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SPATIAL ANALYSIS AND INTERVENTION STRATEGIES FOR SUSTAINABLE WATERSHED MANAGEMENT: A CASE STUDY OF MICRO WATERSHED 27K15G

Dilna K S
College of Agriculture, Ambalavayal, Kerala Agricultural University

ABSTRACT

The study focuses on the 27k15g watershed, a sub-watershed of the Kabani River (k), the 27th river from the south, 15th sub watershed and micro watershed 'g' in Wayanad, Kerala (KSLUB, 2024). The main objectives are to control runoff and soil degradation, utilize runoff for beneficial purposes, improve land productivity, and enhance water resources within the watershed. The study likely employed a mixed-methods approach, combining spatial analysis using GIS tools and maps with field observations and socioeconomic data collection (KSPB, 2024). Also, the study involved mapping and spatial analysis, field surveys and socioeconomic data collection. Key findings highlight the influence of spatial factors like slope and existing land use on intervention planning, the importance of considering socioeconomic conditions and community needs for intervention prioritization, and the need for integrating GIS data with field observations for informed decision-making. The study proposes a range of interventions, including arable land interventions, drainage line interventions, livelihood interventions and soil and water conservation interventions. The significance of this study lies in its contribution to sustainable watershed management in the 27K15g watershed and its potential for informing similar efforts in other regions. By identifying site-specific interventions and emphasizing community engagement, the study promotes the efficient use of natural resources, improved land productivity, and enhanced livelihoods for the local population.

KEYWORDS: *Watershed Management, Soil and Water Conservation, Sustainable Land Use, Livelihood Interventions, Kerala, Watershed 27K15g, Meenangadi, Ambalavayal, Sulthan Bathery*

1.INTRODUCTION

Watershed 27k15g, encompassing Ambalavayal, Meenangadi, and Sulthan Bathery, is characterized by laterite soil which is highly prone to erosion, particularly on the steep slopes prevalent in the region. The dominant coffee-based cropping system exposes the land to erosion, especially during periods of intense rainfall *(DES, Kerala ,2024)*. The communities' reliance on agriculture for their livelihoods makes them vulnerable to the impacts of soil erosion, which reduces agricultural productivity and exacerbates the effects of drought conditions *(DES, Kerala, 2024)* that are increasingly impacting the area. This combination of erosion-prone conditions, sensitive crops, and vulnerable livelihoods underscores the urgent need for watershed-based interventions to promote sustainable land and water management practices, enhance agricultural resilience, and improve the well-being of the communities in watershed 27k15g.

Farmers in Ambalavayal, Meenangadi, and Sulthan Bathery are facing significant challenges due to drought conditions. A report by the Wayanad principal agricultural officer states that 90% of local self-government institutions in the district are facing drought, with severe crop damage reported *(The New Indian Express, 2024)*. Water bodies have dried up, leading to water scarcity for both residents and farmers. The drought has caused widespread crop damage, impacting coffee, pepper, and banana cultivations across hundreds of hectares, with paddy and vegetable cultivations also affected *(The New Indian Express,2024)*. This situation has resulted in significant financial losses for farmers, with the report estimating crop damage worth Rs 25 crore *(The New Indian Express, 2024)*.

The watershed-based interventions such as stone bunds, earthen bunds, staggered trenches, and rainwater harvesting pits**,** offer multiple benefits. These interventions will help to control runoff and soil erosion**,** leading to improved water retention, soil health and mitigate drought. Consequently, agricultural productivity can be enhanced, contributing to increased and sustained production**.**

GIS-based interventions enhance these benefits by providing a powerful tool for precise and efficient planning and implementation **(***Prasannakumar et al.,2011*). By integrating various spatial datasets, such as slope, soil type, land use, and rainfall patterns**,** GIS allows for the identification of optimal locations for interventions, maximizing their effectiveness *(Vijith et al., 2008)*. This targeted approach ensures resources are used efficiently and interventions are tailored to the specific needs of the watershed, leading to more sustainable and impactful outcomes *(Smiths et al., 2013*)**.**

