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Assessment of Soil Suitability for Horticultural Crops in the Bada Micro Watershed (4D4F2j05) of Haveri District, Karnataka, India

B. Harshith Surya [a++*], B. R. Jagadeesh [a#], V. B. Kuligod [a#], M. P. Potdar [b#], H. M. Santhosha [c†] and K. Anil Kumar [a++]

[a] Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Dharwad, 580 005, Karnataka, India.
[b] Department of Agronomy, University of Agricultural Sciences, Dharwad, 580 005, Karnataka, India.
[c] Krishi Vigyan Kendra, Hanumanamatti, 581 115, Karnataka, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study was undertaken to assess the land suitability of forest, barren land, agricultural and horticultural land use systems within the Bada micro watershed of Haveri district, which lies in the Northern Transition Zone (Zone 8) of Karnataka. Utilizing a base map (1:7,920) in conjunction with satellite imagery total of eight profiles, two from each land use system were identified and

[++] M.Sc. (Agri.) Student;
[#] Professor;
[†] Scientist (Horticulture);
**Corresponding author: E-mail: harshithsuryabhimala@gmail.com;*

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excavated. The morphological attributes of soil profiles were recorded and horizon wise soil samples were analyzed for their physical and chemical properties by employing standard procedures. Subsequently, the potential of these land use systems for the cultivation of key horticulture crops, namely chilli, tomato, coconut, mango, sapota and guava were assessed by using the limitation method by considering oxygen availability to roots, nutrient availability, rooting conditions, soil toxicity and erosion as primary criteria. The crop suitability maps were generated by utilizing ArcGIS software. The results indicated that across the forest, agriculture and horticulture land use systems suitability for crops were classified from moderately suitable (S2) to marginally suitable (S3). In the study area, 90.34%, 90.34%, 39.45%, 50.89%, 84.06% and 84.06% of the total area was classified as moderately suitable (S2) for the cultivation of chilli, tomato, coconut, mango, sapota and guava, respectively. Conversely, 1.36%, 1.36%, 52.25%, 39.45%, 6.28% and 6.28% of the study area identified as marginally suitable (S3) for these crops, respectively. Whereas, the barren land use (1.36% of total geographical area) was classified as not suitable (N) for mango, sapota and guava cultivation due to pronounced physical limitations that affecting the rooting of crops. Conversely, the barren land exhibits marginal suitability (S3) for the production of chilli, tomato and coconut. These outcomes provides an essential baseline information for identifying specific soil constraints and support the formulation of sustainable crop production strategies within the study region.

Keywords: Soil-site suitability; Bada micro watershed; land use system.

1. INTRODUCTION

The world's arable land is experiencing significant pressure, characterized by rapid urbanization, accelerated desertification and over exploitation driven by anthropogenic activities. The poor soil management practices across cultivated lands have resulted in increased soil erosion, diminished crop productivity and deterioration of soil quality (Pimentel and Burgess, 2013). As the sustainability of agricultural practices fundamentally depends on the effective utilization of land resources, there is a heightened focus on land evaluation to identify the most suitable land use alternatives. Land evaluation constitutes a systematic assessment of land suitability for specific purposes such as the cultivation of crops. This process entails a comprehensive analysis of various factors, including soil and topographical properties to inform sustainable and effective land use planning. The primary objective of land evaluation is to align the inherent characteristics of the land with the specific demands of intended uses, thereby optimizing productivity while concurrently mitigating adverse environmental effects. To evaluate the suitability and limitations of a specific piece of land for cultivation purposes, it is imperative to employ a scientific approach of land evaluation.

Land suitability evaluation is a critical component in land use planning, as it entails the assessment of land's capacity to support various existing and potential uses (Sehgal, 1995). Soil properties and site characteristics are pivotal in categorizing land suitability into classes such as Highly Suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3) and Not Suitable (N) for specific crops. This classification facilitates strategic planning aimed at expanding the cultivation area of the respective crop. Sharma *et al*. (2001) emphasized that analyzing the interplay between soil and site attributes alongside crop requirements forms the basis for determining soil suitability and formulating effective land use plans. The process of land evaluation comprises four key stages: (a) the characterization of existing soil, climatic and land use conditions; (b) the development of soil-site criteria based on crop requirements; (c) the comparison of crop requirements with prevailing soil and climate conditions; and (d) the final selection of the most appropriate crop as an alternative cropping strategy. Consequently, the assessment of soil-site suitability is essential for determining viable crop options within a specific region and its associated climatic context.

A land use system can be defined as the practices adopted on a particular tract of land, which substantially impacts soil fertility. Assessing the various land use systems for soil-site suitability is crucial for determining optimal management strategies to site specific conditions. The Bada micro watershed (4D4F2j05) with an area of 592.62 ha is situated in the Haveri district of Karnataka state was selected as a representative unit for evaluating

soil-site suitability for horticulture crops across different land use systems.

2. MATERIALS AND METHODS

The research was carried out during the year 2024 in the Bada micro watershed (4D4F2j05), located in the Haveri district of Karnataka state (Fig. 1). Geographically, the micro watershed lies between 14˚ 55' 30" - 14˚ 58' 0" North latitudes and 75˚ 11' 45" and 75˚ 14' 0" East longitudes. The total area encompassed by the micro watershed is approximately 592.62 hectares. The study area is classified within the Northern Transition Zone (Agroclimatic Zone 8) of Karnataka state, characterized by an elevation range of 450 to 900 meters above mean sea level. The zone experiences an average annual rainfall varying between 620 and 1025 mm.

A preliminary survey was conducted across the entire study area using a 1:7,920 scale base map in conjunction with satellite imagery. Total of four distinct land use systems were identified (Fig. 2). Within each land use system, two representative soil profiles were selected for detailed examination and analysis. The morphological attributes of excavated soil profiles were systematically recorded and physical and chemical properties of horizon wise soil samples were analyzed by employing standard procedures by following Keys to soil taxonomy (Anon., 2022).

Subsequent to comprehensive soil survey and laboratory analysis, the data was subjected to the suitability studies. The assessment of crop suitability was employed using the limitation method, which considers both the quantity and intensity of limiting factors, as described by Naidu *et al*. (2006). The evaluation process comprises three distinct phases.

