Assessment of soil-site suitability for major horticulture crops in Chikkumbi-3 micro-watershed (4D7C5O2f), Karnataka using remote sensing and GIS techniques

Abstract

Detailed soil resource inventorization was carried out at 1:7,920 scale in Chikkumbi-3 microwatershed, savadatti taluk, Belagavi district with an objective to assess the land suitability for various horticultural crops in the watershed. The soils of Chikkumbi-3 micro-watershed are characterized and classified into 3 soil series (CLK, CKB and HNL) comprising of 5 mapping units. The soil site characteristics and climatic factors were evaluated for its suitability for major horticultural crops viz., tomato, cabbage, chilli, rose, jasmine and coconut. The analysis revealed that the soil series CLK (Chulki), CKB (Chikkumbi), and HNL (Hanchinal) are presently not suitable for growing coconut due to significant limitations in physical conditions, rooting, and moisture. However, the region is deemed moderately to marginally suitable for the cultivation of tomato, cabbage, chilli, rose and jasmine. The main limitations in all the soil series found to be texture, $CaCO_3$ content and climatic factors. These findings serve as foundational data for identifying specific soil constraints, aiding in the development of sustainable strategies for crop production in the study area.

Key words: Crop suitability classification, ArcGIS, Chikkumbi-3 micro-watershed.

Introduction

The country's most crucial natural resources are land and water, which are currently facing significant strain as a result of escalating biotic pressure (Wani and Sidhu, 2009). Efficiently managing these resources while minimising negative effects on the environment is crucial, not only for achieving sustainable development but also for ensuring human life. A watershed is an optimal unit that requires a multidisciplinary strategy to manage resources in order to provide ongoing sustainable benefits. Integrated watershed management is essential for the preservation and safeguarding of land, water, and degraded regions to ensure the conservation and protection of biodiversity and genetic resources for future generations. The process of mapping land resources is crucial for effective resource management. It aids in the strategic preparation for future land utilisation, especially in agriculture, since it evaluates the land's resources and its capacity for long-term sustainable agricultural output. The productivity of a crop is mostly influenced by the land resources and the current climatic conditions at the region. In order to improve output and productivity, it is crucial to identify the specific needs of crops and fulfil them using the resources that are already accessible. This is particularly important given the current demands for food (Sehgal, 1996). To improve or sustain the current level of productivity, the management of land resources must adhere to specific principles. Conducting a soil resource inventory is a crucial step in obtaining the necessary information regarding the potential and limitations of these resources. This information is essential for achieving optimal utilization through the characterization and evaluation of land resources (Prabhavati et al., 2017).

Land suitability evaluation is a fundamental step in land use planning, as it involves assessing the capacity of land to support various current and alternative uses (Sehgal, 1995). The integration of soil characteristics with climate and land use is observed. The characteristics of soil and site play a crucial role in determining the level of suitability for land use and aid in the strategic planning of expanding the cultivation area for a specific crop. According to Giri et al. (1994), Singh et al. (1998), and Sharma et al. (2001), The examination of the relationship between soil and site characteristics, as well as crop requirements, serves as the foundation for assessing soil suitability and developing effective land use plans (Vyas et al., 2024). Every crop necessitates distinct soil site characteristics to thrive. In order to optimise use, it is necessary to assess the appropriateness of the soil site for various crops. In order to do this, a thorough inventory of land resources was conducted in the Chikkumbi-3 micro-watershed, located in the Savadatti Taluk of the Belagavi district.

2. Material and Methods

2.1 Study area

Chikkumbi-3 micro-watershed is located in Savadatti taluk of Belagavi district. The microwatershed with total area of 514 hectares lies between 16º 6′ – 16º 7′ North latitudes and 75º 12′ – 75º 14′ East longitude. The elevation of the area is 900 m above mean sea-level (MSL).

The slope ranges from 3-5 per cent (gently sloping). The physiography of the watershed can be broadly divided into uplands (summit and ridge top), side slopes and colluvial valley/lowlands. Rolling to steep sloping land covers around 70% of the area in this micro watershed. It comes under Northern Dry Zone (Zone -3) with the annual precipitation ranges from 278-441 mm. The average annual temperature is 24.68 to 26.67 °C. Natural vegetations of this area are Jack fruit, Neem, Jali, Banni, Touch me not and other thorny plants and creepers with grass cover below.

2.2 Base map used

A comprehensive soil survey was conducted on the Chikkumbi-3 microwatershed utilizing the IRS P6 LISS-IV image and the Belagavi district toposheet. The image and scanned topographic sheet were geocoded and a subset was created using ArcGIS 10.2 at a scale of 1:7,920. The cadastral map displays the demarcation lines of fields together with their corresponding survey numbers, as well as the precise locations of tanks, streams and other enduring characteristics of the region. The remote sensing data products obtained from LISS IV were used in combination with the cadastral maps to discern the landforms and other surface characteristics. Imageries facilitated the recognition and demarcation of borders among hills, highlands and lowlands, bodies of water, forests and places with vegetation, highways, settlements and other cultural characteristics of the region.