2.OBJECTIVE

- Analyze spatial and contextual factors shaping effective watershed interventions.
- Control damaging runoff and degradation, thereby conserving soil and water.
- Protect, conserve, and improve the land of the watershed for more efficient and sustained production

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3.MATERIALS AND METHODS

3.1 Study Area

- **Geographic Location and Climate**: Watershed 27k15g is part of the Kabani river basin, the 27th river from the south in Kerala, Wayanad district *(KSLUB, 2024).*
- **Topography**: The watershed's topography is characterized by varying slopes, influencing land use patterns and susceptibility to soil erosion *(KSPB, 2024).*
- **Soil Characteristics**: The predominant soil type in the watershed is laterite, which is typical of tropical regions with high rainfall.
- **Demographics**: The total population of the watershed is 300,529, with a population density of 384 per square kilometer *(DES, Kerala, 2024)*. The overall literacy rate is 89.32% *(LSGD, 2023).*
- **Socioeconomic Context**: Agriculture is the primary economic activity in the watershed, with major crops including paddy, black pepper, coffee, coconut, ginger, turmeric, tea, and arecanut *(KSPB, 2024)*. This diversity in agricultural practices influences land management decisions and the types of interventions required to promote sustainable livelihoods.

3.2 Data Collection and Fieldwork

- Secondary data: watershed boundaries, soil and slope data, land use data from the Kerala State Land Use Board *(KSLUB, 2024).*
- Primary data: field surveys to document drainage, fallow land, and eroded areas, with photographs.
- Contextual data: local government (population, housing, cropping patterns, water bodies *(LSGD, 2023); (DES, Kerala, 2024)*

Ambalavayal Gramapanchayat

Table 1 – Demographic details of Ambalavayal gramapanchayat (LSGD, 2023)

Specifications	Data
Total number of wards	20
Total area	6065 Ha
Total population	35207
Male	17214
Female	17993
SC	955
ST	5867
Sex ratio	0.95
Population density	580
Number of households	6963
Soil type	Laterite
Elevation	974 m
Cropping pattern	Coffee based
Major crops	Ginger, coffee, pepper, banana, turmeric
Canal	2
Pond	180
Open well	200
Stream	2
Ditches	3
Rainwater harvest pond	1

Sulthan Bathery Municipality

Table 2 – Demographic details of Sulthan Bathery Municipality (LSGD, 2023)

Specifications	Data
Total number of wards	35
Total area	103 sq Km
Total population	45417
Male	22342
Female	23075
SC	1761
ST	5346
Sex ratio	0.97
Population density	416
Literates	88%
Number of households	10230

Soil type	Laterite
Elevation	901 m
Cropping pattern	Coffee based
Major crops	Paddy, pulses, arecanut, nutmeg, ginger,coffee, pepper, turmeric
Canal	10
Pond	230
River	1
Check dam	28
Tube well	317

Meenangadi Gramapanchayat

Table 3 – Demographic details of Meenangadi gramapanchayat (LSGD, 2023)

Specifications	**Meenangadi**
Total number of wards	19
Total area	53.51 sq Km
Total population	35859
Male	16624
Female	16826
SC	908
ST	8283
Sex ratio	1007-1000
Population density	646
Number of households	8199
Soil type	Laterite
Elevation	773
Cropping pattern	Coffee based
Major crops	Paddy, coconut, rubber, coffee, pepper, banana, arecanut, turmeric
Canal	32
Pond	826
Open well	3126
Tube well	200
Ditches	15

3.3 Spatial Analysis

Integrating and Analyzing Diverse Datasets in QGIS for Watershed Management

Integrating and analyzing diverse datasets in QGIS is crucial for effective watershed management. Various maps, including slope, relief, soil depth, soil texture, geomorphology, and land use maps, provide valuable insights into the characteristics of a watershed, like 27K15g *(KSLUB, 2024)*. QGIS, a powerful open-source Geographic Information System (GIS) software, allows users to import, overlay, and analyze these diverse datasets. By integrating these maps, spatial relationships and patterns emerge, informing decisions on appropriate interventions, such as identifying areas prone to erosion based on slope and soil type. This integrated analysis, combined with field observations and community input, enhances the effectiveness of watershed management strategies.