In the initial phase, data collection focused on a range of attributes as detailed in Table-1. Soil site characteristics categorized as oxygen availability to roots (soil drainage), nutrient availability (surface texture, soil pH, cation exchange capacity, base saturation, free calcium carbonate and organic carbon), rooting conditions (soil depth and coarse fragments), soil toxicity (salinity and sodicity) and erosion (slope).

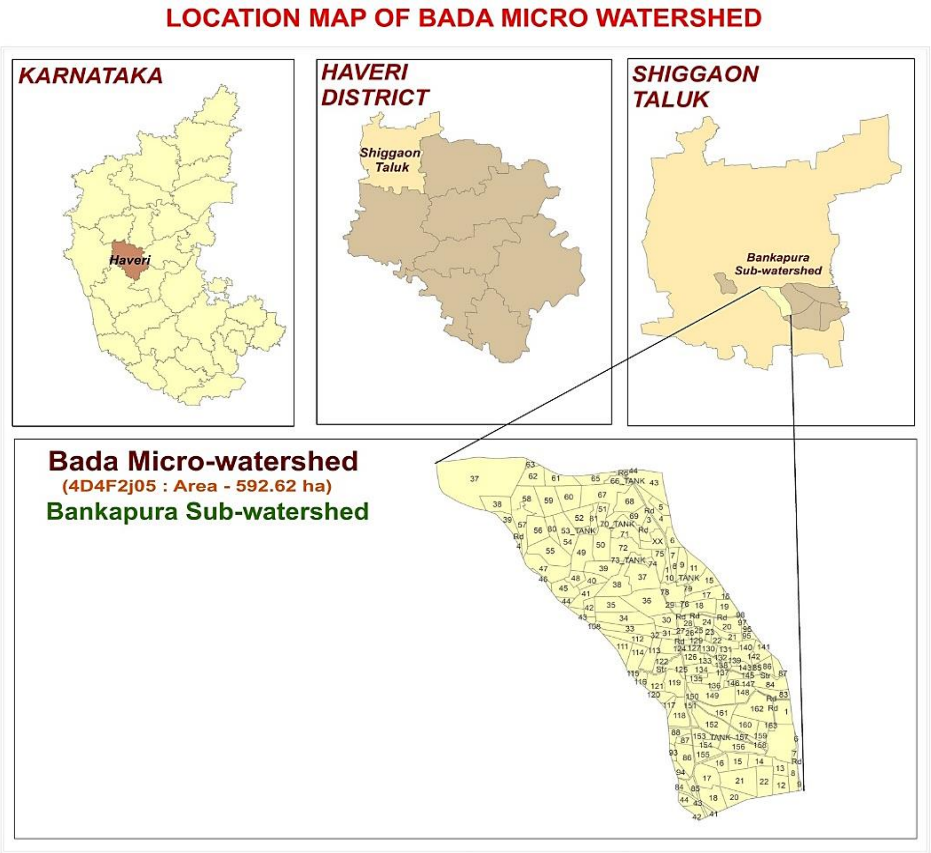

Fig. 1. Location of the study area

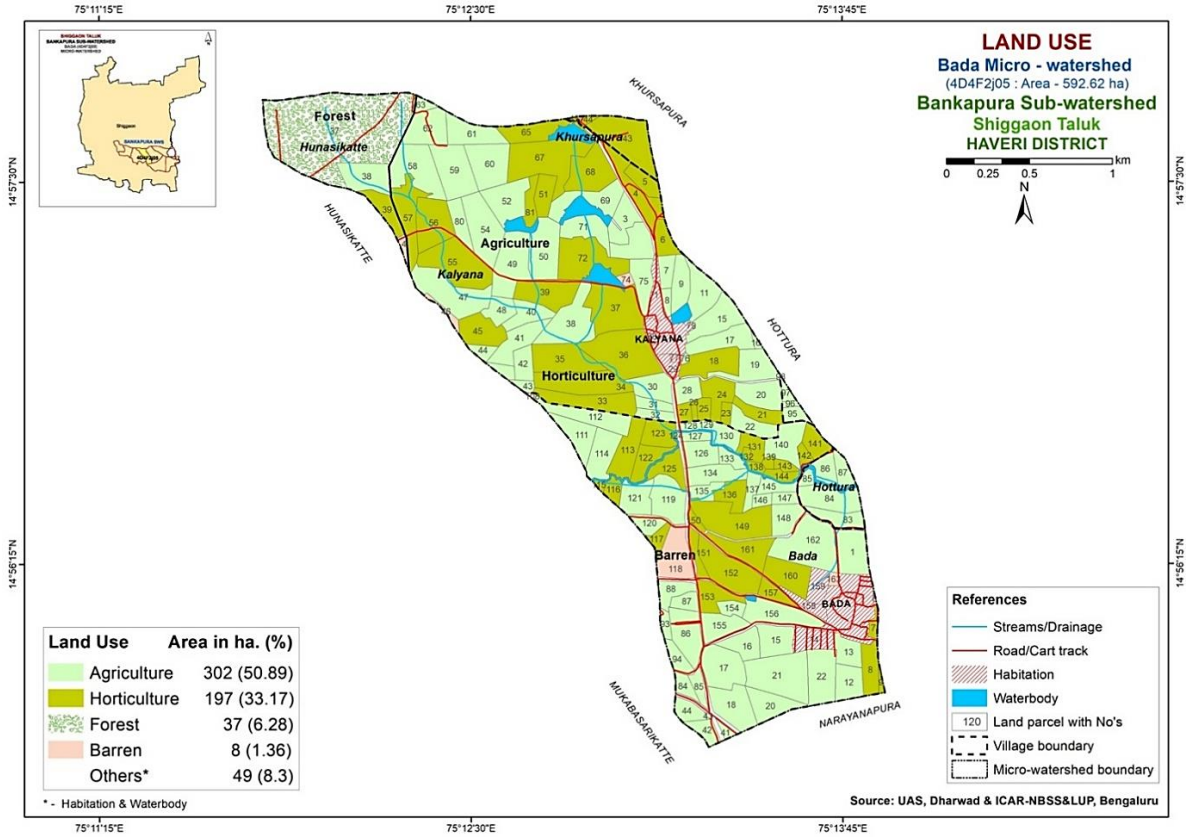

Fig. 2. Land use systems of the Bada micro watershed

Table 1. Soil site characteristics of pedons under different land use systems for soil site suitability evaluation

