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Assessment of land suitability potentials for agriculture in Koranahalli subwatershed using remote sensing & GIS

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Abstract
A study of land resource assessment using remote sensing and GIS techniques was taken up in Koranahalli subwatershed of Chikkamagaluru district of Karnataka for sustainable agriculture. 14 series were identified after detailed soil survey based on the soil characteristics. About 150 soil mapping units were grouped into good and moderate and fairly good cultivable land. Soil site suitability evaluation for different crops revealed that, about 32.95 per cent of area is highly suitable for field bean, followed by 55.94, 35.20, 34.89, 33.74 and 33.60 per cent of area is moderately suitable for groundnut, chickpea, ragi, soybean and pomegranate respectively. About 37.44, 36.52, 30.24, 30.07 and 29.76 per cent of area is suitable for cultivating tomato or brinjal, banana, soybean, ragi and sorghum or chickpea. However, 5.89 per cent of the area is not suitable for cultivating pomegranate or banana due to the limitation of soil depth and gravelliness or stoniness.

Keywords: remote sensing, GIS, land resource assessment, crop suitability

Introduction
Soil is a vital natural resource and its proper use greatly determines the life supporting system and the socio-economic status of the people. Soils provide food, fodder and fuel for meeting the basic needs of human beings and animals. However, the capacity of the soil to produce is limited. The production is limited mainly by intrinsic characteristics, agro-ecological settings and its management. It is very important for developing an effective land use system for augmenting agricultural production on sustainable basis. Hence, a detailed study for characterization and evaluation land resources is needed to realize the concept of watershed approach. From the data collected at the land parcel level, the site specific problems and potentials can be identified (Kharche and Gaikawad 1993) [4], conservation measures required can be planned on a scientific basis. Suitability of the area for various uses can be worked out and finally viable and sustainable land use options suitable for each and every land parcel can be suggested to the farmer and other stakeholders of the area by adapting remote sensing and GIS techniques. Remote sensing and GIS techniques have emerged as effective and powerful tools for generating different spatial information on various natural resources. Therefore, the present study of land resource assessment was taken up using remote sensing and GIS in the Koranahalli subwatershed of Chikkamagaluru district, Karnataka.

Material and Methods
Location and extent: The study area of Koranahalli subwatershed is located in Chikkamagaluru district of Karnataka and lies between 13°36′50.16′′ and 13°43′03.92′′ North latitude and between 75°52′08.50′′ and 75°57′21.80′′ East longitude with a geographical area 5820.710 Ha. The study area comprises of 12 micro watersheds *viz.* A.K. colony, Chattanahalli 1, Chattanahalli 2, Gollarahalli, Jodi bokikere, Koranahalli, Mundre 1, Mundre 2, Mundre 3, Rajanahalli 1, Rajanahalli 2 and Rajanahalli 3 (Fig.1). The average temperature in winter months 21.6 °C and during summer months the temperature averages around 28.1 °C. The mean annual rainfall for the last three decades in study area was 750-900 mm. The region receives rainfall mainly from South-West monsoon and partly from North East monsoon with an annual rainfall season spreading over a period of 4 to 5 months. The South-West monsoon occurs from June to September amounting to about 68 per cent and North East monsoon during October to November contributing about 32 per cent of the rainfall. Average relative humidity is about 65 per cent.

Image Interpretation for Physiography: Visual interpretation of False Colour Composites (FCC) of Quick bird satellite data covering sub watershed area was visually interpreted using image interpretation elements and all the available collateral data with local knowledge. The delineated physiographic boundaries were transferred on to a cadastral map overlaid on satellite imagery. Physiographically, Koranahalli subwatershed area has been covered by Peninsular gneisses of Archean age. The study area is divided into ridges, mounds, uplands and lowlands based on slope. They were further subdivided into physiographic/image interpretation units based on image characteristics.

Field survey: The cadastral map and satellite image were used as base map for traversing the entire subwatershed area. Visual interpretation of FCC of Quick bird data on 1:7920 scale was carried out to identify the physiographic units in the subwatershed. Traversing of the entire subwatershed area was undertaken in order to check the physiographic units. The transects were delineated in such a way that each transect should cut across at least three or more physiographic units. In each physiographic unit, profiles were studied for morphological characteristics to establish relation between physiography and soils depending on the length of slope (Soil Survey Staff 1999 [6]). Soil samples collected from the typifying pedons were analyzed for physical and chemical properties as per standard procedure.

Land evaluation: Based on the soil pedon characteristics viz., depth, colour, texture, gravelliness, calcareousness and horizon sequence the profiles were grouped into different soil series. A soil series is the most homogeneous unit having similar horizons and properties and behaves similarly for a given level of management. The area under each soil series was further separated into soil phases i.e., based on the observed variations in the surface soil texture, slope, erosion, gravelliness, stoniness etc. A soil phase is a subdivision of the soil series based mostly on surface features that affect its use and management. The soil map finalized based o field and soil analysis data were scanned and digitized using Geographical Information System (GIS) software to get the digital soil map.

The soil and land resource units (soil phases) of Koranahalli subwatershed were assessed for their suitability for growing major crops by following the procedure as outlined in FAO, 1976 [2] and Naidu *et.al.* (2006) [5]. The soil phase map can be used for identifying the land capability units and suitability classes for growing specific crops or for other alternative uses.

Results and Discussion

Detailed information pertaining to the nature, extent and distribution of different kinds of soils occurring in Koranahalli subwatershed is presented in table 1. Based on geology, fourteen soil series were identified. The area under each soil series was further separated into soil phases *i.e.* based on the observed variations in the surface texture, soil slope, erosion, gravelliness, stoniness *etc*. The depth of soils varying from 25 to 150 cm, colour from 5 YR to 10YR and sandy clay loam to clayey texture in sub surface and gravel content from 0 to 75 per cent. About 108 soil phases i.e., mapping units were delineated based on the soil site characteristics like soil depth, texture, slope, erosion and gravelliness. The soil map representing different soil phases presented in Fig.2.

