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Land evaluation in halayapura1 micro watershed in Tumkur district of Karnataka, India, using remote sensing and geographical information system (GIS) tools

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Abstract
The present study was undertaken to evaluate four soil series belonging to Halayapura1 micro watershed (Tumkur district) in the southern transition zone of Karnataka for sustainable land use planning. Seven soil series were identified and mapped into twenty six soil phases using GIS technique. These soil phases were grouped in to land capability class II and III. Twenty two soil phases belongs to land capability class II having four subclass, IIs occupied 166 ha (32.94 %) of the study area. These soils had none to slight limitations ranging from slope, erosion, drainage, depth, texture, coarse fragments, $CaCO_3$, pH, organic carbon. Four soil phases belongs to class III having two subclass, IIIes and occupied 57 ha (11.43 %) of the study area. Soil site suitability evaluation for field crops like ragi, ground nut, red gram, castor and horticulture crops like coconut, areca nut mango, sapota, guava, marigold showed that some of soil series were highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable for some soil phases. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses. Major proportion of the study area belonged to land capability class IIs followed by IIes, IIew, IIIes, IIw, IIIs respectively in the order of land capability rating. Hence the study area concludes that 88 % of the study area is suitable for agricultural purposes. Land suitability is the fitness of a given type of land for a defined use. The land may be considered in its present condition or after improvement.

Keywords: land capability classification, soil suitability, soil limitation, remote sensing and GIS

Introduction
Soil, water and air are the three basic natural resources upon which plant life depends. The balance between economic viability and destruction of a nation often depends on how the land resource base is managed. Proper land management cannot be done without land use planning. An essential part of land use planning is land evaluation. Land evaluation is the assessment of the potential of land for alternative uses using systematic comparison of the land use requirements (LURs) with land quality / characteristics. Land evaluation forges a link between the basic survey of resources and the taking of decision on land use planning and management. It puts at the disposal of users relevant information about land resources that are necessary for planning development and taking management decisions.
Land evaluation constitutes a valuable resource inventory that is linked with the survival of life on the earth and involves the process of evaluation of a particular tract of land for specific purposes involving the execution and interpretation of data of natural resources and other related aspects of land in order to identify and make a comparison of promising kinds of land uses. Information on soil and related properties obtained from land evaluation can help in better delineation of land suitability for irrigation and efficient irrigation water management. Hence, depending on the suitability of the mapped land units for a set of crops, optimum cropping patterns could be suggested by taking into consideration the present cropping system and the socio-economic conditions of the farming community.
Land evaluation provides an insight into the potentialities and limitations of soil for its effective exploitation. An appropriate land evaluation creates the awareness among land users, planners, research workers and administrators in order to ensure the proper and effective utilization of soil resources,

as well as providing an accurate and scientific inventory of different soils, their kind and nature and extent of distribution so that one can make predictions about their characteristics and potentials. In addition, it also provides adequate information in terms of land form, terraces, vegetation as well as characteristics of soils (viz., texture, depth, structure, stoniness, drainage, acidity, salinity, etc.), which can be utilized for land use planning and development.

In recent years, as part of environment and land degradation assessment policy for sustainable agriculture and development, soil erosion is increasingly being recognized as a hazard which is more serious in mountain areas of India (Sharma, 2010) [18]. Soils in general are degrading due to poor management and faulty land use at a rate faster than their natural regeneration, it becomes imperative to protect them from further degradation as there is a concomitant decline in soil quality to produce healthy crops. In the recent past, concept of watershed based holistic development has emerged as one of the potential approaches in rainfed areas, which can lead to higher productivity and sustainability in agricultural production. Different measures are adopted and executed carefully in each toposequence according to their capability. Hence, a detailed study of the soil resources is needed to realize the concept of watershed development approach successfully.

Modern agriculture requires precise information on various land use and agro-climatic parameters like soil types and characteristics, rainfall, temperature, water resources etc., which influence directly the soil response to any specific use (Saxena *et al*., 2000). Soil resource inventory through characterization, accurate mapping of soils and developing the rational and scientific criteria for land evaluation. Studies on soil resources through remote sensing and GIS techniques could provide a database on soil resources, which is vital for any land use planning. Knowledge of soil resources with respect to their spatial distribution; characteristics, potentials, limitations and their suitability for alternate land uses helps in formulating strategies to obtain higher productivity on sustained basis. Rapid evolution of satellite remote sensing and Geographical Information Systems (GIS) has made possible the development of new techniques for facilitating mapping of natural resources. Satellite remote sensing has been recognized as a powerful tool for mapping and monitoring of natural resources as it provides a wide range of information available through the electromagnetic spectrum in a synoptic and more frequent manner. Remote sensing and GIS application in soil resource mapping enables the study of soils in spatial domain, in time and in a cost effective manner (Saxena *et al*., 2000). Spatial and quantitative information on soil resources on a micro watershed scale contributes significantly to soil conservation and erosion control planning and management of the watershed environment.

Land capability is a qualitative method of classifying land resources based on the soil, topography and climate parameters without taking into account the yield and social economic conditions. It is not centered on specific crops, kind of recommended practices or economic considerations, but rather considers permanent physical soil parameters, and their effects on vegetation growth (Leonardo *et al*., 2008). The technique that makes it possible to determine the most suitable use for any area of land is land capability classification (Karl *et al*., 1999). Land capability classification is also useful in the implementation of sustainable land management practices because it is a composite assessment of land and soil, which incorporates the key physical characteristics that limit sustainable land management (FAO, 2008). Therefore, land capability classification provides a convenient checklist of the natural resource limitations that need to be considered when natural resource planning is undertaken in a given watershed. It was on this note that the present study was conducted to identify the different categories of land with respect to their potentials and limitations.

Soil –site suitability studies provide information on the choice of crops to be grown on best suited soil unit for maximizing crop production per unit of land, labour and inputs. The land suitability for defined use and the impact of the use on environment is determined by land condition and land qualities. Each plant species requires specific soil – site conditions for its optimum growth. These suitability models provide guidelines to decide the policy of growing most crops depending on the suitability or capability of each soil unit.

Materials Methods

Halayapura1 micro-watershed (Hosalaya sub-watershed, Tumkur taluk, Tumkur district) is located at North latitude 11^0 40’ 58" and 12^0 06‘ 32" and East longitude 76^0 24' 14"and 77^0 46‘ 55" covers an area of about 503 ha bounded by Halayapura1, Thondagere, Thondagere Kaaval, Budipalya and T.R. playa (Fig 1). The micro-watershed is located in Central Karnataka plateau, hot, moist, semi-arid eco-sub region, Southern Plateau and Hill Region. The agroclimatic zone 4 (Tumkur, Madhugiri, Pavagada, Kortagere, Chikkanayakanahalli and Sira) extends over all the six taluks of Tumkur district and four districts of Chitradurga, Davangere, Chickmagalur and Hassan. The total geographical area of the zone is about 19, 43, 830 ha of which 12, 93, 011 ha is under cultivation with 2,51,270 ha under irrigation. Most of the zone is at an elevation of 800-900m MSL in major areas, in remaining areas 450-800m MSL. Average annual rainfall of the zone ranges from 455.5 to 717.4 mm. The major soils are Red Sandy loams and shallow to deep black soil. The main cropping season is Kharif.