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4.RESULTS

4.1 Spatial Patterns and Contextual Observations

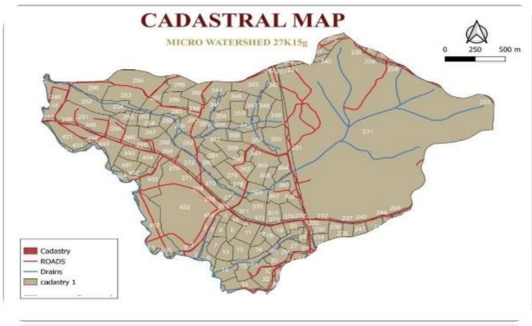

Figure 1 – Cadastral map

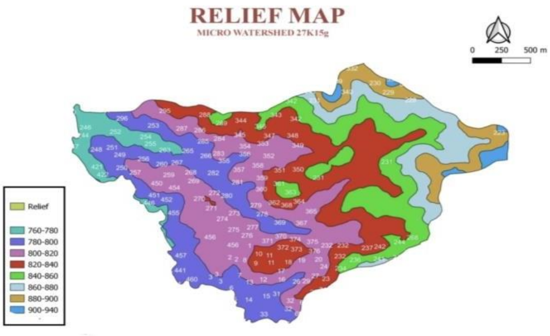

Figure 2 – Relief map

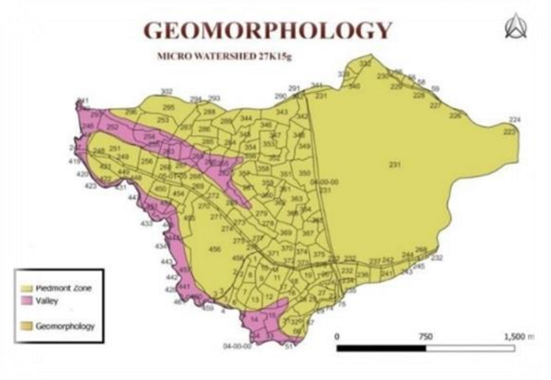

Figure 3 – Geomorphology map

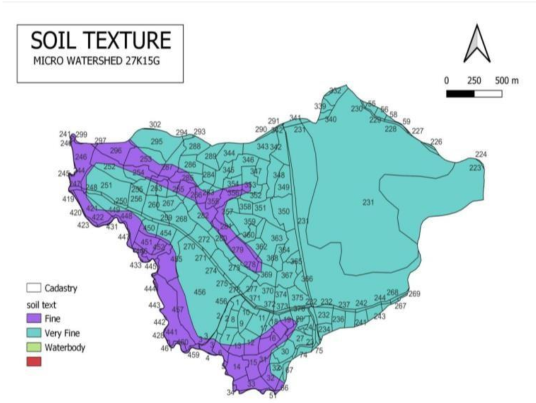

Figure 4- Soil texture map

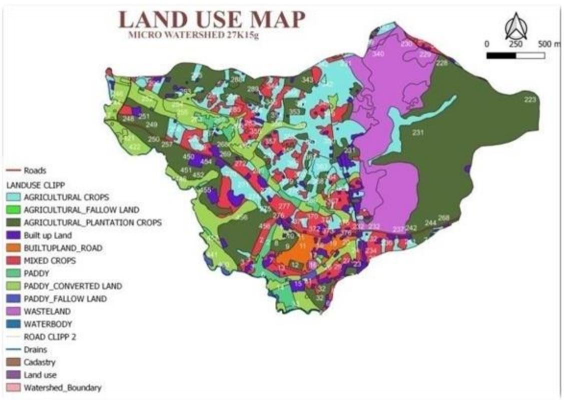

Figure 5 – Land use map

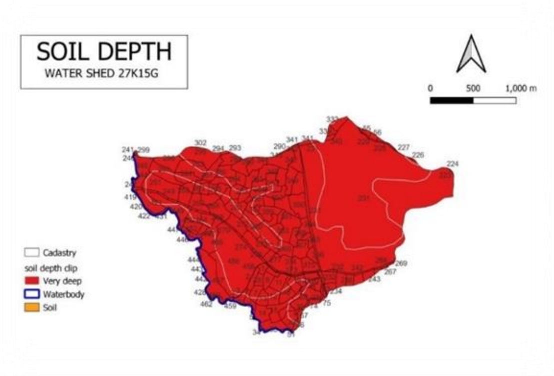

Figure 6- Soil depth map

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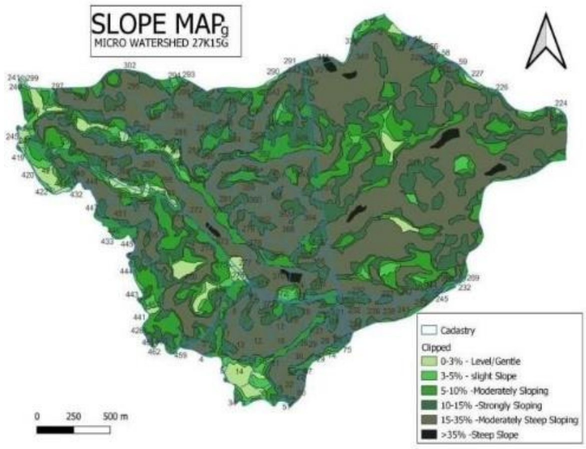

Figure 7- Slope map

Cadastral Map: This map delineates the boundaries of land ownership within the watershed.

Slope Map: The slope map classifies the watershed area based on the degree of slope, which is a crucial factor for planning interventions. For example, the map reveals that the largest portion of the watershed (49.96%) has a moderately steep slope ranging from 15-35%, while only a small area (0.72%) has a steep slope exceeding 35%.1 These steep areas are particularly vulnerable to soil erosion and might necessitate interventions like terracing or agroforestry to stabilize the slopes and reduce runoff.

Relief Map: The relief map visually represents the elevation and topography of the watershed. Understanding the terrain helps in identifying high-altitude areas, valleys, and drainage patterns, which are crucial for planning interventions related to water management, irrigation, and flood control.1

Soil Depth Map: The soil depth map is essential for understanding the soil's capacity to hold water and support vegetation. Areas with shallow soil depth might require interventions like soil conservation measures to improve water infiltration and prevent erosion.