Soil properties	Land use			
	Forest	Barren land	Agriculture	Horticulture
	Oxygen availability to roots			
Soil drainage	Moderately well	Moderately well	Moderately well	Moderately well
	Nutrient availability			
Surface texture	Clay	Clay	Clay	Clay
pH*	6.43	8.39	7.68	7.31
CEC [cmol (p^+) kg^{-1})*	56.97	16.34	46.95	48.21
BS (%)*	53.16	77.20	86.07	81.80
Free $CaCO_3$ (g kg^{-1})*	1.29	4.33	3.56	2.64
OC (g kg^{-1})*	7.79	1.88	4.38	5.53
	Rooting conditions			
Soil Depth (cm)*	103	85	135	105
Coarse fragments (%)	15-35	35-60	<15	<15
	Soil toxicity			
Salinity - EC (1:2.5) (dS m^{-1})*	0.15	0.40	0.24	0.28
Sodicity - ESP (%)*	3.14	2.89	4.28	5.25
	Erosion			
Slope (%)	1-3	3-5	0-1	1-3

**Weighted average value*

In the second phase of the study, the landscape and soil requirements for six crops were derived from the NBSS and LUP manual by Naidu *et al*. (2006). The third phase involves assessing soil-site suitability by comparing landscape and soil characteristics with crop requirements, considering different suitability orders: Highly suitable (S1), Moderately suitable (S2), Marginally suitable (S3) and Not suitable (N) in accordance with the FAO framework (Anon., 1976). Further, crop suitability maps for major horticulture crops in the Bada micro watershed were generated by utilizing ArcGIS version 10.8.2.

3. RESULTS AND DISCUSSION

The soil characteristics within the study region were evaluated in relation to the soil-site suitability criteria established for the few horticultural crops which were usually cultivated in the northern part of Karnataka. The Table-2 presents the assessment of soil-site suitability for major horticultural crops.

3.1 Chilli

Chilli (*Capsicum annuum* L.) is a widely cultivated and adaptable spice crop, recognized for its pungency and its unique flavour. It is extensively employed in culinary applications worldwide. In India, chilli cultivation is distributed across several states, with significant production concentrated in Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu and Gujarat. These regions offer favourable warm climatic conditions and soil properties suitable for chilli cultivation.

This study evaluated the suitability of pedons across various land use systems for chilli cultivation, classifying them within the range of moderately suitable (S2) to marginally suitable (S3) (Fig. 3). The findings indicated that pedons under forest land were categorized as suitability class S2, subclass S2gt, with principal limitations related to soil drainage, texture and gravelliness. Pedons under agricultural and horticultural land uses were also assigned to class S2, subclass S2nt, reflecting significant constraints including soil drainage, texture, pH and organic carbon content. Conversely, barren land pedons were classified as suitability class S3, subclass S3gn, primarily restricted by soil pH, organic carbon and gravelliness. Supporting these results, Narsaiah*et al*. (2020) reported that soils in the central and eastern regions of Warangal district, Telangana, exhibited marginal suitability (S3) for chilli cultivation. This marginal classification was mainly due to factors such as medium soil texture, slight variations in pedon depth and clay content, the presence or absence of coarse fragments and soil physical and fertility characteristics, including pH and organic carbon levels. Similarly, the Chikkumbi-3 micro watershed region was categorized as moderately suitable (S2) to marginally suitable (S3) for chilli cultivation. The primary constraints affecting suitability were determined to be soil texture, calcium carbonate concentration and climatic factors (Vyas *et al*., 2024a).

3.2 Tomato

Tomato (*Solanum lycopersicum*) represents a significant vegetable crop widely cultivated throughout India, fulfilling demands for both fresh consumption and processing. It is highly valued for its considerable nutritional value, notably its content of vitamin A and ascorbic acid. The cultivation of tomato is feasible across the majority of Indian states and demonstrates optimal growth in fertile loam soils characterized by a moderate sand fraction in the topsoil, which facilitates sufficient drainage and aeration.

Table 2. Soil-site suitability classification for major horticulture crops in the Bada micro watershed

Crop	Land use			
	Forest	**Barren land**	**Agriculture**	**Horticulture**
Chilli	S2gt	S3gn	S2nt	S2nt
Tomato	S2gt	S3g	S2nt	S2nt
Coconut	S2gt	S3gn	S3n	S2nt
Mango	S3gr	N	S2gnrt	S3r
Sapota	S3g	N	S2gnrt	S2grt
Guava	S3g	N	S2gnt	S2gt

Note: S1 – Suitable, S2 – Moderately suitable, S3 – Marginally suitable, N – Not suitable; g – Gravelliness, l – Topography, n – Nutrient availability, r – Rooting condition, t – Texture