2.3 Field investigations

A preliminary survey of the micro watershed was conducted using a cadastral map that displays the borders of the fields. Through the first traverse, we recognised the drainage patterns, surface features, slope characteristics, landforms and land use patterns of the area's geological formations. A comprehensive soil survey was conducted at a scale of 1:7,920, providing a high level of detail. Three transects were chosen to examine the profile at closely spaced intervals in order to account for any variations in land characteristics such as changes in slope, erosion, presence of gravels, stones, etc. Profiles were excavated at certain locations, reaching a maximum depth of 2 metres, or until the excavation was hindered by solid rock or a hard surface. All profiles were thoroughly examined to analyse their morphological and physical attributes. The comprehensive analysis of a watershed area involves examining various factors such as the topography (including land slope, erosion, drainage, and presence of rock fragments) and soil properties (including depth, texture, colour, structure, consistency, coarse fragments, porosity, and soil pH) (Soil survey staff, 2017) (Table 1). This is followed by categorizing similar areas based on their soil and site characteristics into homogeneous management units and depicting their boundaries and distribution on the cadastral map of the village. The assessment of soil site appropriateness for the main existing crops was conducted based on the soil site and climatic parameters, as described by Naidu *et al*. (2006). The classification of soil site appropriateness was divided into two categories: Highly suitable (S1) - referring to land that is favourable for plant development with little or easily correctable limits, and Moderately suitable (S2) - indicating circumstances that are close to optimum but may have modest restrictions or up to three moderate constraints that do not significantly impact production. The land unit in question is moderately appropriate (S3), meaning that its state has a substantial impact on production, yet it remains marginally affordable. Unsuitable (N) - A land unit that has limits that make it unable to be used continuously for the intended purpose and is classified with specific subclasses (limitations) added at the end. Soil and soil-site suitability maps were generated using ArcGIS10.2.2 software. The evaluation of soil-site suitability for horticultural crops such as Tomato, Cabbage, Chilli, Coconut, Rose and Jasmine was conducted using the criteria proposed by Sehgal (1996), and Naidu et al. (2006).