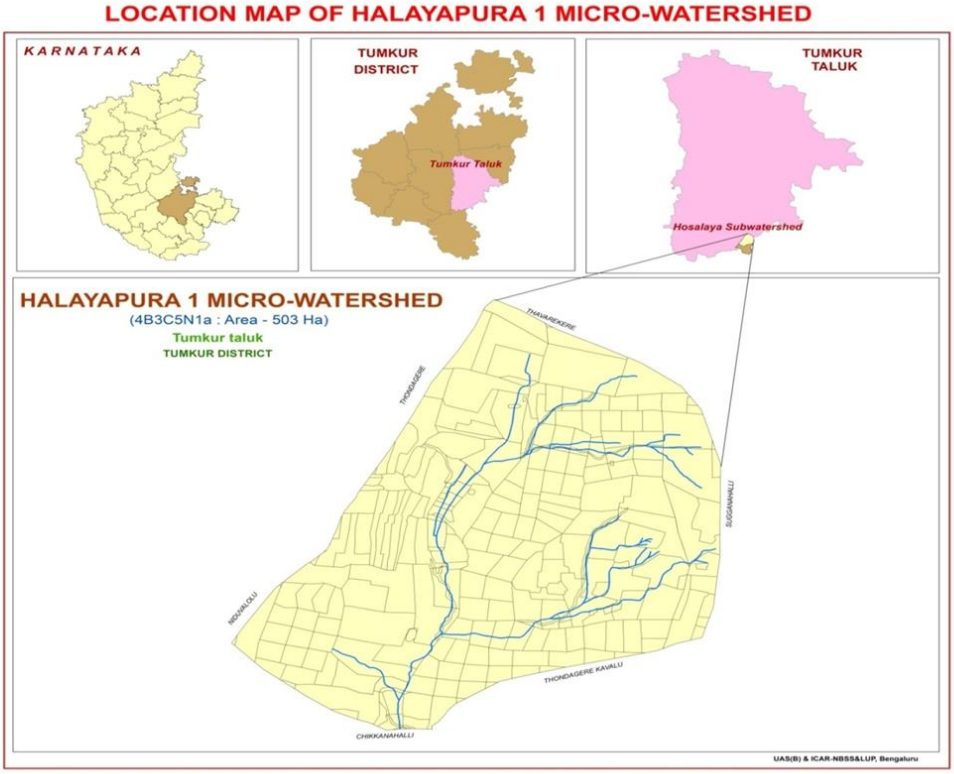


Fig 1: Location map of Halayapura1 micro watershed

Soil description and physic-chemical determination
Soil profile description was conducted for four soil profiles of various depth according to the methods given in the soil survey manual and field guide. The required site and soil characteristics are described and recorded on a standard proforma by following the protocols and guidelines given in the soil survey manual and field guide. The soil samples were collected from different diagnostic horizons and important physical and chemical parameters including particle size distribution, soil pH, EC, organic carbon, available N, P, K, CEC, exchangeable bases Ca^{+2}, Mg^{+2}, K^{+}, Na^{+}, were determined following standard procedure.

Delineation of the study area
Study area was delineated with the help of topographic map and watershed.

Land evaluation studies
Land capability and land suitability classification for major crops were derived as per the standard procedure.

Land capability classification
The classification is based on the inherent soil characteristics, external land features and environmental factors that limit the use of land. Based on the susceptibility of soils to erosion (e), soils(s), topography (t) and drainage (d) limitations the study area was classified into different land capability classes. Arable lands that are fit for agriculture were grouped under I to IV and non-arable lands were grouped class VI to VIII. Criteria for the land capability classification is presented in Table 1.

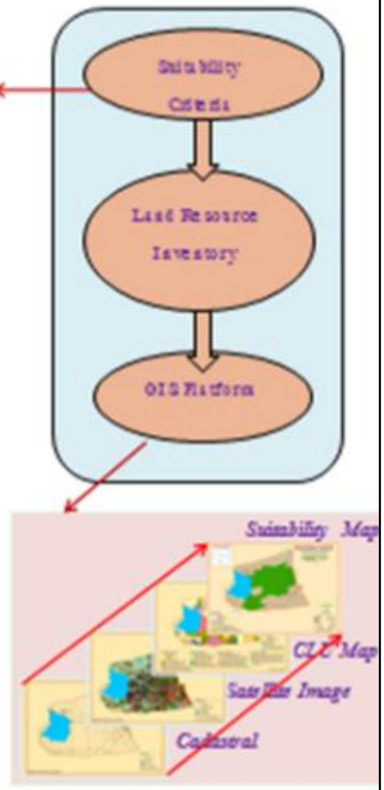
Table 1: Criteria for land capability classification

Characteristics	Class-I	Class-II	Class-III	Class-IV	Class-V	Class-VI	Class-VII	Class-VIII
Topography (t)								
Slope (%)	0-1	1-3	3-8	8-15	upto 3	15-35	35-50	>50
Erosion	Nil	Slight	Moderate	Severe	Nil	Severe	Severe	
Wetness (w)								
Flooding	nil (F0)	nil (F0) (F0/F1)	nil to slight (F1/F2)	Slight to mod. (F3)	mod. to severe (F0/F3)	nil to severe (F0/F4) excessive	nil to very	-
Drainage (l)	Well	Mod. well	Imperfect	Poor	V. poor	Excessive	Excessive	Excessive
Permeability	Moderate	Mod. rapid	Raid slow	V. rapid, vslow	-	-	-	-
Infiltration rate (cm/hr)	2-3.5	1-2.0, 3.0-5.0	0.5-1.0, 5.0-10.0	<0.5, >10.0	2.0			
Physiological soil conditions								
Surface texture	Loam	sil& cl	sl& c	scl	s, c(m)	ls-cl	ls, s, c	ls, s, c(m)
Surface coarse fragments (vol %)	1-3	3-15	15-40	40-75	15-75	75+		
Surface stoniness (%)	<1	1-3	3-5	5-8	8-15	15-40	40-75	>75
Sub-surface coarse fragments (%)	<15	<15	15-35	35-50	50-75	50-75	50-75	>75
Soil depth (cm)	>150	150-100	100-50	50-25	-	25-10	25-10	<10
Profile Development	Cambic/Argillic hor. A-(B)-C	A-B-C	100-50 stratified A-C; A-B-C,	Salic(Z)/Calcic (K) hor. A-Bz- C/A-Bk-C	Az-C, A-B, C	Gypsic (y) hor.A-cy	A-C (stony)	A-C (bouldary)