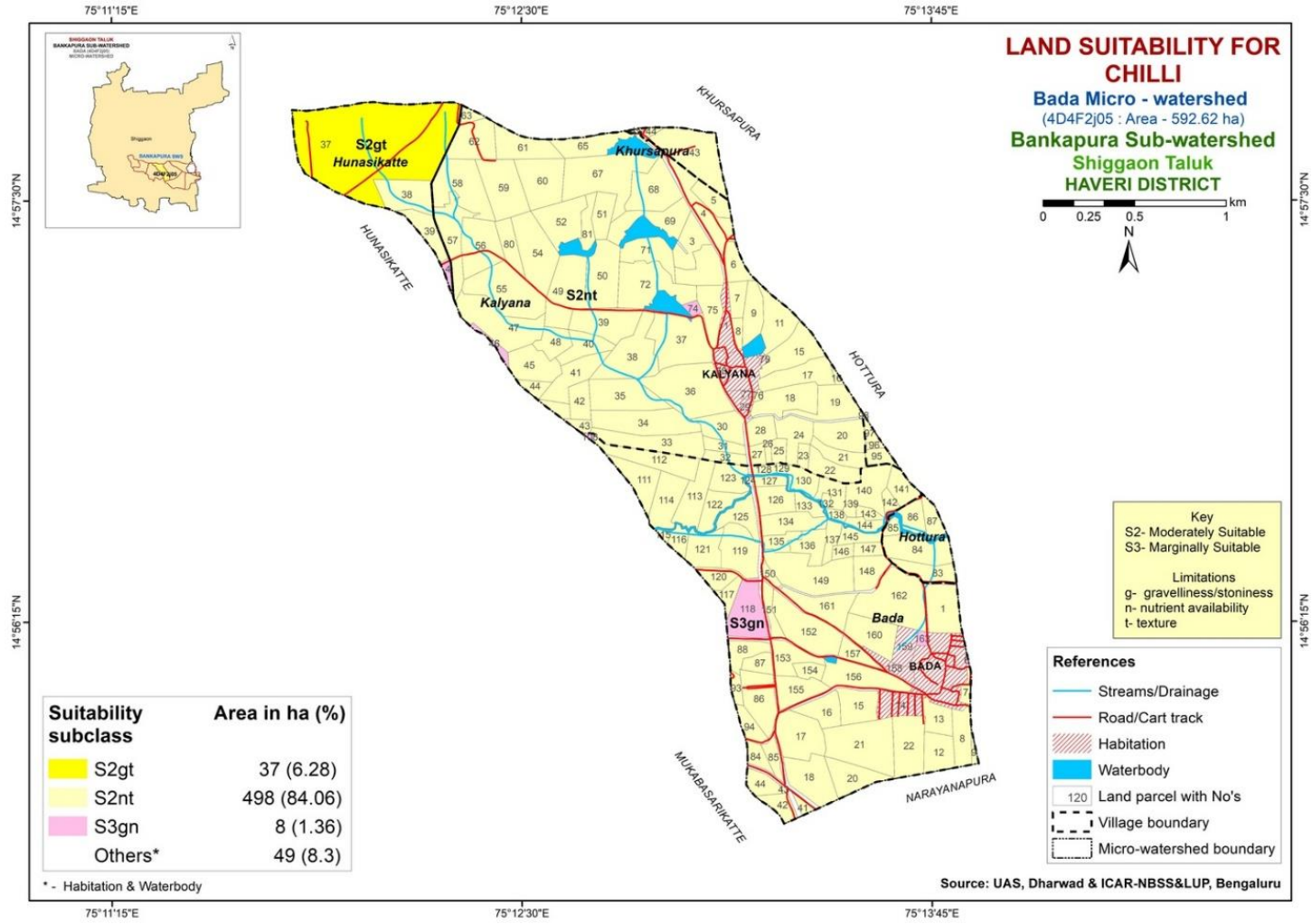

Fig. 3. Soil-site suitability map for chilli crop in Bada micro watershed

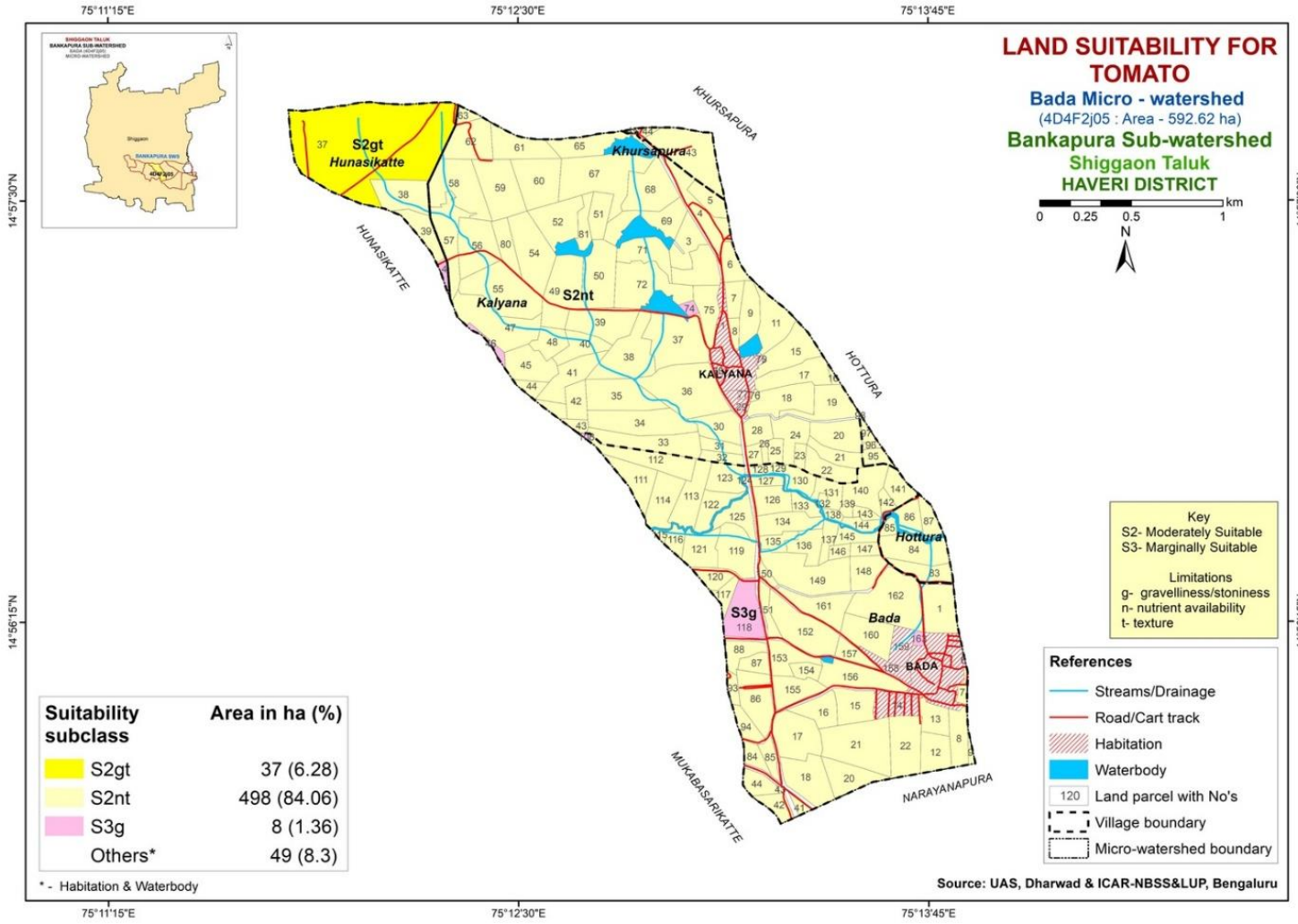

Fig. 4. Soil-site suitability map for tomato crop in Bada micro watershed

An assessment of soil suitability for tomato cultivation across various land use systems indicated classifications ranging from moderately suitable (S2) to marginally suitable (S3) (Fig. 4). Agricultural and horticultural lands were categorized under suitability class S2, subclass S2nt, with primary limiting factors identified as soil drainage, texture and pH. Forest land use was also assigned to class S2, subclass S2gt, where key constraints included soil drainage, texture and gravelliness. Barren lands fell into class S3, subclass S3g, predominantly limited by gravelliness. The soil suitability assessment by Denis *et al*. (2016) in Singhanhalli- Bogur micro watershed revealed that the entire study area is moderately suitable (S2) for tomato production. Yadav and Patil (2025) reported that the majority of the Ganjigatti sub-watershed was classified as moderately (S2) to marginally suitable (S3) for tomato cultivation, exhibiting moderate to severe limitations related to soil drainage, texture, depth and gravelliness. Patil *et al*. (2008) identified comparable limitations affecting tomato cultivation in the Koppal district.

3.3 Coconut

Coconut (*Cocos nucifera* L.) is a plantation crop primarily grown for its oil and edible products. It is chiefly cultivated in tropical coastal regions and island ecosystems. The coconut palm demonstrates adaptability to a wide range of soil types, encompassing coastal sandy and clay soils, lateritic, loamy, black, reclaimed marshy and coral soils. Optimal growth conditions necessitate a water table depth within three meters, effective soil drainage and the absence of a hard substratum within one meter of the soil surface.

A comprehensive evaluation of soil and its site characteristics across diverse land use systems was undertaken to ascertain their suitability for coconut cultivation. The suitability classifications ranged from moderately suitable (S2) to marginally suitable (S3) (Fig. 5). Notably, forest and horticultural lands were categorized within the S2 class, with subclasses S2gt and S2nt, respectively. In both land use types, soil texture and drainage were identified as primary limiting factors, accompanied by gravelliness in forest soils and soil pH as constraint in horticultural soils. Conversely, agricultural and barren