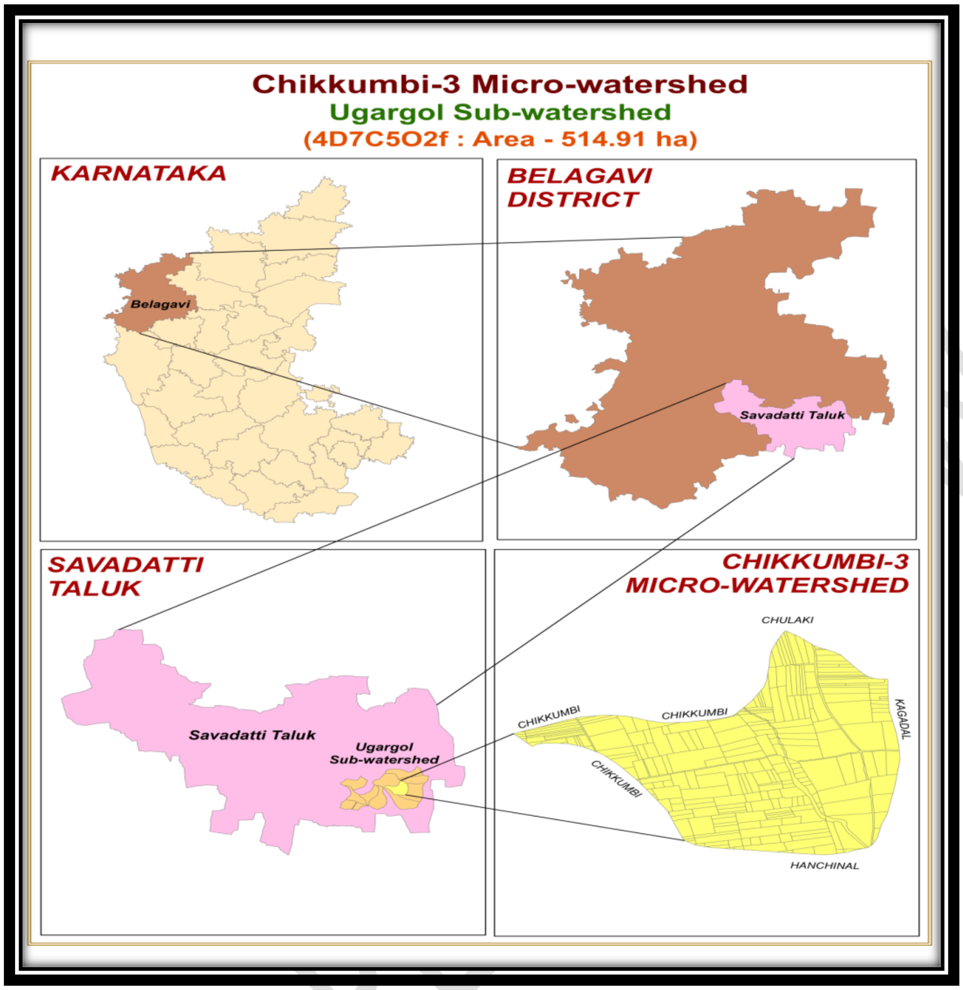

Figure 1 Location of the study area

3. Results and Discussion

The soil properties in the research area were compared against the soil-site suitability criteria for several significant fruit crops cultivated in North Karnataka. The table 2 illustrates the soil-site suitability for major horticultural crops.

3.1 Tomato

According to Naidu *et al*. (2006), tomato flowers have a tendency to drop during periods of high temperature and dryness, as well as during very low temperature circumstances. Additionally, these adverse environmental conditions hinder the germination of pollen grains, leading to the development of puffy fruits. Furthermore, the presence of dry winds exacerbates these effects. The optimal temperature range for this particular context is between 21 and 24 °C. Mean temperatures that go below 16 °C or exceed 27 °C are considered undesirable. Additionally, it is recommended that the soil pH fall within the range of 5.5 to 7.5.

Each of the mapping units exhibited marginal suitability (S3) for tomato cultivation, with moderate to severe constraints in terms of climate and physical condition of the soil.The mapping units HNLmB2, HNLmB2Ca, CKBmB2, CLKmB2, and HNLmB3Cag1 exhibited marginal suitability (S3cs) due to significant constraints related to $CaCO_3$ content, texture, pH, and length of the growing period (Figure 2).The analysis of soil site suitability indicated that all the mapping units within the research region exhibited marginal suitability for cultivating tomatoes. The comprehensive analysis revealed that the whole region exhibited moderate to marginal restrictions in terms of pH, drainage, and texture, and the area was classified within the suitability subclass S3cs. The findings were consistent with the research conducted by Kumar (2011) in the Bastwad micro-watershed in Belagavi district, Karnataka.

Table 1 Soil-site characteristics of soil mapping units of Chikkumbi-3 micro-watershed

S.No.	Soil Phases	Wetness (w)	Physical condition of soil (s)					Fertility (f)				Salinity/ alkalinity (n)		Erosion (e)
		Drainage	Texture	Depth (cm)	Stoniness	Gravel (%)	$CaCO_3$ (%)	pH	OC (g kg^{-1})	CEC [cmol (p^+) kg^{-1}]	BS (%)	EC (dS m^{-1})	ESP (%)	Slope (%)
1	HNLmB2	Moderately well drained	clay	Very deep (180+)	Nil	<15	11.61	8.46	10.67	45.52	85.84	0.43	3.62	1-3
2	HNLmB2Ca	Moderately well drained	clay	Very deep (180+)	Nil	<15	13.46	8.5	6.83	51.66	84.47	0.35	2.42	1-3
3	CKBmB2	Moderately well drained	clay	Very deep (180+)	Nil	<15	6.73	8.65	6.5	45.67	83.29	0.18	3.07	1-3
4	CLKmB2	Moderately well drained	clay	Very deep (180+)	Nil	<15	14.09	8.54	6.79	47.06	85.87	0.28	3.13	1-3
5	HNLmB3Cag1	Moderately well drained	clay	Very deep (180+)	Nil	15-35	14.85	8.55	6.67	51.22	91.77	0.27	2.90	1-3

3.2 Cabbage

Cabbage cultivation is widespread across India, making it the prevailing vegetable throughout the winter seasons. The plant has the ability to thrive in many climatic circumstances; however, it is most ideally suited for cold and moist climates. Cauliflower has a comparatively lesser tolerance to intense cold and frost when compared to the subject under consideration. The taste diminishes under warm climatic conditions.

The suitability of all the mapping units for cabbage cultivation was found to be marginally suitable (S3), with moderate to severe constraints in terms of physical condition of the soil.The mapping units HNLmB2, HNLmB2Ca, CKBmB2, CLKmB2, and HNLmB3Cag1 exhibited marginal suitability (S3s) due to significant constraints related to texture, pH, soil physico-chemical parameters, and fertility limits.The findings of the soil-site suitability assessment for cabbage in the study area indicate that the majority of the land is classified as marginally suitable. This classification is attributed to the presence of moderate to severe restrictions in slope, drainage, texture, coarse fragments, and pH. The very severe slope limitations, as shown in Figure 3, have a significant impact on suitability.Conversely, the drainage, texture, and pH showed varying degrees of suitability, ranging from high to moderate.