Source: Klingebiel and Montgomery (1996

Table 2: Suitability criteria table

Land use requirement		Rating			
Soil-site characteristics	Unit	Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Slope	%	<3	3 – 5	5 – 10	>10
Length of growing period	Days	>110	90 – 110	60 – 90	<60
Soil drainage	Class	Well drained; moderately well drained	Imperfectly drained; somewhat excessively drained	Poorly drained; excessively drained	Very poorly drained
Soil reaction	pH	5.5 – 7.5	7.6 – 8.5; 4.5 – 5.4	8.6 – 9.5; 4.0 – 4.4	<4.0
Surface soil Texture	Class	l, sil, sl, cl, sicl, scl	sic, c, sc	ls, s, c >60%	
Soil depth	cm	>75	51 – 75	26 – 50	<25
Gravel contents	% vol.	<15	15 – 35	>35	
Salinity (ECe)	dsm⁻¹	<1.0	1.0 – 2.0	2.0 – 4.0	>4.0
Sodicity (ESP)	%	<10	10 – 15	15 – 25	>25



Land suitability classification for crops

Land suitability was evaluated following FAO (1979) guidelines. It involved formulation of climate and soil requirements of the crop and ratings of these parameters highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and unsuitable (N1). The suitability criteria for sorghum, cotton, tomato and coconut are given by Naidu *et al*. (2006) [9] were followed and were given in Table 2. Respectively.

Result and Discussion

Land capability classification is an interpretative grouping of soils to show the capability of different soils to produce field crops or to be put to other alternative uses such as pasture, forestry, as habitat for wildlife, recreation and tourism etc., on a sustained basis. It is based on inherent soil characteristics, external land features and other environmental factors that limit the use of land. Eight land capability classes are identified. Soils suitable for agriculture are grouped under classes I to IV according to their limitations for sustained agricultural production. Soils not suitable for agriculture are grouped under classes V to VIII for use for pasture, forestry, recreation and tourism purposes, quarrying and mining and as habitat for wildlife. The land capability classes and their suitability for different uses. Soil site characteristics of the different phases were matched with criteria for land capability classification.

The land capability classes have subclasses to indicate the dominant limitations for agricultural use. Four kinds of limitations are recognized at the subclass level and denoted by "e" for problems caused by water and wind erosion. "w" for problems of drainage, wetness or overflow, "s" for soil limitations affecting plant growth like soil depth, heavy clay or sandy texture, gravelliness and stoniness, salinity or sodicity etc., and "c" for climate limitation. The assumptions made in classifying the soils are that within a capability subclass, the soils have similar potentials or limitations and also hazards.

Based on the soil site characteristics of the study area, the soils were classified into two land capability classes (Fig 2). These soil phases were grouped in to land capability class II and III. Twenty two soil phases belonges to land capability class II having four subclass, IIs occupied 166 ha (32.94 %) of the study area. These soils had none to slight limitations ranging from slope, erosion, drainage, depth, texure, coarse fragments, $CaCO_3$, pH, organic carbon. Four soil phases belonges to class III having two subclass, IIIes and occupied 57 ha (11.43 %) of the study area. Major proportion of the study area belonged to land capability class IIs followed by IIes, IIew, IIIes, IIw, IIIs respectively in the order of land capability rating (Table 3).

Table 3: Land capability classification in Halayapura1 micro watershed

LCC	Area	Per cent
IIes	104	20.72
IIew	56	11.06
IIs	166	32.94
IIw	46	9.15
IIIes	57	11.43
IIIs	14	2.7
Rockout crop	0	0.08
Eroded land	2	0.4
Mining	1	0.22
Scrub land	22	4.31
Others	35	6.99
	503	100

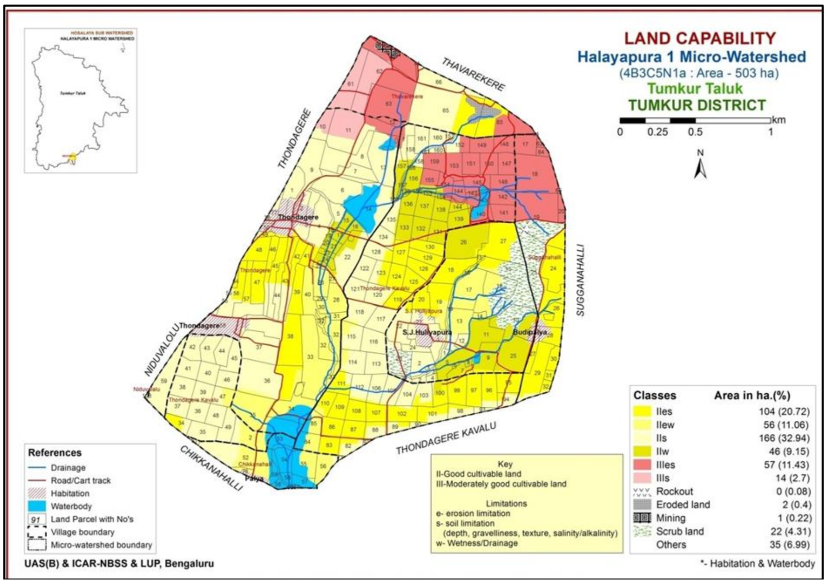


Fig 2: Land capability map of Halayapura 1 micro-watershed

Land suitability

Land suitability is the fitness of a given type of land for a defined use. The land may be considered in its present condition or after improvement. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses. The framework at its origin permits complete freedom in determining the number of classes within each order. However, it has been recommended to use only three classes within order S and 2 classes within order N. The class will be indicated by an Arabic number in sequence of decreasing suitability within the order and thereof.

Soil-site suitability evaluation for crops: The optimum requirements of a crop are always region specific. Climate and soil-site parameters play significant role in maximizing the crop yields. The kind and degree of limitations were evaluated and soil properties from the study area were matched with soil site suitability criteria (Sehgal 1996).

Land suitability for Agricultural crops

Land suitability for Ragi (*Eleusine coracana*)

Hardy and popular food crop but also wonder grain crop next to wheat, maize and rice in India. The grain is valued as staple food, it is also known as dry land crop cultivated in both tropical and subtropical region, it has wonderful health benefits. It can be grown in a wide range of soils from rich loam to poor shallow upland soil with low organic matter content. It grows best in pH range of 4.5-8.0.

The suitability of land for ragi in Halayapura1 micro watershed indicated that about 36.54 per cent of area (184 ha) is highly suitable and 51.46 per cent of area (259 ha) is moderately suitable due to limitations of gravelliness, topography, restricted rooting depth and wetness (Fig 3).