Land capability classification is an interpretative grouping of soil map units (soil phases) mainly based on inherent soil characteristics, external land features and environmental factors that limit the use of land for agriculture, pasture, forestry or other uses on a sustained basis (Anonymous, 1961 and IARI, 1971) [1, 3] The land and soil characteristics used to group the land resources in an area into various land capability classes, subclasses and units. The land capability subclasses are recognised based on the dominant limitations observed within a given land capability class. The subclasses are designated by adding a lower case letter like ‘e’, ‘w’, ‘s’, or ‘c’ to the class numeral. The subclass “e” indicates that the main hazard is risk of erosion, “s” indicates shallow soil depth, coarse or heavy textures, calcareousness, salinity/alkalinity or gravelliness. The land capability subclasses have been further subdivided into land capability units based on the kinds of limitations present in each subclass. The capability units thus identified have similar soil and land characteristics that respond similarly to a given level of management.

The soil map units identified in the Koranahalli subwatershed are grouped under three land capability classes *i.e.*, class II and III and IV with three capability subclasses (*Fig*.3) *i.e.* erosion, excess of water and soil limitation. About 1406.25 ha area is occupied by land capability class II, *i.e.* Good cultivable land with minor limitations of soil depth, erosion and drainage. Nearly 1950.21 ha area is under land capability class III *i.e.* moderately good cultivatable land with major limitations of erosion, soil depth and drainage which reduce the choice of crops or that require special conservation practices and about 477.13 ha area is under land capability class IV *i.e.*, fairly good land that have very severe limitations that reduce the choice of crops or that require very careful management.

The soil and land resource units (soil phases) of Koranahalli subwatershed were assessed for suitability of cereals (Ragi and Sorghum), pulses (Field bean and Chick pea), oilseed crops (Soybean and Ground nut), vegetable crops (Tomato and Brinjal) and fruit crops (Pomegranate and Banana) growing in the study area by following the procedure as outlined in FAO, 1976 [2]. As per FAO land suitability classification, two orders are recognized *viz*. Suitable (S) and Not suitable (N). The orders have classes, sub classes and units. The suitable order comprises three classes *viz*. highly suitable (S1), moderately suitable (S2) and marginally suitable (S3). The not suitable order comprises classes, *viz*. currently not suitable (N1) and permanently not suitable (N2). There are no subclasses within the class S1 as they will have very minor or no limitations for crop growth. Classes S2 and S3 are divided into subclasses based on the kind of limitations encountered *viz*. erratic rainfall distribution and length of growing period (c), erosion hazard (e), rooting condition (r), lighter or heavy texture (t), gravelliness or stoniness (g), topography (l), drainage (w), moisture availability (m) and nutrient availability (n) presented in table 2.