The previous findings that cabbage necessitates an ideal soil temperature range of 2.8 to 15.6 °C for successful germination, as well as the correlation between well-drained soils and high crop production and the optimal pH level of 6 to 6.5, are supported by the marginally acceptable characteristics of the research region (Naidu *et al.*, 2006).

The research location has the potential for cabbage production, similar to tomato cultivation, provided that climatic, soil, and fertility limitations are adequately handled. Hence, in order to optimise crop productivity, tomato growers must effectively address the limits that have been highlighted.

3.3 Chilli

The production of chilli is substantially influenced by the climate and physico-chemical qualities of soils. The suitability of all the mapping units for chilli cultivation was determined to be marginal, as seen in Figure 4.All of the mapping units exhibited marginal suitability (S3) for cultivating chilli due to moderate to severe limits in factors such as climate and physical condition of the soil.

The mapping units HNLmB2, HNLmB2Ca, CKBmB2, CLKmB2, and HNLmB3Cag1 exhibited marginal suitability (S3cs) due to significant constraints related to $CaCO_3$ content, texture, pH, and duration of the growing season

The evaluation of suitability for both crops indicated that the whole micro-watershed region exhibits a marginal level of suitability. The primary limitations for areas that are marginally suitable are determined by the properties of the soil and the prevailing climatic conditions.The study of soil site suitability for chilli production indicated that the whole region was classified as marginally suitable for this crop. This classification was primarily based on the limitations posed by inadequate rainfall and temperature conditions. Consequently, the area was categorized under the suitability subclass S3cs. Patil *et al*. (2008a) and Kumar (2011) both reported comparable findings on the limitations imposed by soil depth and rainfall on the growing of chilli peppers in the Koppal area.

3.4 Rose

The rose has consistently held the position of being the most popular and unchallenged flower worldwide. Effective cultivation of this plant may be achieved in many climatic zones; however, optimal conditions for flower production include moderate temperatures, abundant sunlight, and high light intensity (Naidu *et al*., 2006). The primary states in India where rose cultivation is prominent are Rajasthan, Maharashtra, Karnataka, Uttar Pradesh, and West Bengal.

The suitability of all the mapping units for rose cultivation was found to be marginally suitable (S3), with moderate to severe limits seen in terms of physical condition of the soil. However, no significant constraints were identified in relation to land form features.The mapping units HNLmB2, HNLmB2Ca, CKBmB2, CLKmB2, and HNLmB3Cag1 exhibited marginal suitability (S3s) due to significant constraints related to texture, $CaCO_3$ content, and duration of growth period. Additionally, these units showed minimal to mild limits in terms of land form features.

The Chikkumbi-3 micro-watershed exhibited marginal suitability for rose production as a result of soil physico-chemical limits and minor limitations in landform features (Figure 5). The mapping units exhibited moderate to marginal constraints in terms of rainfall, drainage, texture, pH, and soil depth for the purpose of rose production. These units were classified as belonging to the suitability subclass S3s. Manjunatha *et al*. (2017) and Denis *et al*. (2014) have documented comparable findings about the somewhat favourable environment for roses.The cultivation of roses is not prevalent among farmers in the designated research region. It exhibits robust growth in very rich soil conditions. Considering the extensive acceptance of this crop as a commercially cultivated plant in India, it is advisable to advocate its cultivation in conjunction with soil enhancement techniques. Hence, it is recommended that farmers cultivating this particular crop be mindful of the recognized limitations in order to achieve optimal productivity.

3.5 Jasmine

The Chikkumbi-3 micro-watershed exhibited marginal suitability for jasmine production as a result of soil physico-chemical limits and minor limitations in landform features.The suitability of all the mapping units for jasmine cultivation was found to be marginally suitable (S3), with moderate to severe restrictions seen in terms of physical condition of the soil. However, there were no significant limitations identified in relation to land form features.The mapping units HNLmB2, HNLmB2Ca, CKBmB2, CLKmB2, and HNLmB3Cag1 exhibited marginal suitability (S3s) due to significant constraints related to texture, $CaCO_3$ content, and length of the growth period. Additionally, these units showed nil to modest limits in terms of land form features.

The whole region exhibited moderate to marginal constraints in terms of average temperature, drainage, soil texture, and pH levels for the cultivation of jasmine. These constraints were categorized as suitability subclass S3s. Kumar (2011) found a similar finding in the mapping units of the Bastwad micro-watershed in Karnataka, where the suitability for jasmine cultivation ranged from moderate to marginal (Figure 6).