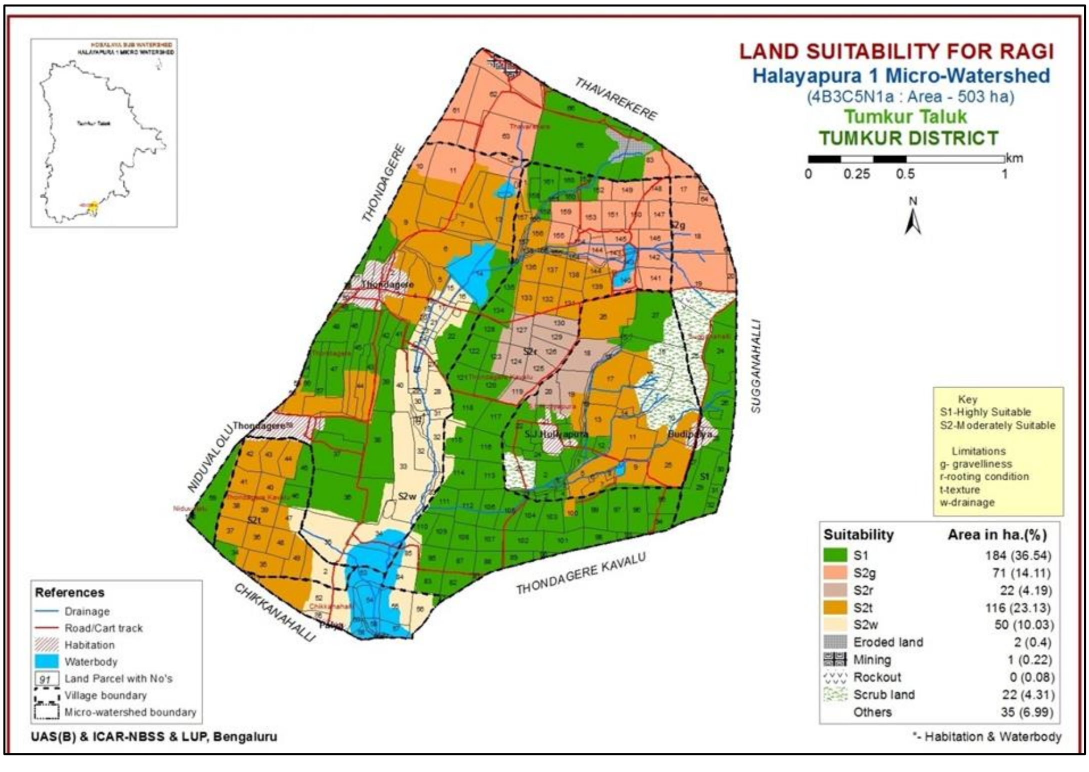


Fig 3: Ragi map of Halayapura 1 micro-watershed

Land suitability for Redgram (*Cajanus cajana*)

Redgram is an important pulse crop rich in proteins. It contains about 22 per cent protein, which is almost three times that of cereals. Redgram supplies a major share of protein requirement of vegetarian population of the country.

The suitability of land for redgram in Halayapura1 micro watershed showed that about 36.54 per cent of area (184 ha) is highly suitable. The gravels, rooting depth, topography and wetness constraints made the 259 ha of land (51.46 %) moderately suitable for redgram crop. In this watershed, scrub land accounts to the tune of about 22 ha (4.31 %) and is not fit for redgram cultivation (Fig 4).

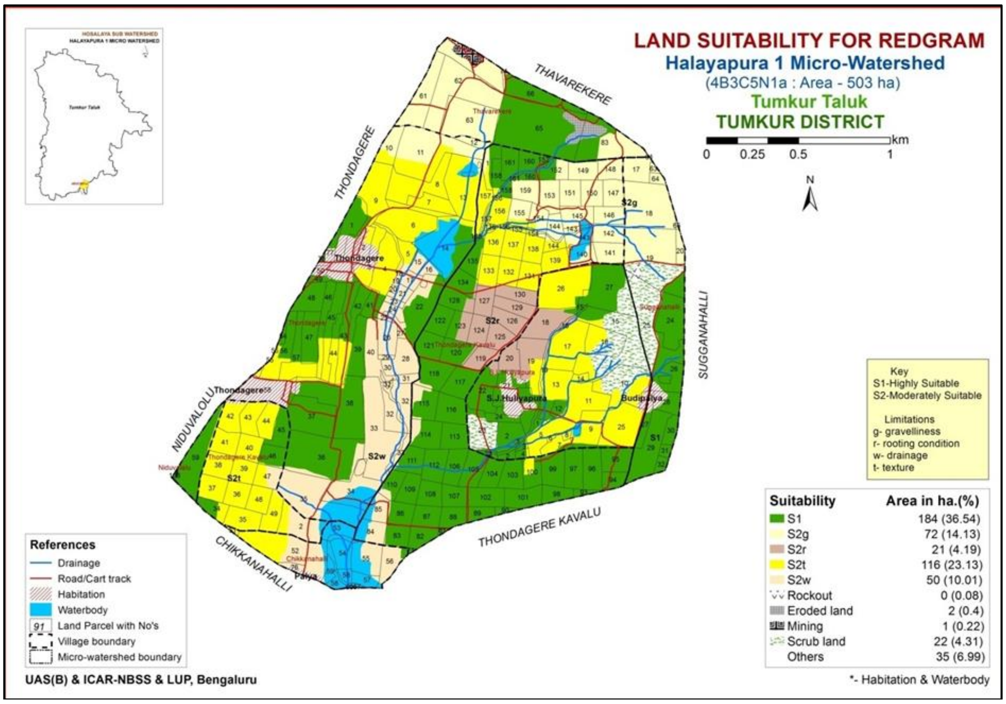


Fig 4: Redgram map of Halayapura 1 micro-watershed

Land suitability for castor (*Ricinus communis*)

Castor is generally grown for seeds. Castor seed oil is being used widely for various purposes. It is used as a lubricant in high-speed engines and aeroplanes, in the manufacture of soaps, transparent paper, printing-inks, varnishes, linoleum and plasticizers. The cake is used as manure and plant stalks as fuel or as thatching material or for preparing paper-pulp. In the silk-producing areas, leaves are fed to the silkworms. The crop requires a loamy soil of medium texture. Castor beans do well on either alkaline or acid soils, as long as the subsoil is permeable and there is good drainage. Seed will not set if soil moisture is inadequate.

The suitability of land for castor in Halayapura1 micro watershed indicated that about 36.54 per cent of area (184 ha) is highly suitable, 51.46 per cent of area (259 ha) is moderately suitable due to subsurface gravelliness, rooting depth, topography and soil wetness limitation. Among these limitations, topography is the main limitation and it makes 116 ha of area not suitable for castor cultivation fallowed by gravelliness (71 ha) (Fig 5).