Soil Texture Map: The soil texture map reveals that a significant portion of the watershed (81.20%) comprises very fine soil, while only 18.56% has fine soil.2 Understanding soil texture informs decisions related to crop suitability and soil management practices. For instance, very fine soil might be prone to compaction and require interventions like organic matter addition to improve soil structure and drainage.

Geomorphology Map: The geomorphology map depicts the landforms and geological features of the watershed. This information helps in understanding the watershed's susceptibility to erosion, landslides, and other natural hazards, thus informing interventions aimed at mitigating these risks.

Land Use Map: The land use map illustrates the distribution of different land uses within the watershed, such as forests, agriculture, settlements, and water bodies. Analyzing the current land use patterns is essential for identifying areas suitable for specific interventions. For instance, the map could reveal areas of fallow land suitable for fodder cultivation or degraded forest areas requiring restoration efforts.

Integrating Map Information for Effective Watershed Management

By combining the information from these maps, a comprehensive understanding of the 27K15g watershed can be developed. This integrated analysis can guide the selection and prioritization of interventions that address specific challenges and opportunities in the watershed. For instance, areas with steep slopes, shallow soil depth, and existing land use conflicts might be prioritized for soil and water conservation measures. Conversely, areas with gentle slopes, fertile soil, and proximity to water sources might be suitable for promoting sustainable agricultural practices or developing community-based irrigation systems.