lands were assigned to the S3 class, with subclasses S3n and S3gn, respectively, indicating soil pH and gravelliness as critical limiting factors for coconut cultivation. The findings of Kabber*et al*. (2024) corroborate these results, demonstrating that areas such as Krishnarajapete and Arasikere possess moderately suitable (S2) lands for coconut, whereas other regions exhibit more pronounced limitations related to drainage or soil fertility, thereby resulting in marginal suitability classifications. Similarly, findings by Agcaoili (2023) documented that 420,000 hectares of the study area were found as suitable for coconut production.

3.4 Mango

Mango (*Mangiferaindica*), often referred to as the "king of fruits," is well-suited to tropical and subtropical environments and can grow at altitudes up to 1500 meters above sea level. This fruit is cultivated across nearly all Indian states, contributing to approximately 56 per cent of the world's total mango production. The states of Andhra Pradesh, Uttar Pradesh, Bihar, Karnataka, Maharashtra, West Bengal and Gujarat collectively account for about 82 per cent of India's mango production.

A comprehensive evaluation of soil pedons across different land uses was conducted to assess their suitability for mango cultivation. The suitability was classified on a scale ranging from moderately suitable (S2) to not suitable (N) (Fig. 6). Soils under agricultural land use were classified as S2, with a subclass designation of S2gnrt, indicating primary limitations related to soil drainage, texture, pH, organic carbon content, depth and gravelliness. In contrast, soils from horticultural and forest land uses were assigned to class S3, with subclasses S3r and S3gr, respectively, reflecting significant constraints such as limited soil depth in horticultural lands and both restricted depth and high gravelliness in forest lands. Barren land pedons were categorized as not suitable (N), with gravelliness and rooting depth as the principal limitations, followed by deficiencies in organic carbon and soil depth. Furthermore, soil series from the Chikkumbi-3 micro watershed in Dharwad district have been classified as unsuitable (N) for mango cultivation due to pronounced physical constraints, including inadequate rooting conditions and insufficient moisture availability (Vyas *et al*., 2024b). Furthermore, soil series from the Ganjigatti sub watershed were not suitable (N) for mango production, due to severe restrictions in soil depth and slope gradient (Yadav *et al*.,2023).