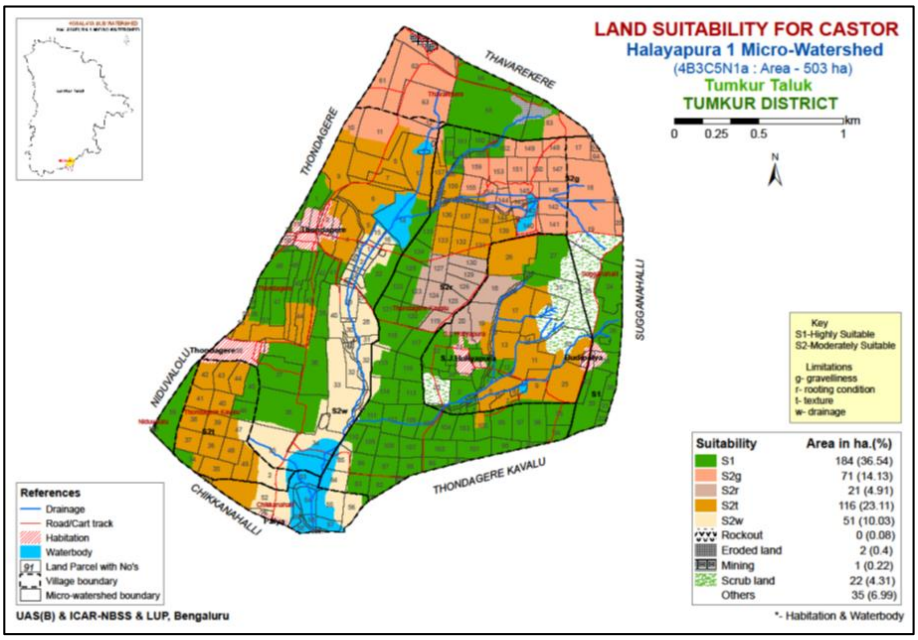


Fig 5: Castor map of Halayapura 1 micro-watershed

Land suitability for Groundnut (*Arachis hypogaea*)

Groundnut is the major oilseed of India called as "King of Oilseeds". It is one of the most important food and cash crop especially in rainfed areas. It accounts for around 25% of the total oilseed production of the country. It is perfectly grown in a well-drained sandy loam or sandy clay loam soil. Deep well drained soils with a pH of 6.5-7.0 and high fertility are ideal for groundnut. Lack of proper drainage adversely affects root respiration, resulting in inhibition of root growth, ultimately affecting the plant growth. Heavy and fine textured soils with stiff clay minerals cause serious difficulties in groundnut harvesting owing to a higher pod retention.

The land suitability for groundnut in Halayapura1 micro watershed indicated that only 32.18 per cent of area (162 ha) is highly suitable without any limitation. Further, gravelliness, rooting depth and topography constraints makes the 41.43 per cent of area (231 ha) into moderately suitable. Whereas, 14.39 per cent of area (72 ha) is marginally suitable due to topography and wetness limitation (Fig 6).

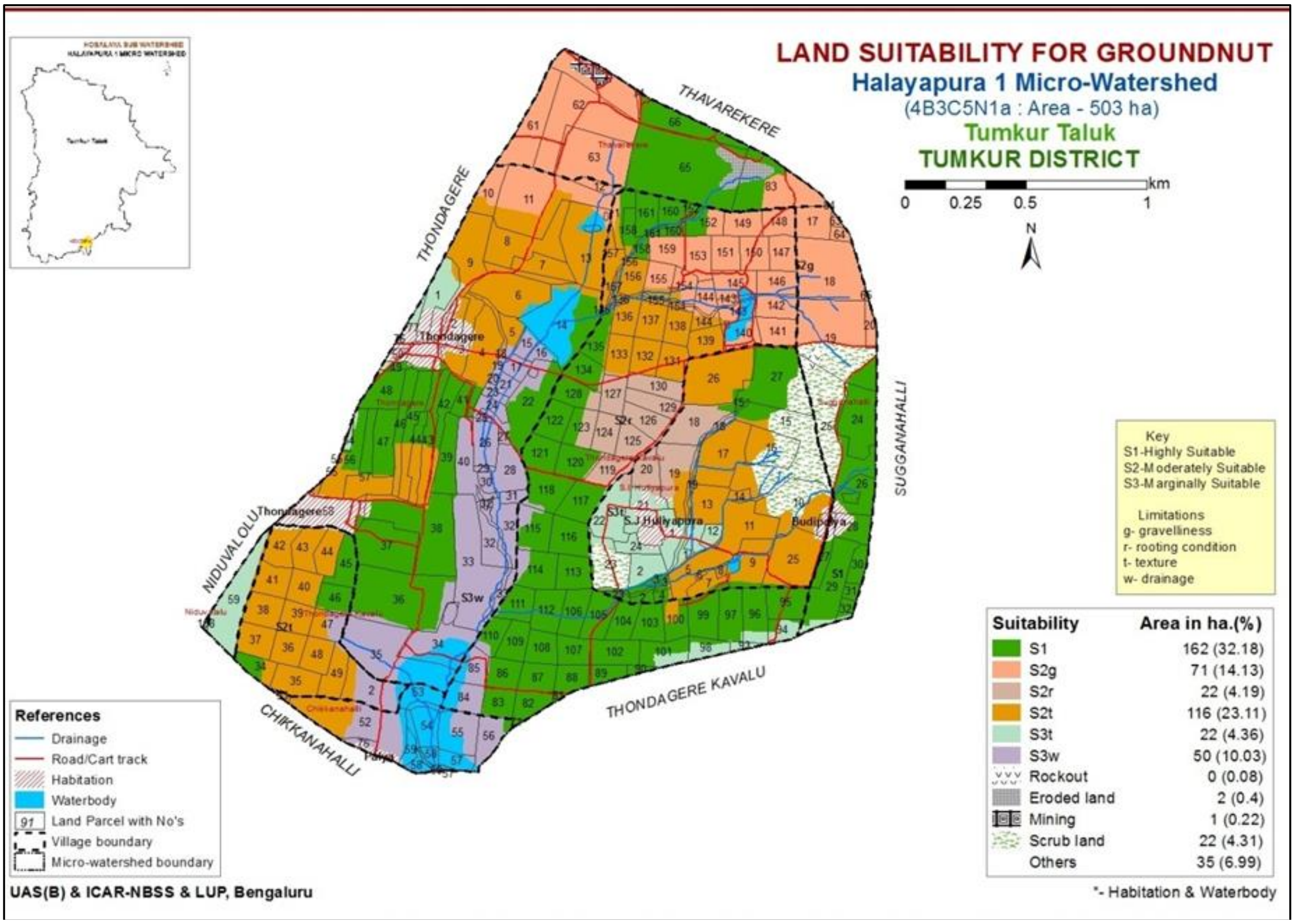


Fig 6: Groundnut map of Halayapura 1 micro-watershed

Land suitability for horticultural crops

Land suitability for mango (*Mangifera indica*)

Mango is a major fruit crop of the tropics and subtropics, it is the king of fruits and grows under temperature of 21-25 ºC and rainfall of at least 600 mm per year. The crop is intolerant to saline conditions. Mango requires deep soils with good drainage not necessarily fertile but can thrive in a wide range of soil types.