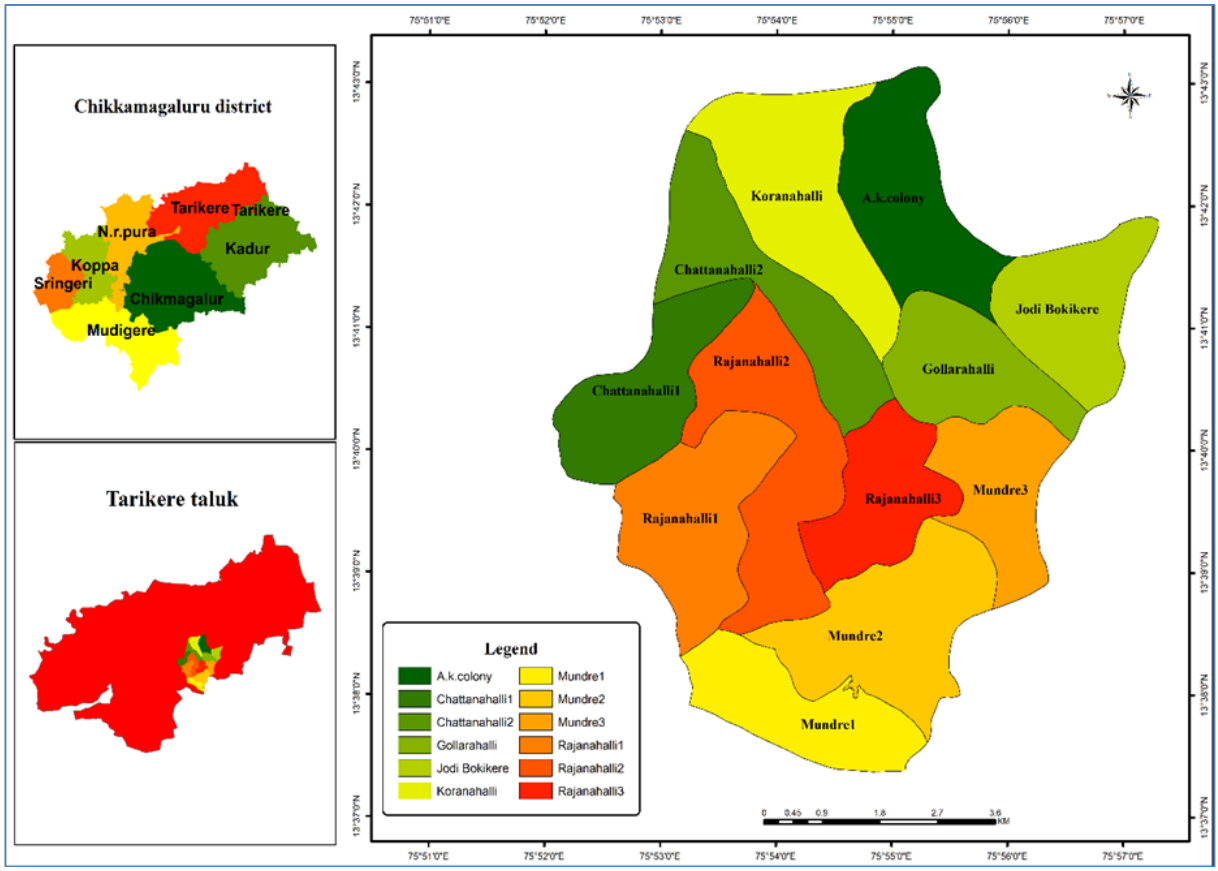

Fig 1: Location map of Koranahalli subwatershed

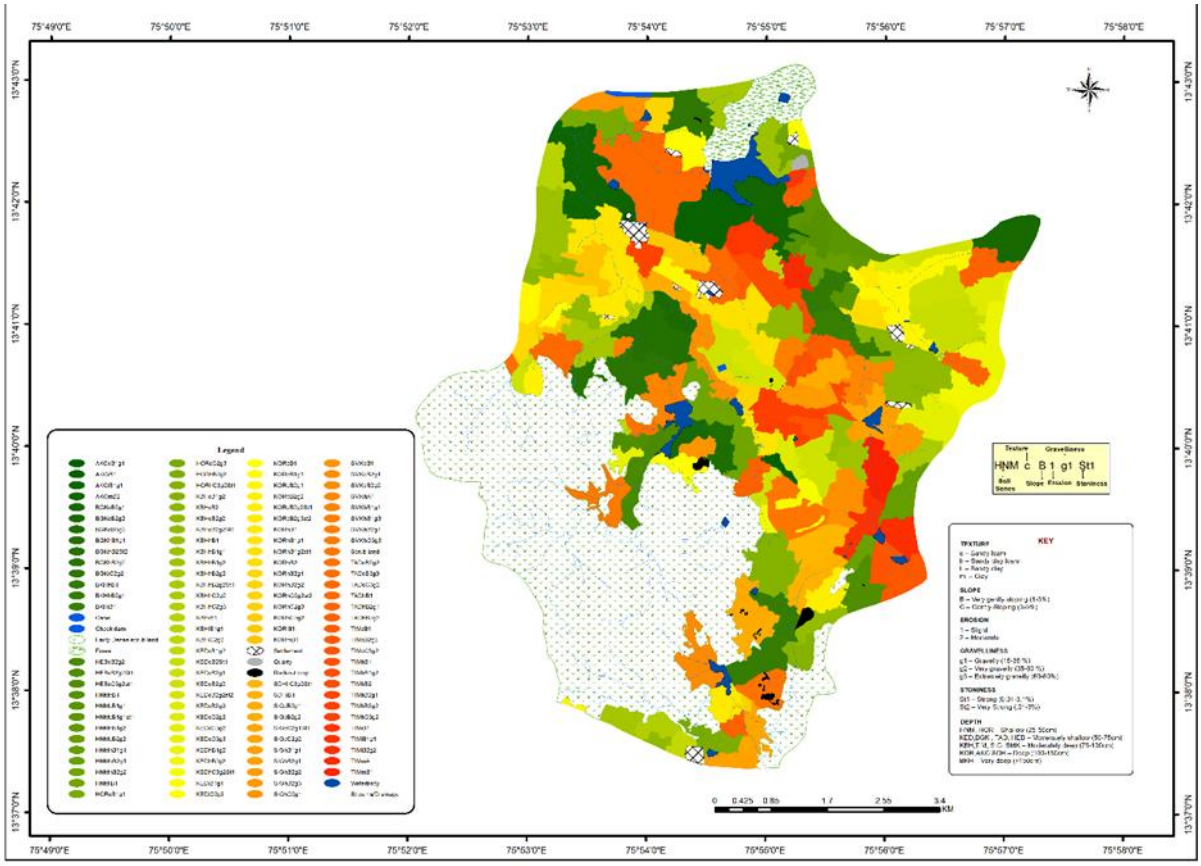

Fig 2: Soil phase map of Koranahalli subwatershed

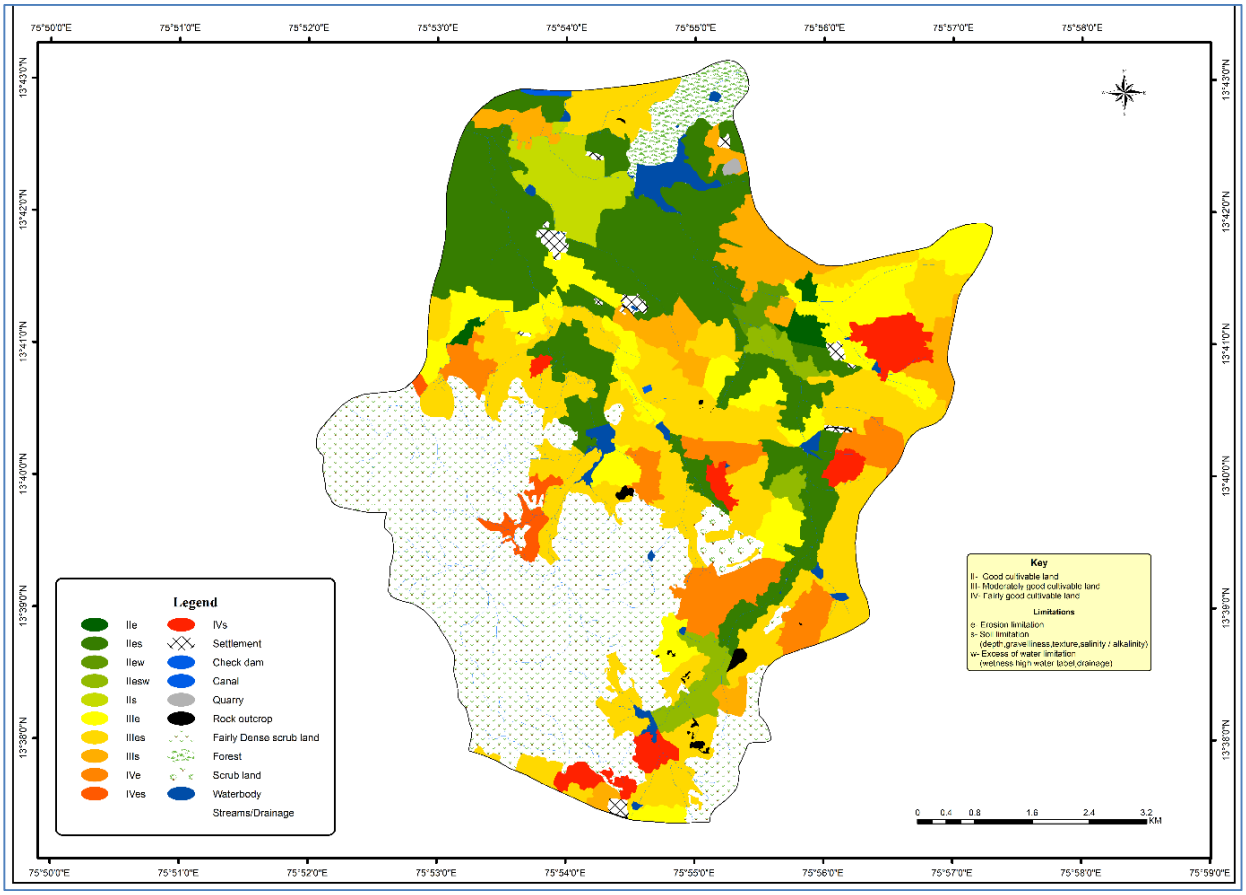

Fig 3: Land capability map of Koranahalli subwatershed

Land suitability for cereal crops

The crop suitability for cultivating cereals i.e., Ragi *(Eleusine coracana)* and Sorghum (*Sorghum bicolor*) crops were checked with the soil site suitability criteria and land suitability map of the study area was prepared (Fig. 4 & 5). Soil site suitability for ragi and sorghum in the study area ranged from highly to marginally suitable for the cultivation. About 2031 ha and 1848 ha of the subwatershed area is found to be moderately suitable, followed by marginally suitable of 1750 ha and 1732 ha and highly suitable of 53 ha and 254 ha of land for the cultivation of ragi and sorghum respectively.

Table 1: Soil series characteristics of Koranahalli Sub Watershed

Name of Soil series	Soil depth (cm)	Moist Colour		Texture		Gravel (%)	Calcareousness	Horizon sequence
		Surface	Sub surface	Surface	Sub surface			
Hanumapura	25-50	5YR4/6	5YR4/6	SCL	SC,C	35-60	Non calcareous	Ap-Bt-CR