By utilizing these maps in conjunction with field observations and community input, watershed managers can develop more effective and targeted interventions that contribute to the sustainable management of the 27K15g watershed.

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Proposed Interventions for Watershed Management

- **Arable land interventions**

Table 4 – Arable Land Interventions

Survey No.	Soil	Slope	Existing land use	Problem	Interventions	Expected outcome
278	Fine soil	0-3 %	Fallow land	Weed infestation, soil erosion	Weeding and fodder cultivation (Hybrid napier)	Improved soil fertility, reduced erosion, provision of nutritious fodder for livestock
351	Very fine soil	10-15%	Fallow land	Weed infestation and underutilization of land.	Weeding, land preparation and banana cultivation	Improved utilization and income from the land
352	Very fine soil	5-10%	Arecanut field	Weed infestation, YLD and less space utilization	Mixed cropping with ginger, black pepper and vegetables	Enhanced soil fertility and diversification of farm income.
362	Very fine soil	15-35%	Fallow land	Weed infestation and degraded soil	Tapioca cultivation along with cowpea	Increased crop yields, and diversification of farm income.
368	Very fine soil	15-35%	Fallow land	Weed infestation and under-utilized land area	Weeding, land preparation and strip cropping with coffee and calogonia	Reduced soil erosion, increased land suitable for cultivation and improved water management
369	Very fine soil	15-35%	Eroded roadside boundary	Soil erosion	Weeding and side wall construction	Improved pest and disease control, soil erosion control

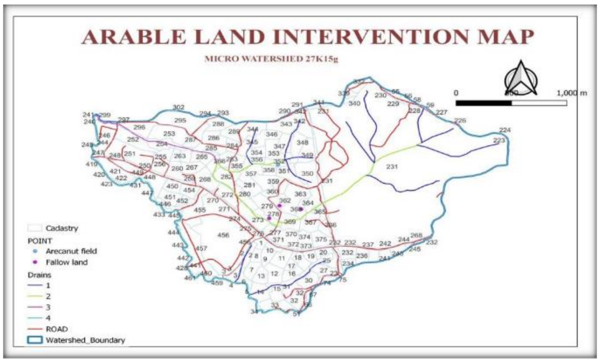

Figure 8- Arable land interventions

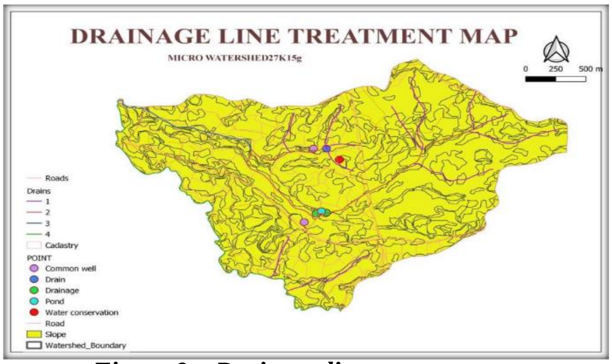

Figure 9 – Drainage line treatment map

Drainage Line Treatment Interventions

Table 5- Drainage line treatment interventions

Survey no	Soil	Slope	Existing land use	Problem	Interventions	Expected Outcome
352	Very fine soil	5-10%	Drain	Unprotected boundary	Maintenance and repair, boundarystrengthening.	Reduced drain bank erosion, improved stability and longevity of drainage structures, and reduced maintenance costs.
278	Fine soil	0-3%	Drain	Heavy weed infestation, unprotected boundary and soil clogging	Weeding and cleaning, construction of side wall	Reduced gully erosion, decreased downstream sedimentation, improved water infiltration, and potential for restoring degraded land.
352	Very fine soil	5-10%	Common well	Algal infestation, torn net covering	Cleaning and provision of net cover	Improved water quality.