The suitability of land for mango in Halayapura1 micro watershed showed that nearly 49.47 per cent area (249 ha) is highly suitable and nearly 14.13 per cent area (71 ha) marginally suitable due to gravelliness and rooting depth limitations. However, 24.4 per cent of area (123 ha) is not suitable due to varied limitations and 6.23 per cent of area (60 ha) is not suitable to grow mango (Fig 7).

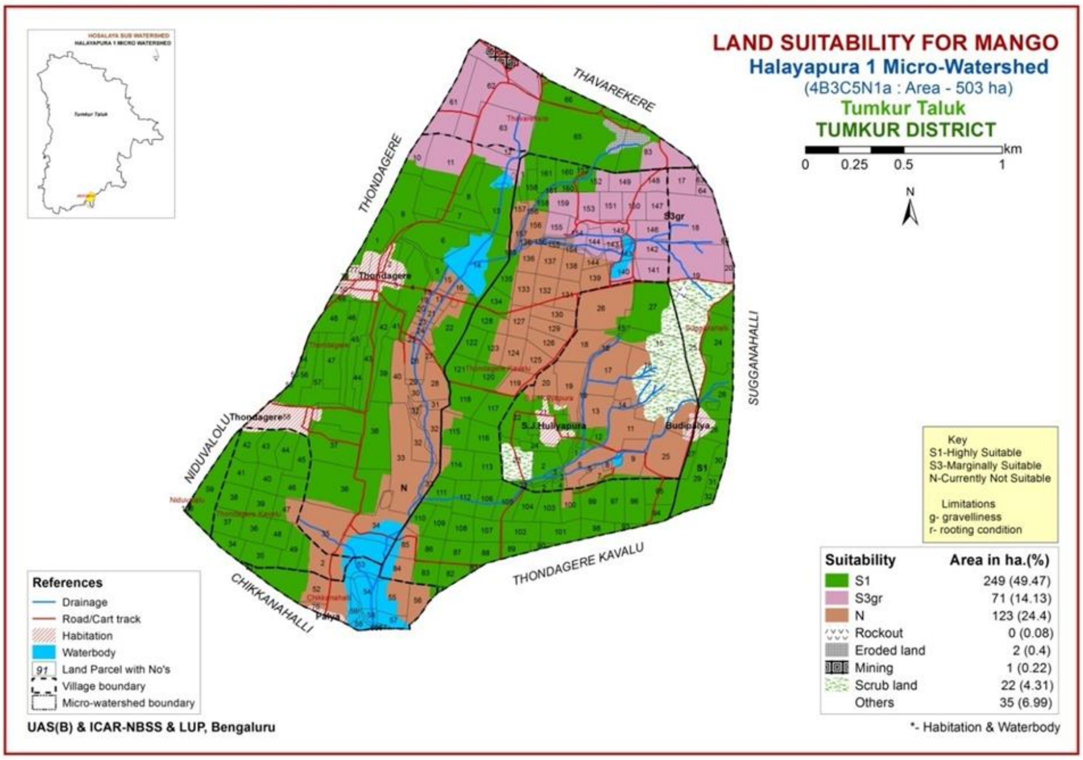


Fig 7: Mango map of Halayapura 1 micro-watershed

Land suitability for Marigold

Marigold is one of the famous flowers belongs to compositae family and cultivated throughout India all round the year. Due to short cropping period and low investment and made this flower to become popular among flower growers. The ideal temperature for optimal growth is 15ºC to 29ºC. This flower grows on wide range of soils. However, fertile sandy loam soils with good internal drainage is best suitable for marigold cultivation. Acidic and saline soils are not suitable and the soil pH range should be 6.5 to 7.5.

The suitability assessment of land for marigold in Halayapura1 micro watershed showed that nearly 49.48 percent of area (249 ha) is highly suitable. About 10.18 per cent of area (52 ha) is moderately suitable due to wetness and nearly 14.13 per cent area (71 ha) marginally suitable due to gravelliness. The marigold is not suitable to grow in 71 ha of land due to varied limitations (Fig 8).