The cultivation of jasmine by farmers in the research region is not prevalent. It exhibits robust growth in very rich soil conditions. Considering the extensive acceptance of this crop as a commercially cultivated plant in India, it is advisable to advocate the use of soil improvement techniques. Hence, it is recommended that the farmers cultivating this particular crop be cognizant of the limitations mentioned in order to attain optimal productivity.

3.6 Coconut

The coconut is well recognized as a significant contributor to the edible oil production in India, accounting for around 7% of the overall output. Kerala, Tamil Nadu, Andhra Pradesh, and Karnataka are prominent states in India known for their significant contributions to coconut production. Kerala comprises 54.7% of the overall geographical area and contributes 42.3% of the total output, with Tamil Nadu and Karnataka following suit. The analysis of soil-site suitability for coconut cultivation indicated that the whole region exhibited limited suitability, mostly owing to significant constraints related to rainfall, the presence of coarse fragments, and pH levels (Figure 7).

The mapping units HNLmB2, HNLmB2Ca, CKBmB2, CLKmB2, and HNLmB3Cag1 exhibited marginal suitability (S3c) due to significant constraints related to average temperature, precipitation, soil texture and pH, as well as restrictions in soil physico-chemical characteristics and fertility.The current investigation revealed that many factors such as climate, landform features, and soil parameters, including rainfall, mean temperature, slope, drainage, texture, coarse fragments, and pH, significantly impact the growth and productivity of coconut in the designated research region. The findings shown here align with previous studies that have indicated the desirability of rainfall ranging from 1000 to 2250 mm, spread equally (Menon and Pandalai, 1958). A minimum annual precipitation of 1000 mm, provided it is evenly distributed, is considered sufficient for optimal growth and development of coconut palm (*Cocos nucifera*) (Thampan, 1975). Conversely, coconut palm exhibits reduced vigour and fails to thrive when exposed to temperatures below 21 °C.

There is a possibility for enhancing soil quality by addressing the primary limitations and deficits of both major and micronutrients through the use of appropriate fertilizers. By means of these endeavours, the soils have the potential to exhibit moderate to marginal suitability for the cultivation of the crop. However, in order to optimize coconut productivity in the research region, it is recommended that farmers cultivating this crop be mindful of these limitations. All of the mapping units exhibited marginal suitability (S3) for coconut cultivation, with moderate to severe limits in terms of climate.

Table 2. Soil-site suitability classification of mapping units for vegetable, flower and plantation crops.

Mapping unit	Tomato	Cabbage	Chilli	Rose	Jasmine	Coconut
HNLmB2	S3cs	S3s	S3cs	S3s	S3s	S3c
HNLmB2Ca	S3cs	S3s	S3cs	S3s	S3s	S3c
CKBmB2	S3cs	S3s	S3cs	S3s	S3s	S3c
CLKmB2	S3cs	S3s	S3cs	S3s	S3s	S3c
HNLmB3Cag1	S3cs	S3s	S3cs	S3s	S3s	S3c

Conclusion

It is concluded that the soils of the Chikkumbi-3 micro-watershed showed different degrees of suitability for growing tomato, cabbage, chilli, rose, jasmine and coconut. The soil series CLK, HNL and CKB are currently marginally suitable for the production of tomato, cabbage, chilli, rose, jasmine and coconut. The main limitations in all the soil series found to be heavy texture, $CaCO_3$ content and climatic factors. However the degree of these limitations in all these soil series varies from slight to very severe. Further integrated use of organic manures and inorganic fertilizers not only paves the way to achieve sustainable yields of crops but also sustains the soil health for future generations undergoing deterioration and also helps in doubling the farmer's income.