Hortithimmanahalli	25-50	10YR5/4	10YR5/5	SCL	SCL	15-35	Non calcareous	Ap-Bw-CR
Tadaga	50-75	5YR4/4	5YR3/4	SL	C	35-60	Non calcareous	Ap-Bt-BC-CR
Hebburu	50-75	10YR3/4	10YR3/3, 3/1	C	C	--	Non calcareous	Ap-Bw-BC
Baggavali kaval	50-75	10YR2/2	7.5YR2.5/3, 3/3	SCL	CL-C	<15	Non calcareous	Ap-Bt-BC
Kedihalli	50-75	5YR3/3	5YR3/4, 2.5YR4/6	SL	SC-C	35-60	Non calcareous	Ap-Bt-BC
Sigehadlu	75-100	5YR3/4	2.5YR4/6	SL	SC	35-60	Non calcareous	AP-Bt-BC
Timmapura	75-100	7.5YR3/3	7.5YR3/2, 5YR4/4	SL	SCL-SC	35-60	Non calcareous	Ap-Bt-CR
Kere basavanahalli	75-100	2.5YR3/4	2.5YR3/4, 3/6	SCL	SCL-C	15-35	Non calcareous	Ap-Bt-BC
Santhaemaradi kaval	75-100	7.5YR3/4	7.5YR3/3, 4/3	SCL	SC-C	<15	Non calcareous	Ap-Bt-CR
Kornahalli	100-150	5YR3/4	7.5YR4/3, 2.5/4, 3/3, 3/4	SCL	SCL- SC-C	15-35	Non calcareous	Ap-Bt-BC
Siddarahalli	100-150	7.5YR3/6	7.5YR3/3,3/4,	SL	C	--	Non calcareous	Ap-Bt-BC
A K colony	100-150	10YR3/2	10YR3/1, 3/2, 5/6	SL	C-SC	--	Non calcareous	Ap-Bw-CR
B Kodihalli	>150	7.5YR2.5/3	7.5YR2.5/3, 3/3	C	C	--	Non calcareous	Ap-Bw-CR

Note: SCL- Sand Clay Loam, SL-Sandy Loam, SC- Sandy Clay, C-Clay,

Table 2: Soil site suitability criteria for cereals, pulses, oilseeds, vegetables and fruit crops