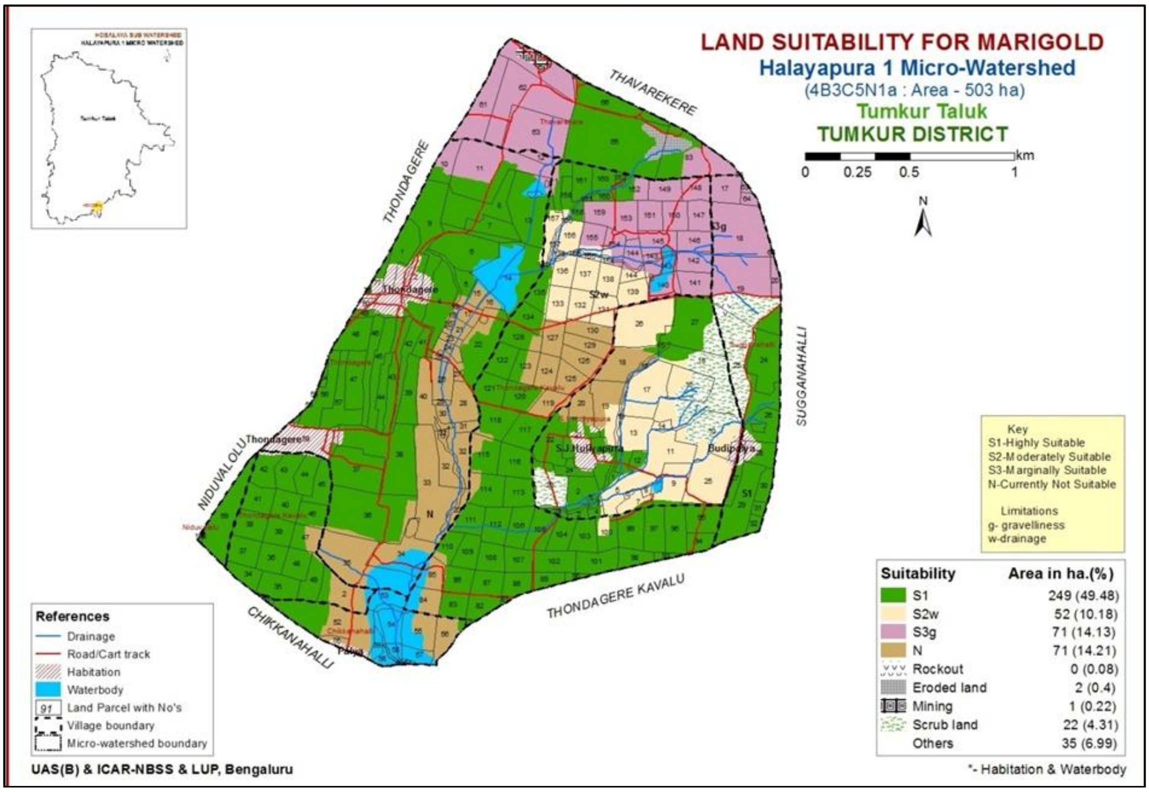


Fig 8: Marigold map of Halayapura 1 micro-watershed

Land suitability for Arecanut
Arecanut grows under varying climatic condition and Different soil types. The suitability of land for arecanut in Halayapura1 micro watershed indicated that about 36.54 % of area (184 ha) is highly suitable and 42.71 % of the area (215 ha) is moderately suitable due to limitations like gravelliness, topography and wetness. Further, 8.75 per cent of area is marginally suitable because of higher limitations with respect to rooting depth and topography (Fig 9).

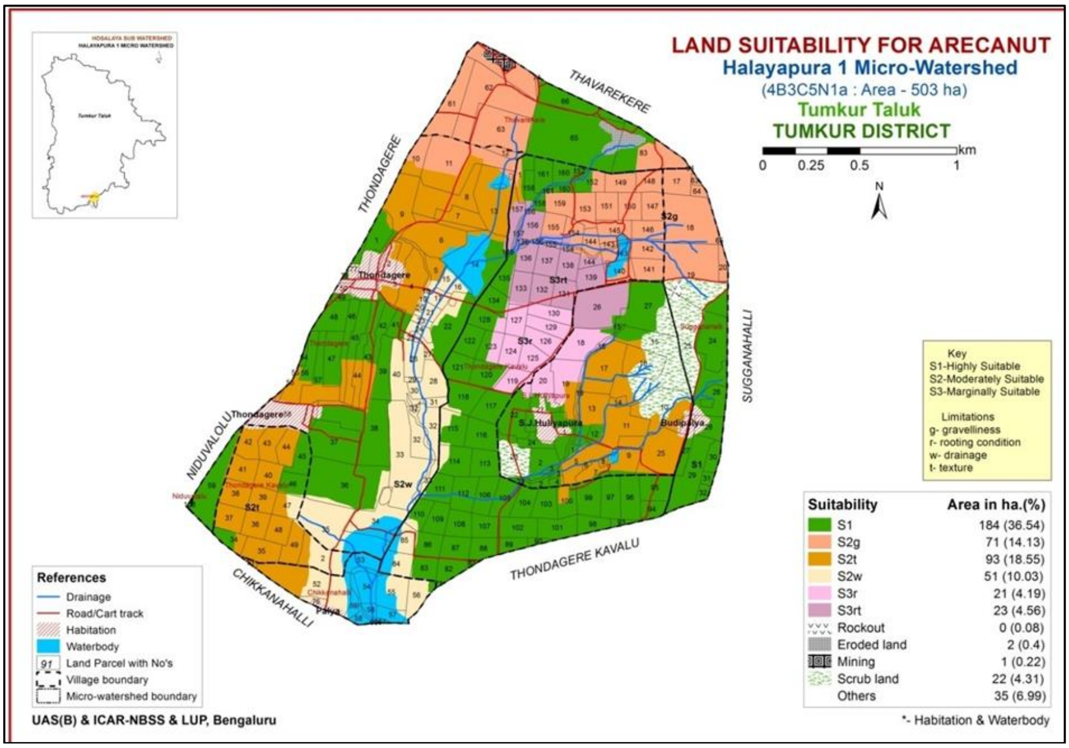


Fig 9: Arecanut map of Halayapura 1 micro-watershed

Land suitability for Coconut (*Cocos nucifera*)
Coconut grows under varying climatic condition and soil types. The rainfall required is 2000 mm per year.
The suitability of land for coconut in Halayapura1 micro watershed indicated that about 36.54 % of area (184 ha) is highly suitable, 22.97 per cent of area (115 ha) is moderately suitable and 19.75 per cent of area (100 ha) is marginally suitable. The main constraints are topography and wetness in moderately suitable soils. Sub surface gravels, topography and rooting depth are the main constraints in marginally suitable land (Fig 10).

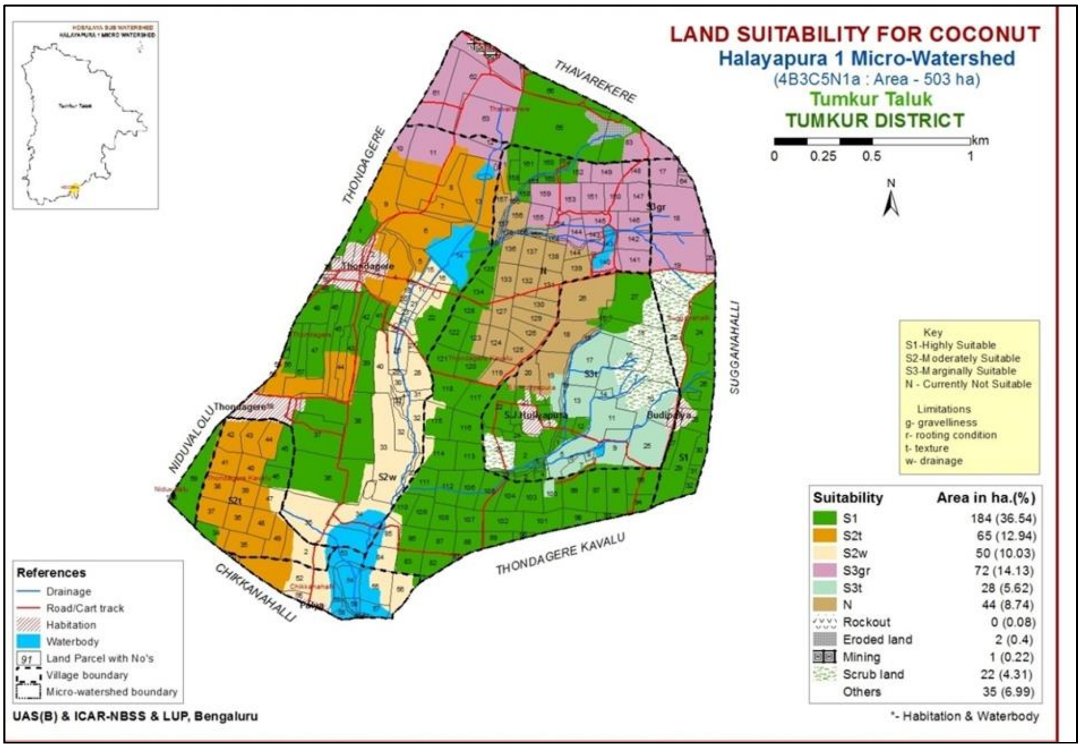


Fig 10: Coconut map of Halayapura 1 micro-watershed

Land suitability for sapota (*Manilkhara achras*)

Sapota, a crop of tropical region, needs warm (10-38 ^{0}C) and humid (70 % relative humidity) climate and it flowers and fruits throughout the year. Sapota being a hardy tree can be grown on a wide range of soils. Soil should be well drained without any hard pan. Deep and porous soils are preferred. The most ideal soils are deep alluvium, sandy loams, red laterites and medium black soil. It can tolerate the presence of salts in the soil and irrigation water to certain extent.