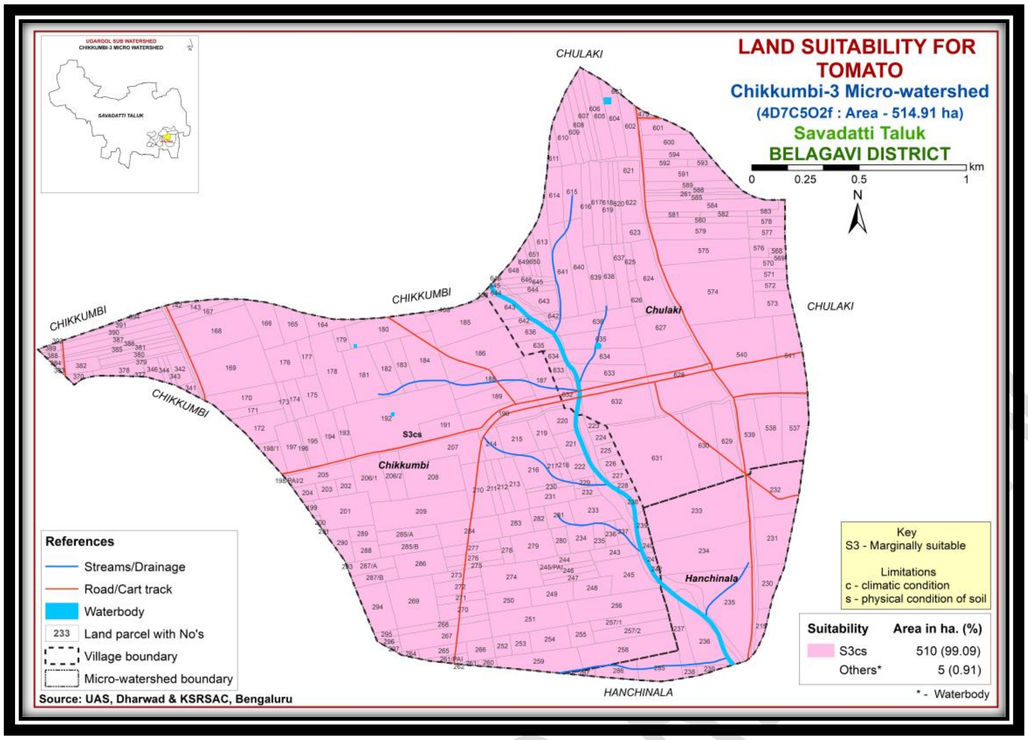

Figure 2 Soil-site suitability map for tomato in Chikkumbi-3 micro-watershed

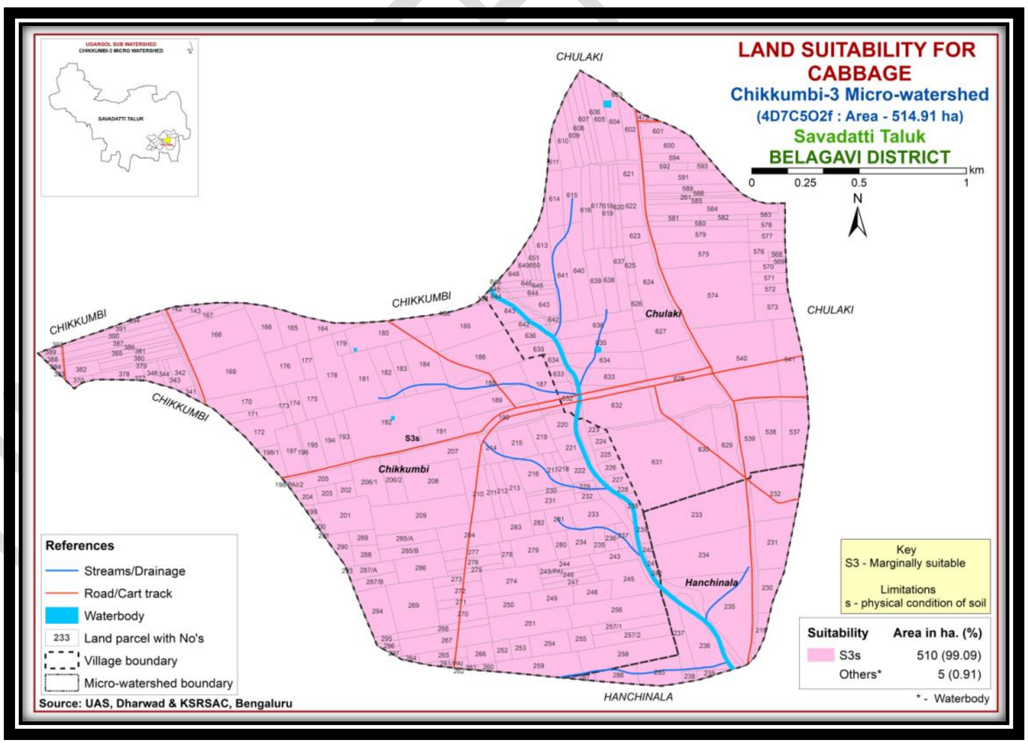

Figure 3 Soil-site suitability map for cabbage in Chikkumbi-3 micro-watershed