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277	Very fine soil	15-35%	Common well	No proper covering, lack of rope and bucket for water collection.	Cleaning, provision of covering net and installation of solar panel motor	Improved water quality, reduced maintenance costs.

Livelihood Interventions

Table 6-Livelihood Interventions

Survey no	Soil	Slope	Existing land use	Problems	Interventions	Expected outcome
363	Very fine soil	10-15%	Fallow land	Weed infestation and soil erosion	Weeding and fodder cultivation	Improved soil fertility, reduced erosion, provision of nutritious fodder for livestock, and potential income generation from surplus fodder.
279	Fine soil	10-15%	Rubber field	Lesser space utilisation	Construction of apiary unit	Increased income diversification, reduced dependence on single crops, potential for value addition and processing, and creation of employment opportunities.
369	Very fine soil	15-35%	pond	Weed infestation and under utilisation	Geotextiles and pisciculture	Increased income, improved nutrition, and potential for integrated aquaculture-agriculture systems (e.g., using pond water for irrigation).

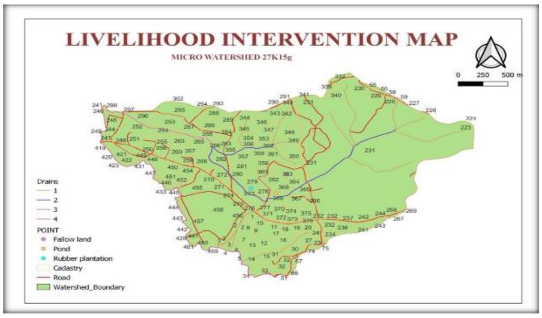

Figure 10- Livelihood intervention map

Soil and water conservation intervention

Table 7- Soil and water conservation intervention

Specific Intervention	Description	Expected Outcomes
Stone Bunds	Constructed across the slope to intercept runoff, reduce soil erosion, and promote water infiltration.	Reduced soil erosion, enhanced soil moisture, improved crop yields, and reduced downstream sedimentation.
Earthen Bunds	Similar to stone bunds, but constructed with earth. They are cost-effective but may require more frequent maintenance.	Reduced soil erosion, improved soil moisture, and enhanced agricultural productivity.
Staggered Trenches	Excavated trenches arranged in a staggered pattern along the contour to slow down runoff, trap sediment, and increase water infiltration.	Reduced runoff velocity, decreased soil erosion, improved soil moisture, and enhanced groundwater recharge.
Rainwater Harvesting Pits	Excavated pits or ponds designed to collect and store rainwater runoff.	Increased water availability for irrigation, livestock, and domestic use. Reduced runoff and soil erosion.
Check Dams	Small dams constructed across gullies or streams to control erosion, reduce peak flows, and promote sediment deposition.	Reduced gully erosion, decreased downstream flooding, improved water availability, and potential for groundwater recharge.

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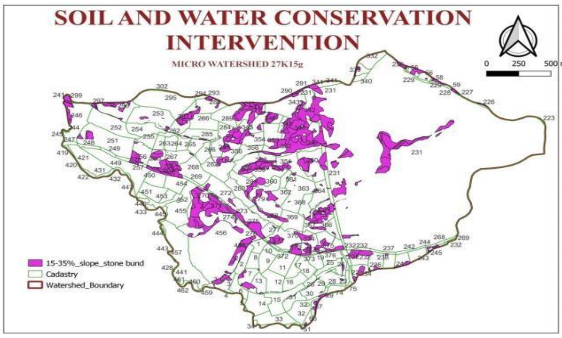