Soil site characteristics	Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Ragi (*Eleusine coracana*)					
Mean temperature	ºC	28-34	25-27 ; 35-38	39-40 ; 20-40	>40 ; <20
Total rainfall	mm	750-900	600-750	450-600	<450
Length of Growing period	Days	>110	90-110	60-90	<60
Effective soil depth	cm	>75	51-75	25-50	<25
Slope	%	<3	3-5	5-10	>10
Sorghum (*Sorghum bicolor*)					
Mean temperature	ºC	26-30	31-34 ; 24-25	35-40 ; 20-23	>40 ; <20
Total rainfall	mm	650 -850 ; >850	650-550	450·550	<450
Length of Growing period	Days	120-150	120-90	<90	--
Effective soil depth	cm	100-75	50-75	30-50	<30
Slope	%	2-3	3-8	8-15	>15
Field bean (*Vecia faba)*					
Mean temperature	ºC	20-35	18-19 ;36-40	15-17 ; 41-45	<15 ; >45
Total rainfall	mm	750-900	600-750	500-600	<500
Length of Growing period	Days	>120	90-120	70-90	<70
Effective soil depth	cm	>75	50-75	25-50	<24
Slope	%	<5	5-10	10-15	>15
Chick pea (*Cicer arietinum)*					
Mean temperature	ºC	20-25	15- 19	5- 15 ; 26-30	>30 ; <5
Total rainfall	mm	800 -1000	600-800	400-600	<400
Length of Growing period	Days	>100	90-100	70-90	<70
Effective soil depth	cm	>75	51-75	25-50	<25
Slope	%	<3	3-5	5-10	>10
Groundnut (*Arachis hypogaea*)					
Mean temperature	ºC	24-30	22-23 ; 31-33	20-21; 34-40	<20 ; >40
Total rainfall	mm	700-1000	500-700	350-500	<350
Length of Growing period	Days	100-125	90-105	75-90	100-125
Effective soil depth	cm	>75	50-75	25-50	<25
Slope	%	<3	3-5	5-10	>10
Soybean (*Glycine max*)					
Mean temperature	ºC	25-28	29-32	33-36	>36
Total rainfall	mm	600-750	500-600	400-500	<400
Length of Growing period	Days	>120	100-120	85-100	<85
Effective soil depth	cm	>75	50-75	50-25	<25
Slope	%	<3	3-5	5-8	>8
Tomato (*Solanum lycopersicum*) and Brinjal (*Solanum melongena*)					
Mean temperature	ºC	25-28	29-32 ; 20-24	15-19 ; 33-36	<15 ; >36
Total rainfall	mm	600-750	500-600 ; 750-1000	400-500 ; >1 000	--
Length of Growing period	Days	>150	120-150	90-120	--
Effective soil depth	cm	>75	50-75	25-50	<25
Slope	%	1-3	3-5	5-10	>10
Pomegranate *(Punica granatum)*					
Mean temperature	ºC	30-34	35-38 ; 25-29	39-40 ; 15-24	
Salinity	dS/m	Nil	<9	>9	<50
Length of Growing period	Days	>150	120-150	90-120	<90
Effective soil depth	cm	>100	75-100	50-75	<50
Slope	%	<3	3-5	5-10	
Banana (*Musa paradisiaca*)					
Mean temperature	ºC	26-33	34 -36 ; 24 - 25	37 - 38	>38
Total rainfall	mm	100	50-100	25-50	<25
Salinity	dS/m	<1.0	1-2	>2	--
Effective soil depth	cm	>125	76-125	50-75	<50
Slope	%	<3	3-5	5-15	>15

Land suitability for pulse crops

The crop requirements for growing pulse crops like Field bean (*Vicia faba L.*) and Chick pea (*Cicer arietinum)* were matched with the soil site characteristics of the study area and land suitability map is presented in Fig. 6 & 7. Soil site suitability for field bean and chick pea in the study area ranged from highly to marginally suitable for the cultivation. The major portion of the subwatershed area is found to be highly suitable (1918 ha) followed by moderately suitable (1573 ha) and marginally suitable (343 ha) for the cultivation of field bean, whereas for chick pea cultivation maximum area is classified as moderately suitable (3281 ha) followed by marginally suitable (553 ha) and highly suitable (53 ha) due to the limitations of gravelliness, texture, topography, drainage and rooting conditions.

Land suitability for oilseed crops

The suitability assessment for growing oilseed crops like Groundnut (*Arachis hypogaea*) and Soybean (*Glycine max*) in Koranahalli subwatershed area ranged from highly to marginally suitable for the cultivation. About 3256 ha and 1964 ha of study area is found to be moderately suitable,

followed by marginally suitable of 375 ha and 1760 ha and highly suitable of 203 ha and 110 ha of land for the cultivation of groundnut and soybean due to the limitations of gravelliness, texture, topography, drainage and rooting conditions (Fig.8 & 9).

Land suitability for vegetable crops

The suitability assessment for growing vegetables viz., Tomato (*Solanum lycopersicum*) and Brinjal (*Solanum melongena*) in Koranahalli subwatershed area ranged from highly to marginally suitable for the cultivation. The major portion of the subwatershed area is found to be marginally suitable (2179 ha) followed by moderately suitable (1452 ha) and highly suitable (203 ha) for the cultivation of both the crops due to the limitations of gravelliness, texture, topography, drainage and rooting conditions (Fig.10).

Land suitability for fruit crops

The crop suitability assessment for cultivating Pomegranate (*Punica granatum*) and Banana (*Musa paradisiaca*) fruit crops in Koranahalli subwatershed area ranged from moderately suitable to not suitable for the cultivation. However, the maximum area under study is classified as moderately suitable of 1956 ha and 1365 ha, followed by marginally suitable of 1535 ha and 2126 ha of land for the cultivation of pomegranate and banana due to the limitations of gravelliness, texture, soil depth, moisture availability and rooting conditions (Fig.11 & 12). About 343 ha of Koranahalli subwatershed area found to be not suitable for the cultivation of pomegranate and banana fruit crops.

