil and water conservation structures used on sloping agricultural lands to control runoff and reduce erosion. It is particularly useful in rainfed regions with substantial rainfall or limited infiltration, as it’s slow runoff, enhances infiltration, and protects topsoil. Proper surveying is required to determine appropriate gradients and spacing, typically 15 to 30 meters apart. Graded bunding is most effective on slopes between 2% and 6%.

Farm pond

A farm pond is a water harvesting structure for flat areas, providing irrigation for Kharif crops and supporting groundwater recharge. The pond's catchment area ranges from 2 to 25 hectares, with impermeable soil ensuring prolonged water storage. For each hectare needing irrigation, 1000 cubic meters of water storage (20 m x 20 m x 3.0 m) is required, with around 5% of the land allocated for the pond. It helps capture rainwater, control soil erosion by reducing runoff, and enhances groundwater recharge, improving water availability and raising the water table.

Contour trenches

Contour trenches are excavated along land contours to conserve soil and water, especially on slopes up to 15%. Typically measuring 0.3 m by 0.3 m, these trenches stabilize the land, retain moisture and promote vegetation growth. Trenches run level to capture rainwater, which then percolates into the soil, aiding groundwater recharge. Bunds made from excavated material reduce runoff and soil erosion. The construction starts from the ridge, placing topsoil upstream and boulders downstream. This method improves soil moisture, supports vegetation and promotes sustainable land management.

Check dams

Check dams are small structures built across gentle-stream slopes to capture runoff and boost groundwater recharge. They are effective in both hard rock and alluvial areas, with heights usually under 2 meters. Proper site selection and placement of water cushions prevent erosion. These dams work best on lower-order streams with medium slopes and can manage catchment areas of about 25 hectares. Key construction factors include slope, soil cover and rock type, with nearby irrigation wells further aiding water management.

The decision rules are formalized for the selection of sites of various soil and water conservation structures as per the guidelines given by the Integrated Mission for Sustainable Development (IMSD), Indian National Committee on Hydrology and the criteria are presented in Table 1 below.

Table 1. Criteria for selection of different soil and water conservation measures and water harvesting structures

Sr. No.	Structure	Selection Criteria				
		Rainfall (mm)	Slope (%)	Soil Porosity	Runoff coefficient	Stream Order
1.	Contour bund	< 700	< 6	Low	Medium/high	-
2.	Graded bund	400-1200	2-6	Low	Low	-
3.	Farm pond	<500	0-5	Low	Medium/high	1^{st}
4.	Continuous contour trenches	400-1200	10-25	High	Medium/high	1^{st}
5.	Check dam	400-1200	< 15	Low	Medium/high	2^{nd} to 4^{th}

3. RESULTS AND DISCUSSION

The existing soil and water conservation measures/structures for the study area are presented in Fig 2. The survey revealed the existence of 3 farm ponds, 1 check dam and a contour bund within a 96.79 ha area. Various thematic layers viz. slope, stream order, land use and land cover, drainage, soil texture and rainfall data were analyzed to identify sites appropriate for soil and water conservation measures/structures as depicted in Fig. 3. Suitable sites for 5 farm ponds and 4 check dams are suggested. It is also suggested to implement continuous contour trenches across a 9.69 ha area. Additionally, contour bunds are proposed for 206.45 ha and graded bunds for 66.48 ha, as detailed in Table 2. In addition, agronomic practices such as contour cultivation, strip cropping, intercropping, crop rotations, and contour vegetative hedges are advised for agricultural lands. These agronomic measures are effective for land slopes up to 2 per cent and in areas where erosion is not a serious issue.

Table: 2 Soil water conservation measures/structures in the Alanda micro watershed

Sr. No.	SWC Measures/Structures	Existing Nos/Area	New proposed Nos/Area
1.	Farm pond	3 nos	5 nos
2.	Check dam	1 nos	4 nos
3.	Continuous contour trenches	-	9.69 ha