Figure 11- Stone bund intervention map

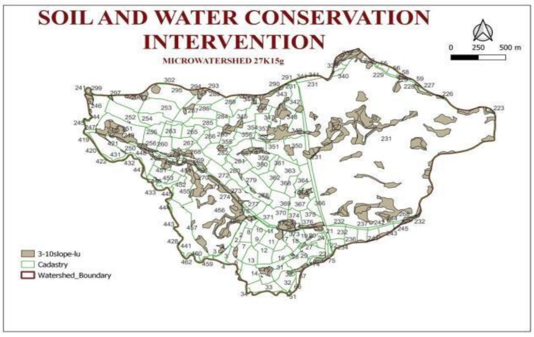

Figure 12-Rainwater harvesting pits map

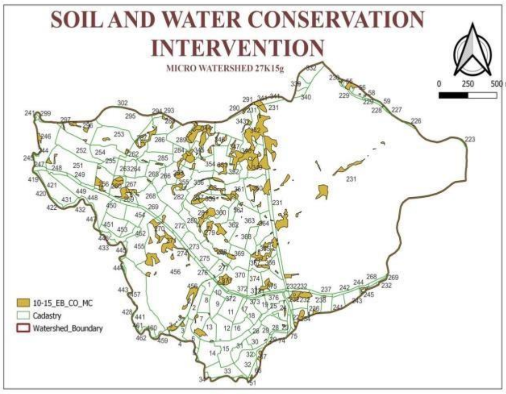

Figure 13- Earthen bund intervention map

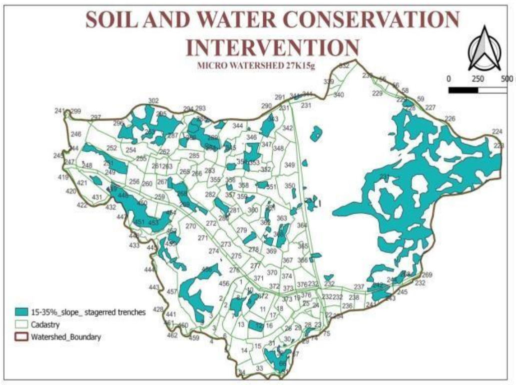

Figure 14- Staggered trenches intervention map

6.DISCUSSION

6.1 Influence of Spatial Factors on Intervention Planning

Spatial factors like slope and land use play a crucial role in determining the type of interventions needed in a watershed. For instance, areas with fallow land and slopes between 10-15% might be suitable for fodder cultivation to prevent soil erosion and provide livestock feed.

6.2 Role of Contextual Factors in Intervention Prioritization

Socioeconomic conditions and community needs are crucial in prioritizing interventions. The data contains the population density, literacy rate, major crops, and cropping patterns of the region, highlighting the importance of understanding the community's reliance on agriculture. Understanding the community's needs ensures that interventions are relevant and sustainable.

6.3 Challenges and Lessons Learned from Integrating GIS with Field Observations

While the source doesn't explicitly discuss the challenges and lessons learned from integrating GIS with field observations, it does provide examples of how spatial data (slope, soil type) is used to inform interventions. Based on common practices in watershed management, some potential challenges and lessons could include:

- **Data accuracy and resolution:** Ensuring that GIS data is accurate and high-resolution is crucial for effective planning. Field observations can be used to verify and refine GIS data.
- **Ground-truthing:** It is important to validate GIS-based plans with field observations. Site visits can help identify practical constraints or opportunities that might not be apparent from the GIS data alone.
- **Community engagement:** Integrating local knowledge and observations with GIS analysis can lead to more effective and locally accepted interventions.

7. CONCLUSION

The study of watershed 27K15g, encompassing Ambalavayal, Meenangadi, and Sulthan Bathery, underscores the critical need for interventions to address the pressing issues of soil erosion, water scarcity, and drought conditions. The study highlights the vulnerability of the region due to its laterite soil, steep slopes, and reliance on coffee-based agriculture. The interventions like construction of stone bunds, earthen bunds, staggered trenches, and rainwater harvesting pits, coupled with the integration of GIS technology for precise planning and resource allocation, hold the promise of mitigating soil erosion, improving water retention, and enhancing agricultural productivity. The successful implementation of these strategies, combined with sustained community engagement, has the potential to transform watershed 27K15g, leading to improved water security, enhanced agricultural resilience, and a better quality of life for the communities in this region *(The Hindu. (2024).*

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