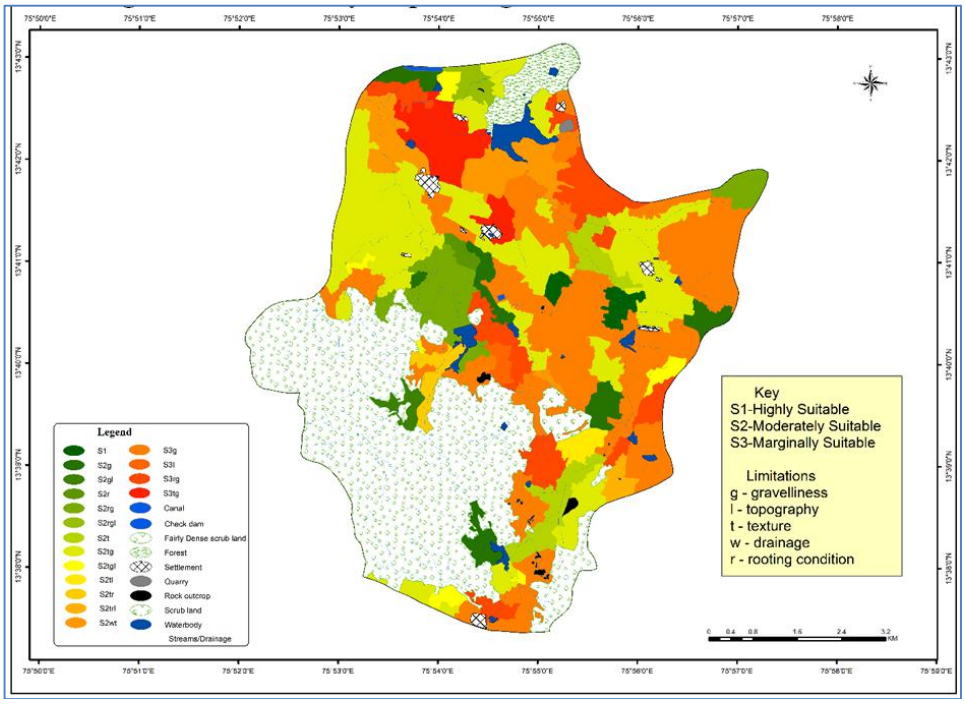

Fig 4: Land suitability map of ragi in Koranahalli subwatershed

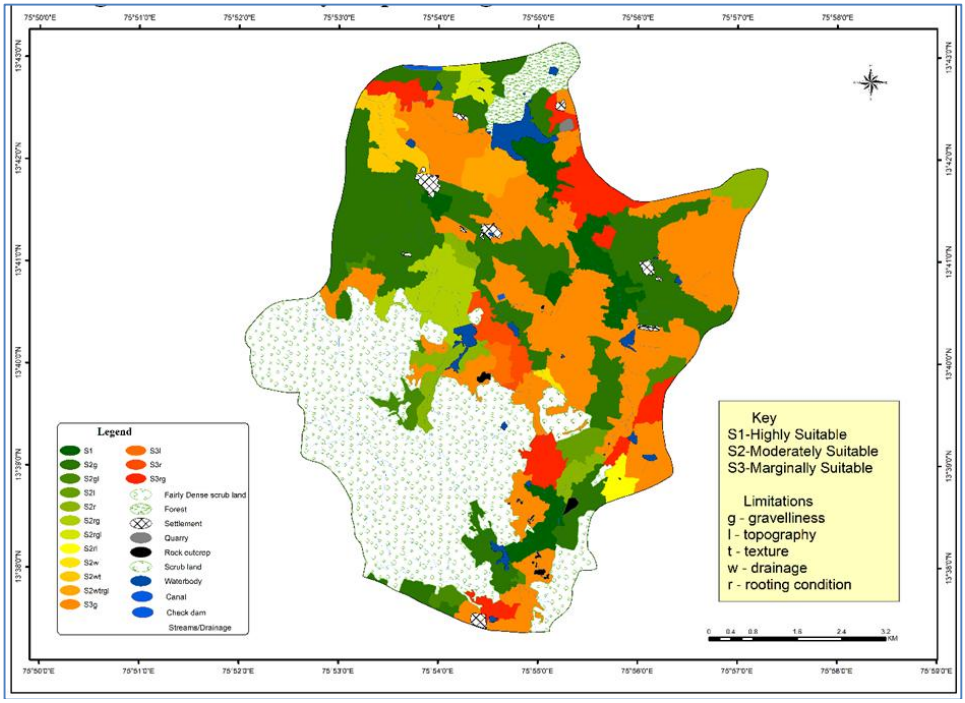

Fig 5: Land suitability map of sorghum in Koranahalli subwatershed