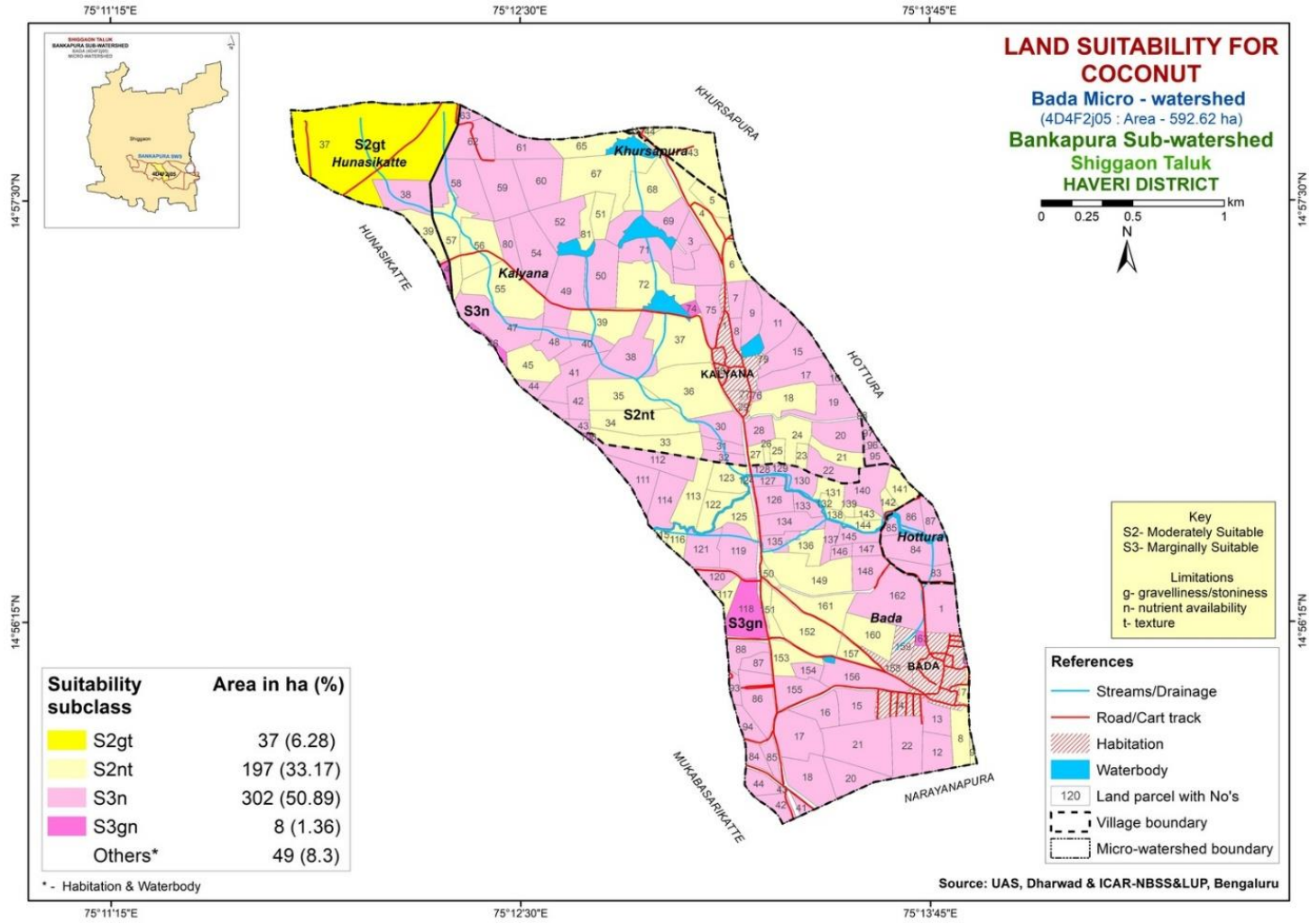

Fig. 5. Soil-site suitability map for coconut crop in Bada micro watershed

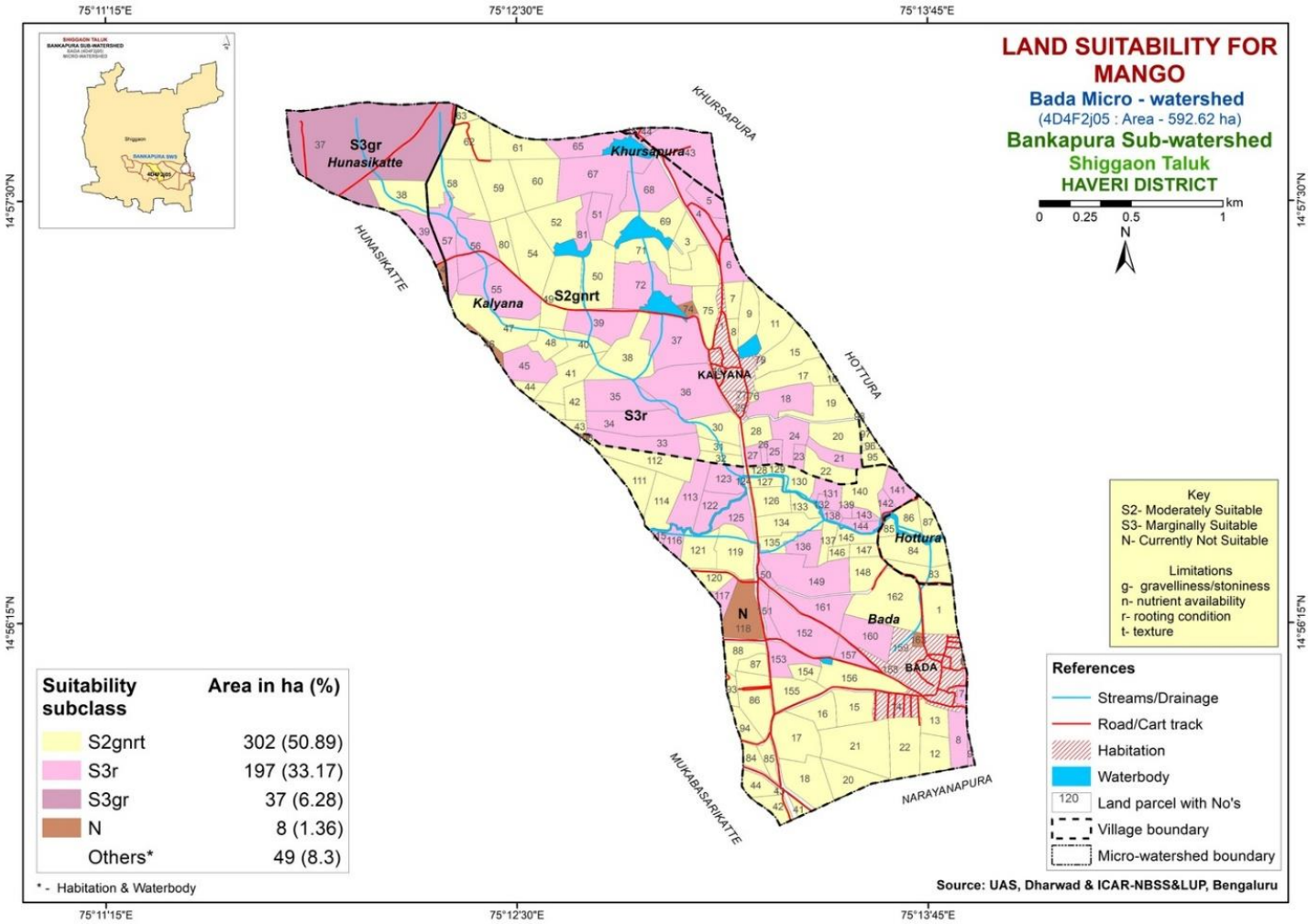

Fig. 6. Soil-site suitability map for mango crop in Bada micro watershed

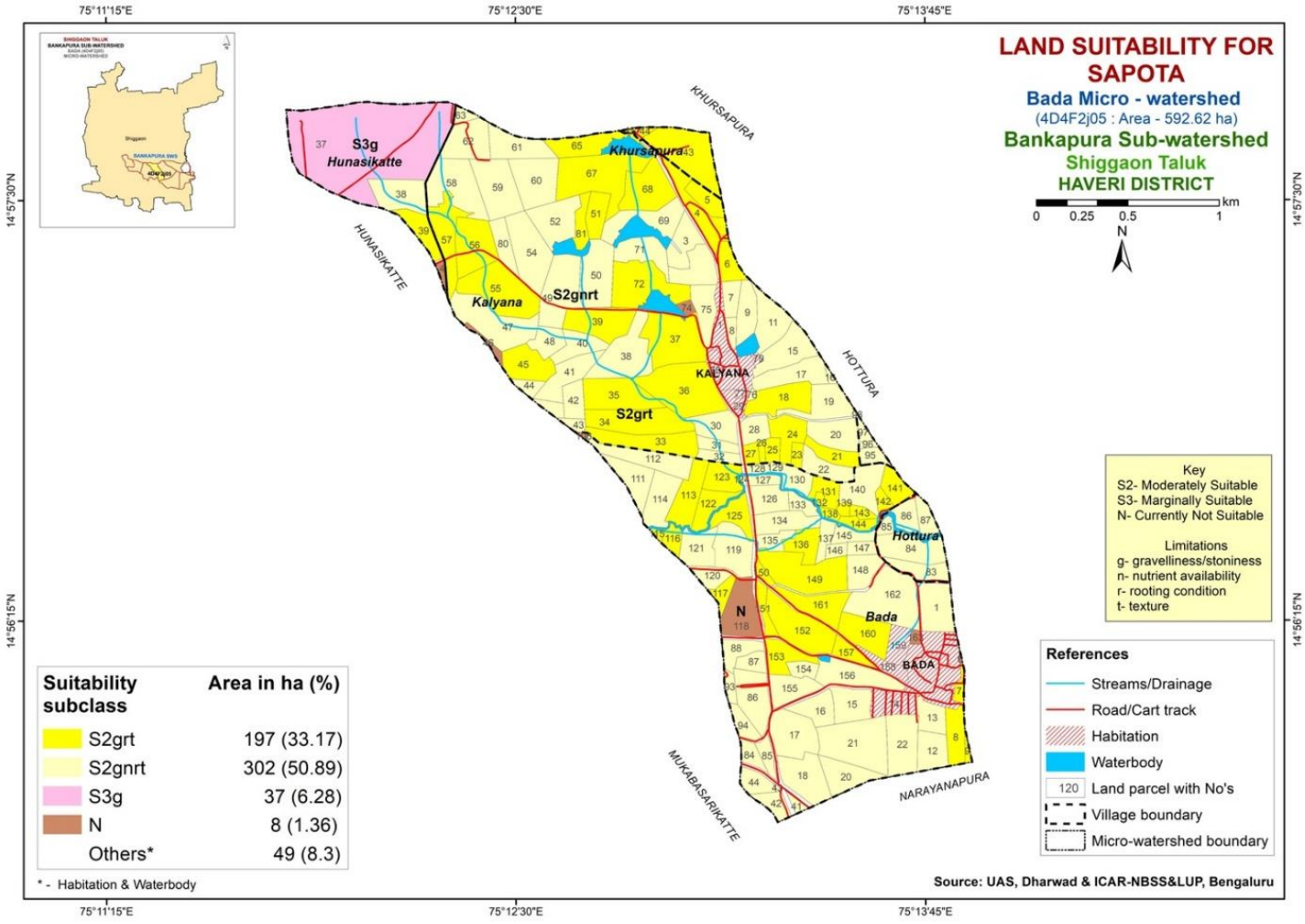

Fig. 7. Soil-site suitability map for sapota crop in Bada micro watershed

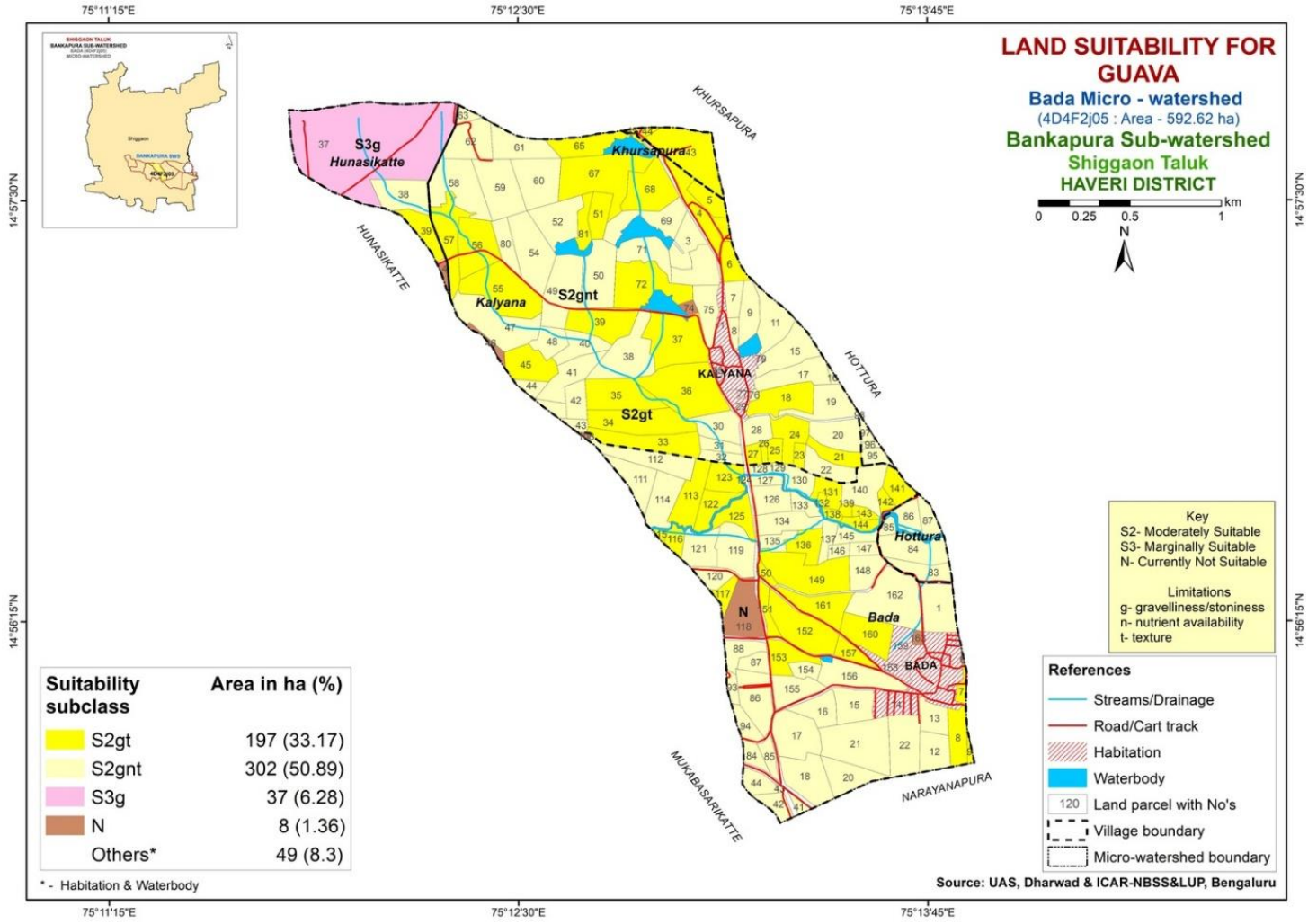

Fig. 8. Soil-site suitability map for guava crop in Bada micro watershed

3.5 Sapota

Sapota (*Manilkarazapota*), commonly known as chiku, is a tropical fruit bearing tree native to Central America and widely cultivated in various regions worldwide. In India, sapota cultivation is predominantly concentrated in the states of Maharashtra, Gujarat, Tamil Nadu, Karnataka and Andhra Pradesh. These regions provide the ideal environmental conditions preferred by sapota trees, characterized by warm climatic temperatures and well drained sandy loam soils with a pH between 6.0 and 8.0.

The study analyzed soil-site suitability for sapota cultivation across various land use systems, categorizing the land from moderately suitable (S2) to not suitable (N) (Fig. 7). Findings indicated that horticultural and agricultural lands were classified within the S2 suitability class, specifically subclasses S2grt and S2gnrt, respectively. These classifications were predominantly influenced by limitations related to soil drainage, texture, depth and gravelliness in both land uses, with soil pH additionally constraining agricultural lands. Forest areas were assigned to suitability class S3, subclass S3g, characterized by significant gravelliness related limitations. Barren lands were designated as class N, deemed unsuitable for sapota