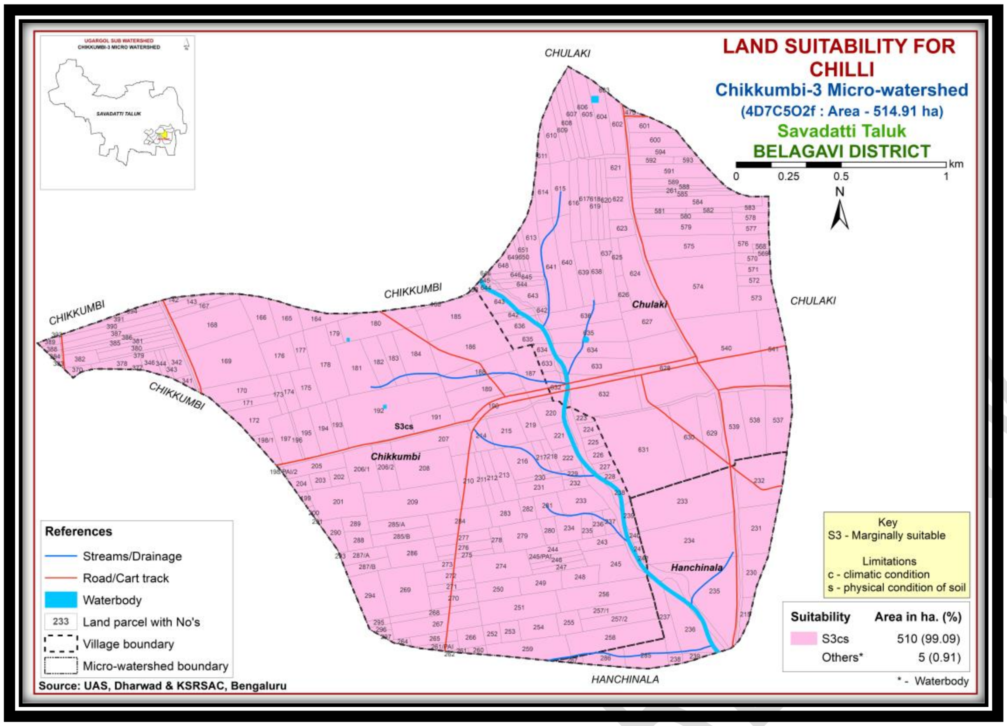

Figure 4 Soil-site suitability map for chilli in Chikkumbi-3 micro-watershed

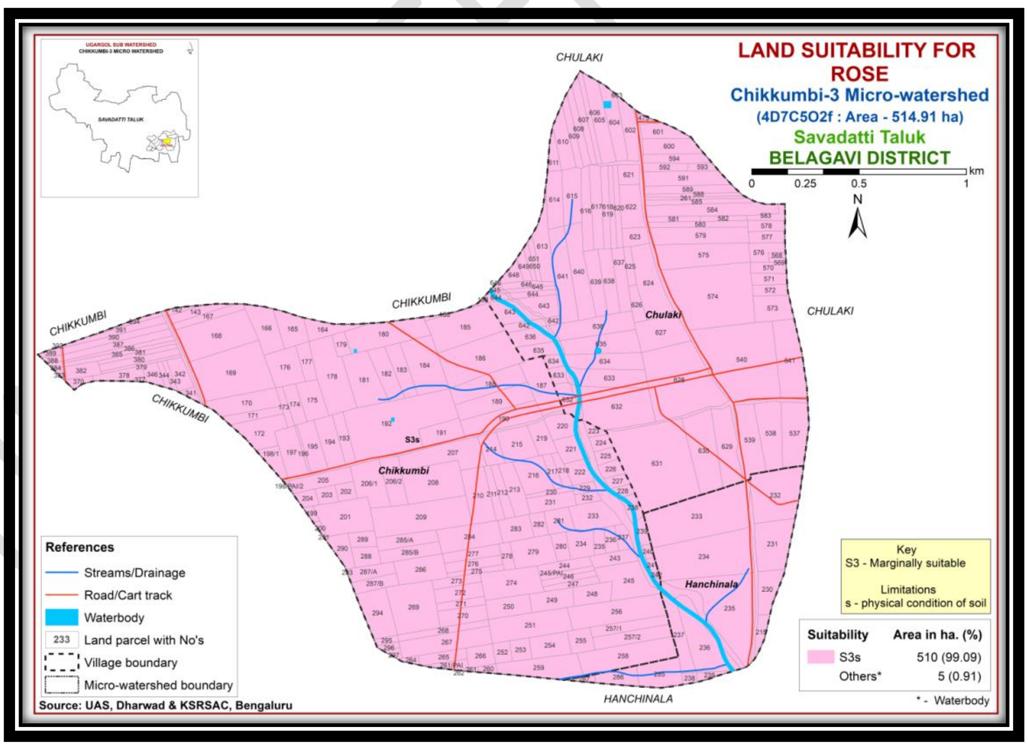

Figure 5 Soil-site suitability map for rose in Chikkumbi-3 micro-watershed

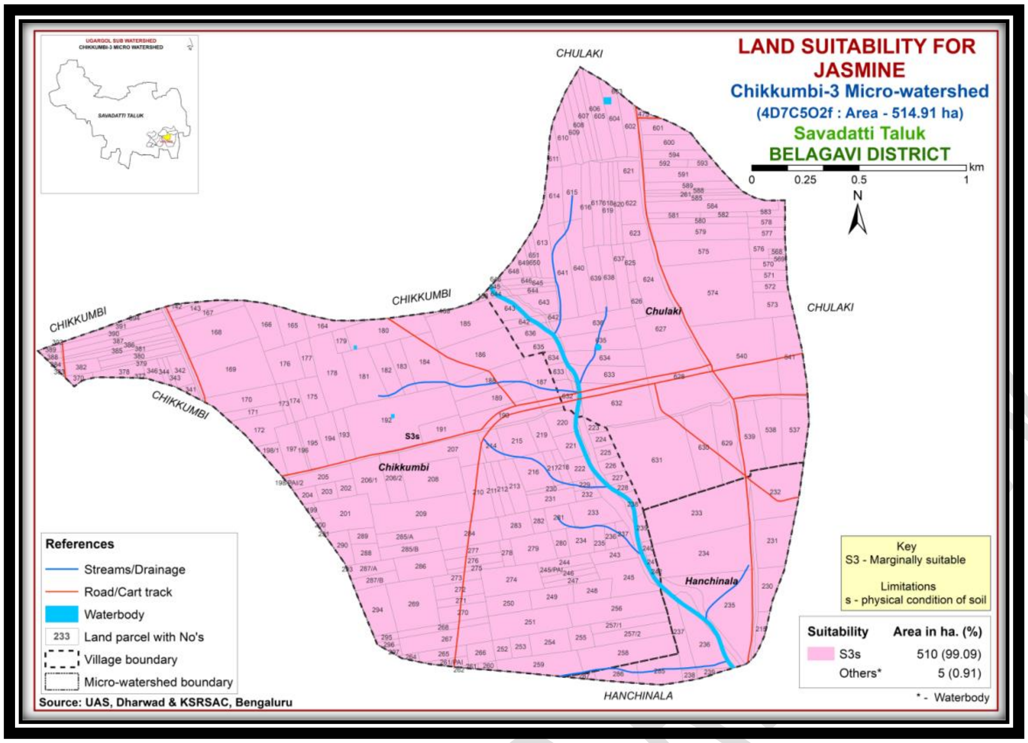