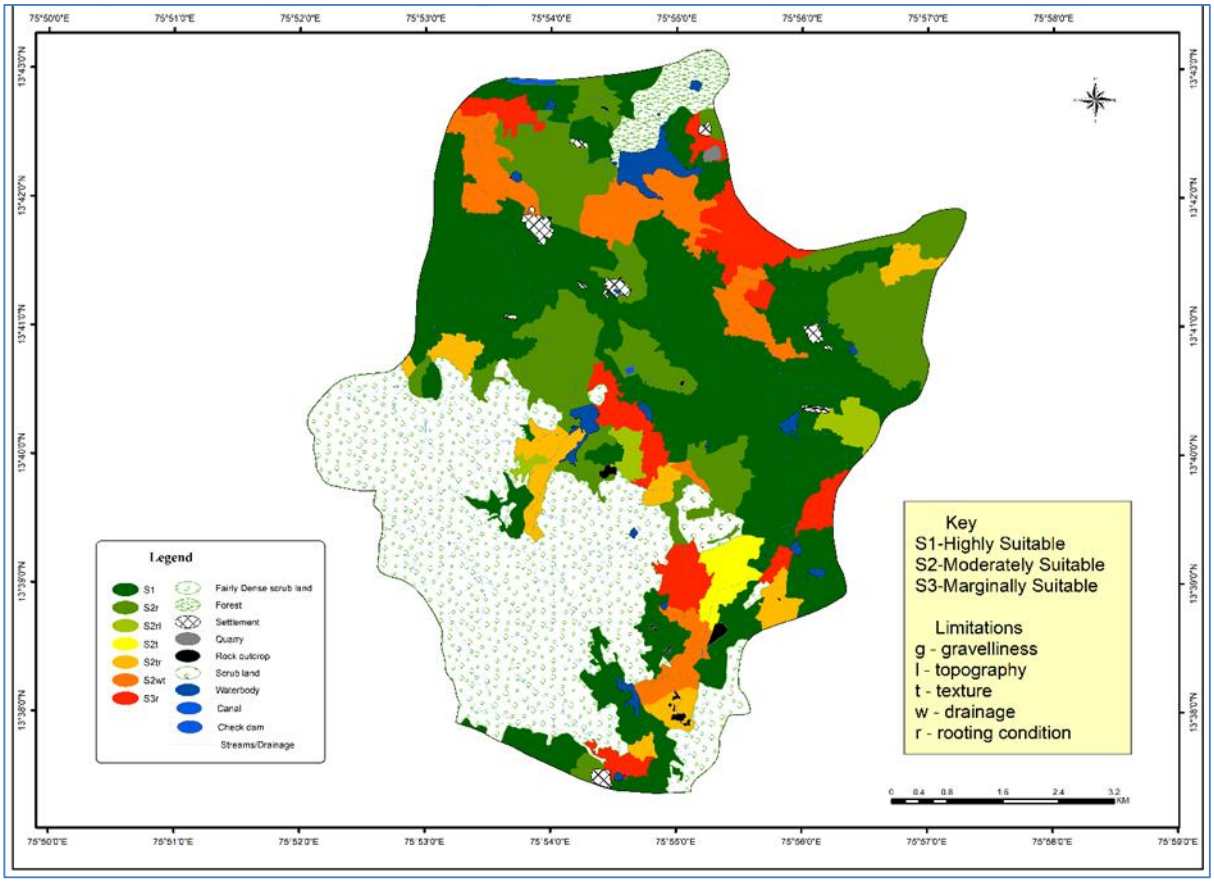

Fig 6: Land suitability map of field bean in Koranahalli subwatershed

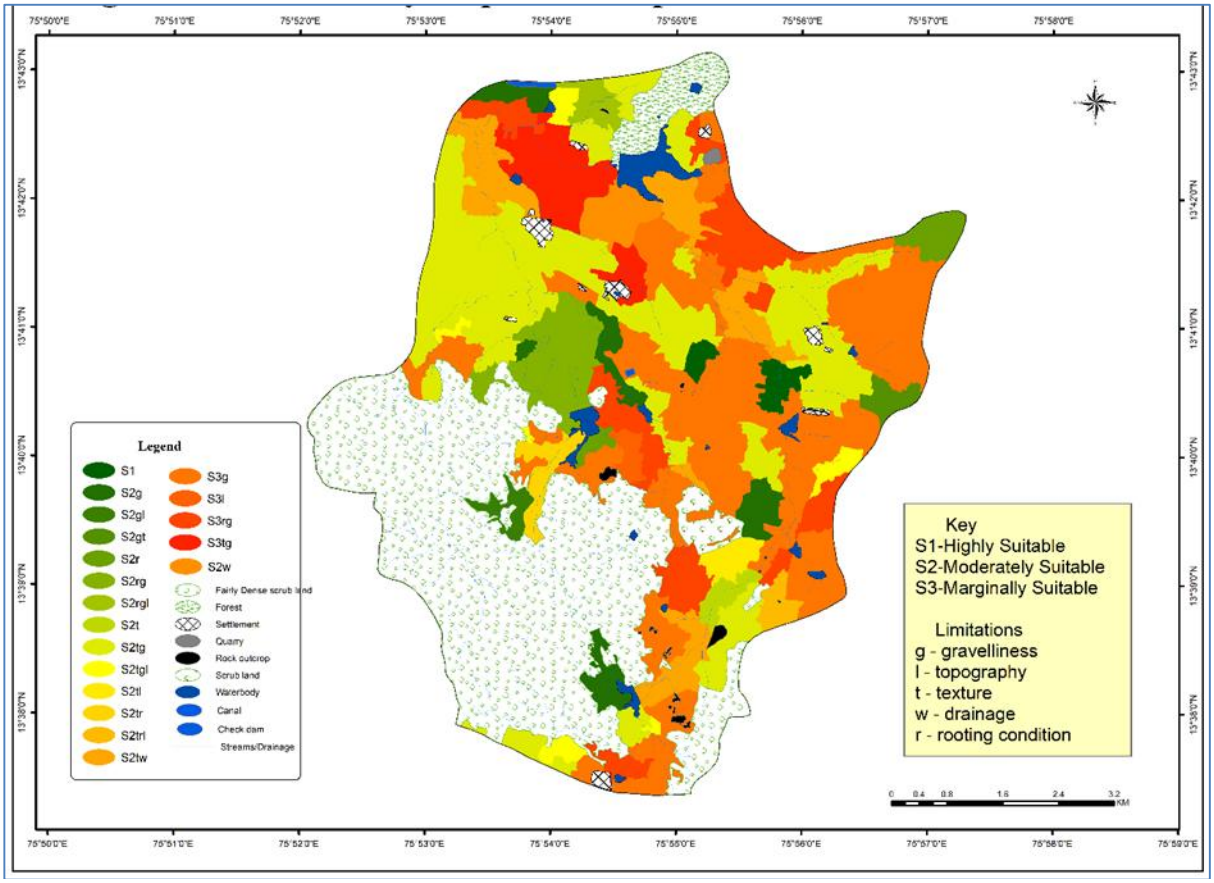

Fig 7: Land suitability map of chick pea in Koranahalli subwatershed