cultivation due to limited rooting depth, which impeding land productivity. Within the Bantanahalli micro-watershed of Davangere district, soils were identified as moderately suitable (S2) for sapota cultivation over 254 hectares and marginally suitable (S3) over 212 hectares, primarily constrained by factors such as limited rooting depth and gravel presence (Anilkumar*et al*., 2017). Similarly, Basavaraj *et al*. (2022) reported that 71.01 per cent of soils in the Dabarbad sub watershed were currently not suitable (N) for cultivating sapota, attributed to severe limitations in rooting depth, soil texture and topographical features. Prathibha*et al*. (2019) documented similar observations regarding the limitations associated with rooting conditions.

3.6 Guava

In India, guava (*Psidium guajava*) is widely cultivated in multiple states such as Uttar Pradesh, Maharashtra, Gujarat, Karnataka and Tamil Nadu. These regions provide optimal conditions for guava cultivation, featuring warm climatic temperatures and well drained soils that vary from sandy loam to clay loam, with pH levels between 5.5 and 7.5.

Evaluation of soil-site suitability for guava orchard cultivation across various land use types indicated a classification range from moderately suitable (S2) to not suitable (N) (Fig. 8). The analysis identified horticultural and agricultural lands as falling within the S2 suitability class, specifically subclasses S2gt and S2gnt, with primary limitations associated with soil drainage, texture, pH and gravelliness. Forest lands were classified under suitability class S3, subclass S3g, where gravelliness was recognized as the principal constraint. Soils in barren land use areas were categorized as class