4.	Contour bund	96.79 ha	206.45 ha
5.	Graded bund	-	66.48 ha

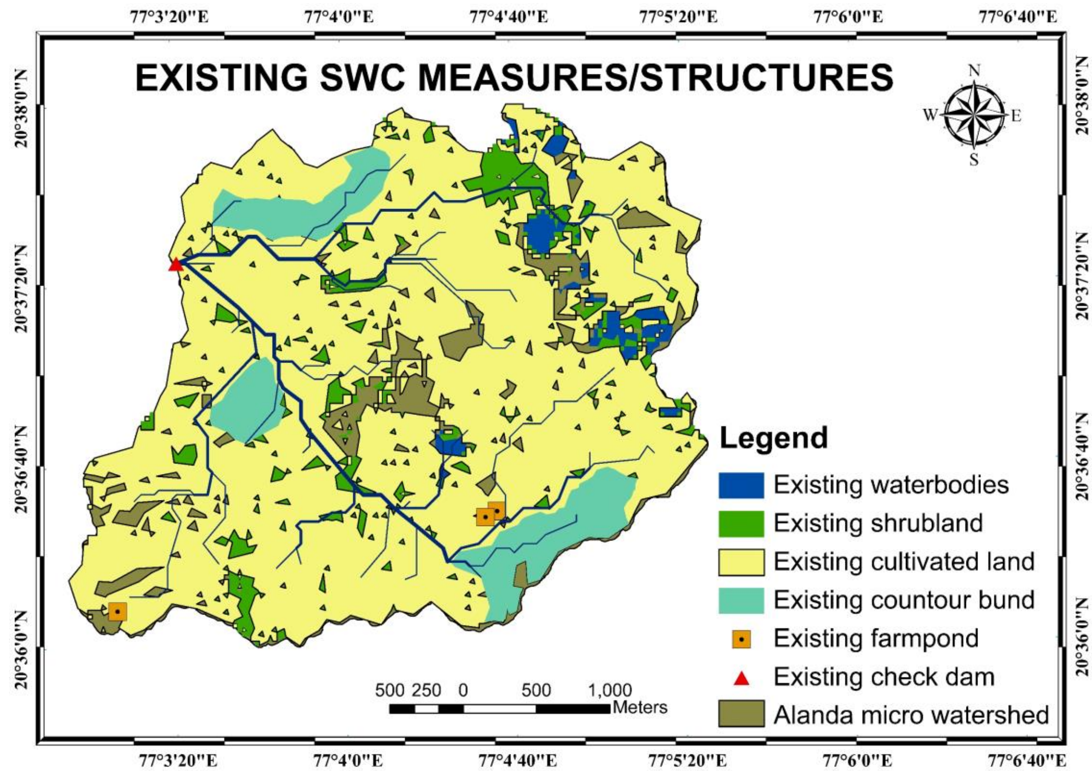

Fig. 2 Existing SWC measures/structures in Alanda micro watershed

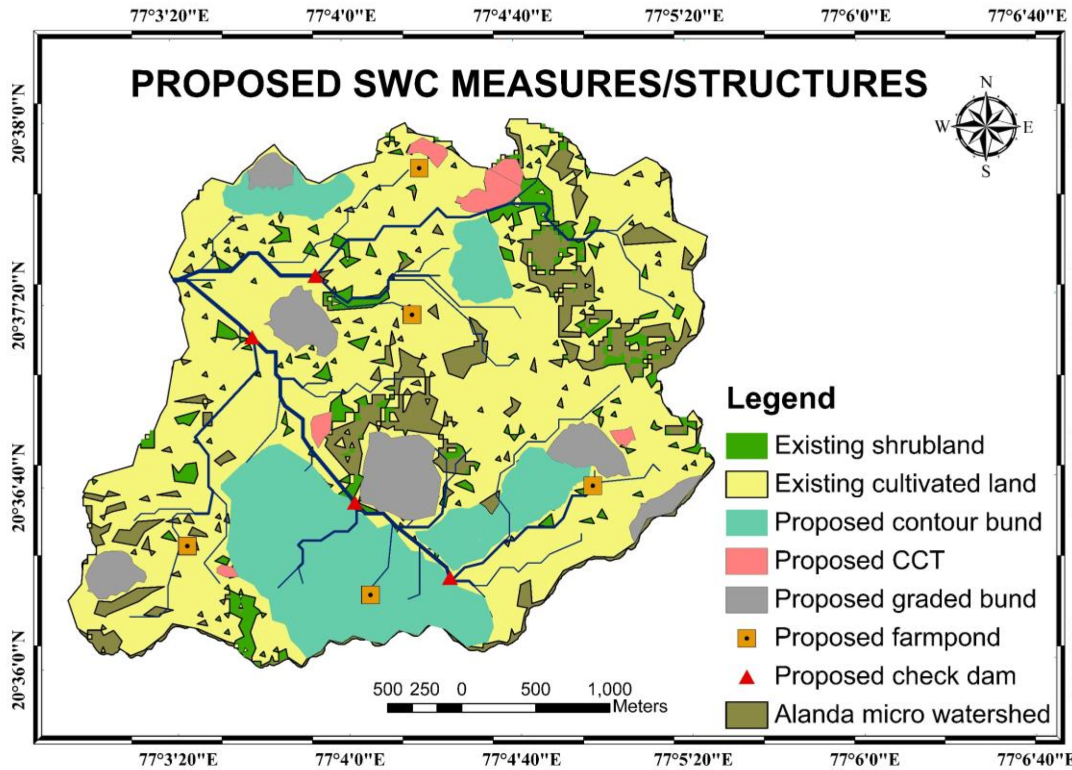

Fig. 3 Proposed SWC measures/structures in Alanda micro watershed

4. CONCLUSION

At present, the study area has 3 farm ponds, 1 check dam and contour bund (96.79 ha) soil and water conservation measures/structures. There is scope to construct an additional 5 farm ponds, 4 check dams, contour bund (206.45 ha), graded bund (66.48 ha) and continuous contour trenches (9.69 ha) in this micro watershed. In this water resources development plan, the renovation of existing water bodies is proposed to increase water availability. Hence, there is a large scope to convert this moderate zone to a high groundwater potential zone in the study area.

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