The suitability of land for sapota in Halayapura1 micro watershed showed that nearly 50.7 per cent of area (255 ha) is highly suitable without any limitations whereas limitations like gravelliness, rooting depth and wetness makes 22.93 per cent of area (116 ha) is moderately suitable and 4.19 per cent of area (21 ha) is marginally suitable due to rooting depth. About 10.18 per cent of area (51 ha) is not suitable to grow sapota due to varied limitations in the micro watershed (Fig 11).

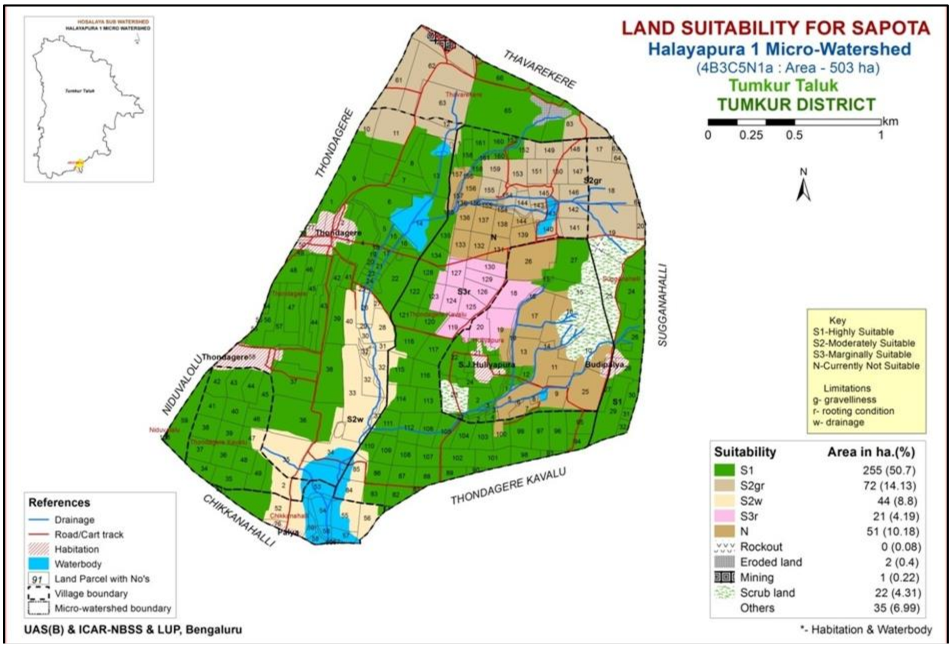


Fig 11: Sapota map of Halayapura 1 micro-watershed

Land suitability for guava (*Psidium guajava*)

Guava is valued for its delectable taste and aroma. Guava is considered the 'apple of the tropics' for its high vitamin C and mineral content. It tolerates a soil pH of 4.5-8.2. Maximum concentration of its feeding roots is present up to 25 cm soil depth. Thus, the top soil should be quite rich to provide enough nutrients for accelerating new growth which bears fruits.

The suitability assessment of land for guava in Halayapura1 micro watershed showed that nearly 49.48 per cent of area (249 ha) is highly suitable and 29.78 per cent of area (150 ha) is moderately suitable due to gravelliness, rooting depth and wetness problems. Nearly 8.74 per cent (44 ha) is marginally suitable (Fig 12).

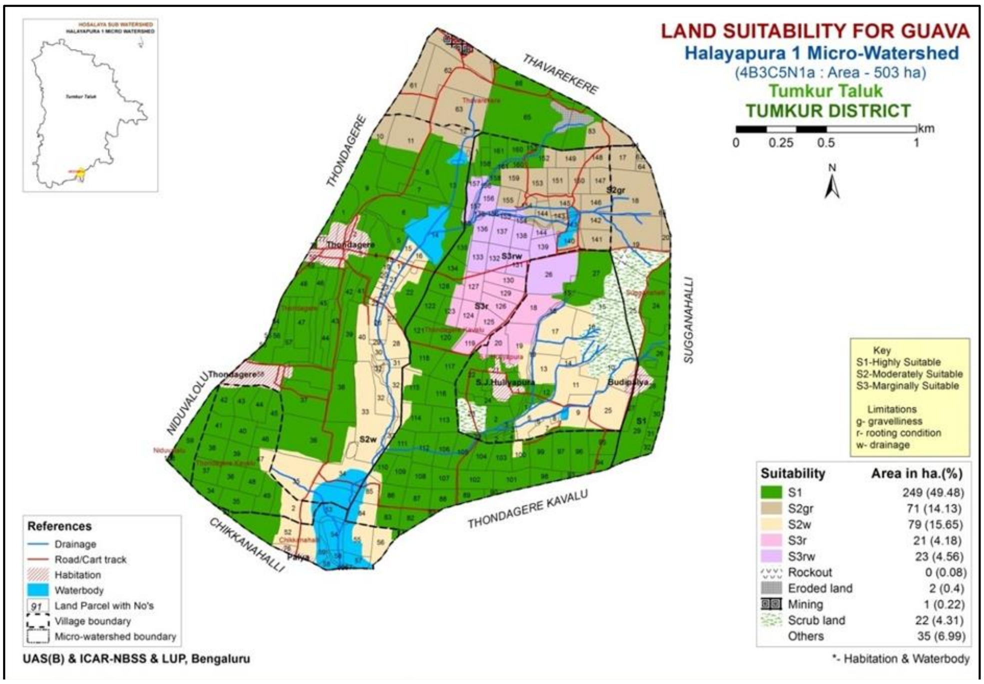


Fig 12: Guava map of Halayapura 1 micro-watershed

Conclusion
In the present study, two land capability classes having three subclasses were identified. Agriculturally important classes were I to IV. Major limiting factors of these agricultural fields were soil depth, drainage, texture, soil stoniness, surface stoniness, erosion, slope, soil reaction, organic carbon. It was observed that major portion of the study area is occupied by land capability class II lands, which are moderately suitable for cultivation of crops. The second largest area was occupied by land capability class III lands which are marginally suitable for cultivation. Ragi, groundnut, castor, redgram and horticulture crops like mango, coconut, arecanut, sapota, guava, marigold are best suited for this micro watershed.

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