N, denoting unsuitability for guava cultivation, primarily due to lower rooting depth and high gravel content. Vyas *et al*. (2024b) reported that the Chikkumbi-3 micro watershed in Dharwad district demonstrates moderate to marginal suitability for guava cultivation. Kumar *et al*. (2021) revealed that about 22.2 and 54.3 per cent of study area comes under class S2 and S3, respectively for guava cultivation. Amara *et al*. (2014) documented comparable findings in the Singhanhalli-bogur micro watershed.

4. CONCLUSION

The study concluded that soils within various land use systems of the Bada micro watershed exhibit varying levels of suitability for cultivating crops such as chilli, tomato, coconut, mango, sapota and guava. Specifically, barren land use systems were deemed unsuitable for the production of fruit crops including mango, sapota and guava due to rooting depth limitation. While, forest land use was classified as marginally suitable for growing mango, sapota and guava. The primary constraints identified across forest and barren land is gravelliness, whereas nutrient availability in agriculture and horticulture land uses. The severity of these limitations ranged from slight to very severe depending on the land use system. Moreover, the integrated application of organic manures alongside inorganic fertilizers is recommended, as this approach not only facilitates sustainable crop yields but also preserves soil health for future generations, thereby mitigating soil degradation and contributing to the enhancement of farmers' income.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image

generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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