Figure 6 Soil-site suitability map for jasmine in Chikkumbi-3 micro-watershed

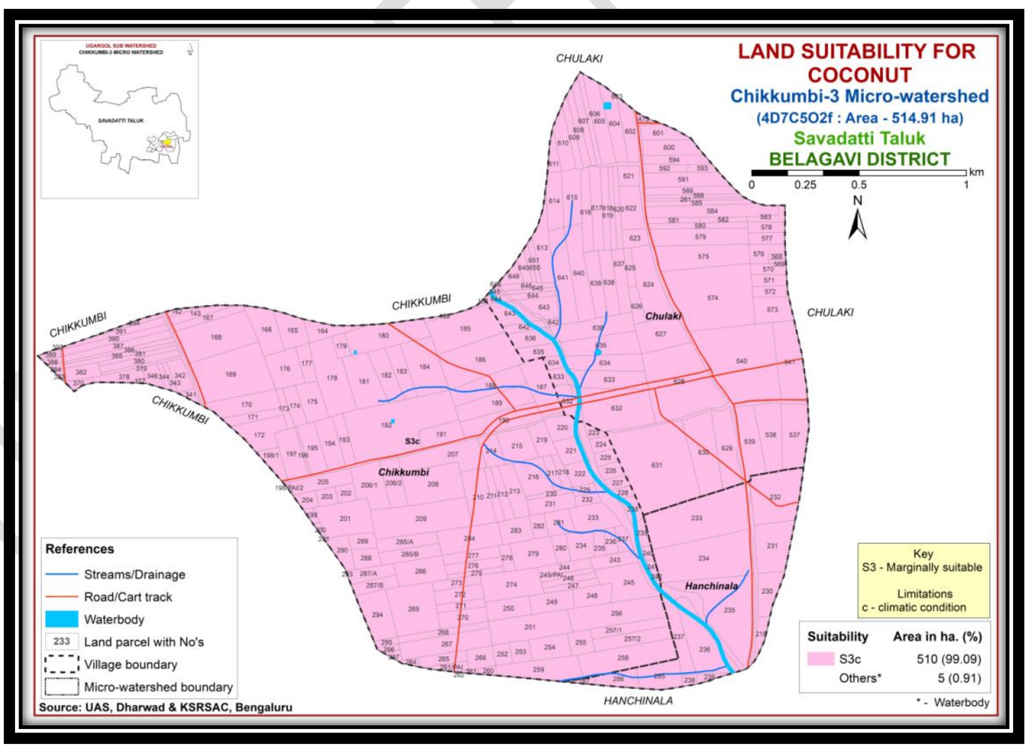

Figure 7 Soil-site suitability map for coconut in Chikkumbi-3 micro-watershed

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