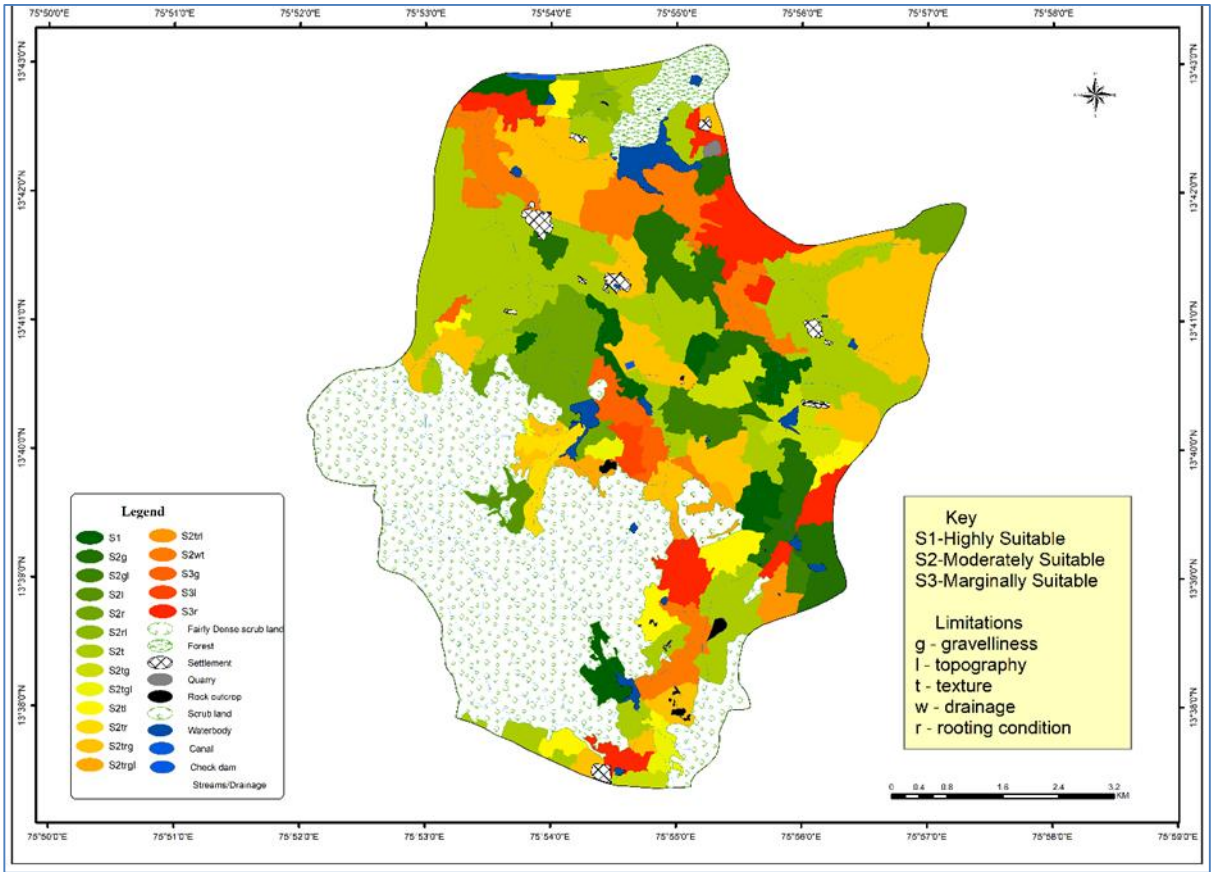

Fig 8: Land suitability map of groundnut in Koranahalli subwatershed

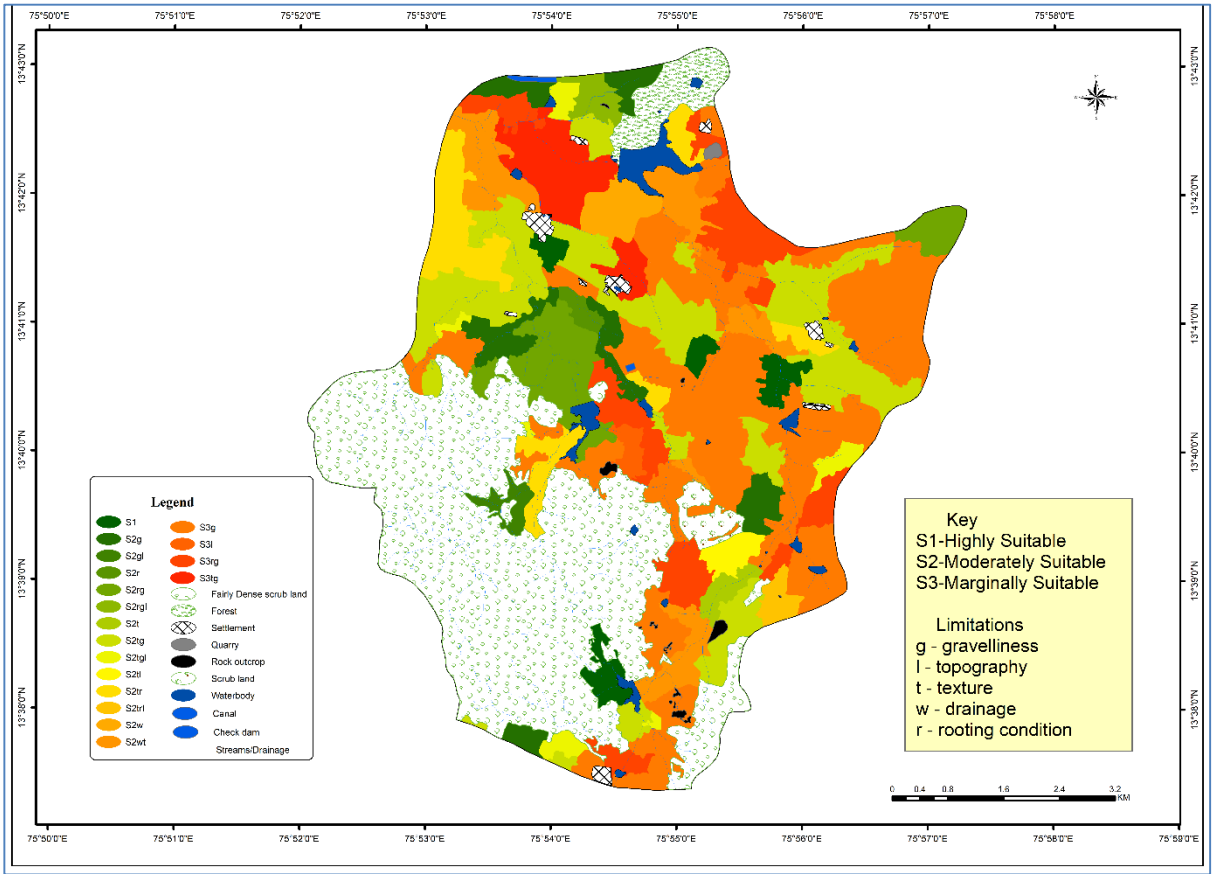

Fig 9: Land suitability map of soybean in Koranahalli subwatershed

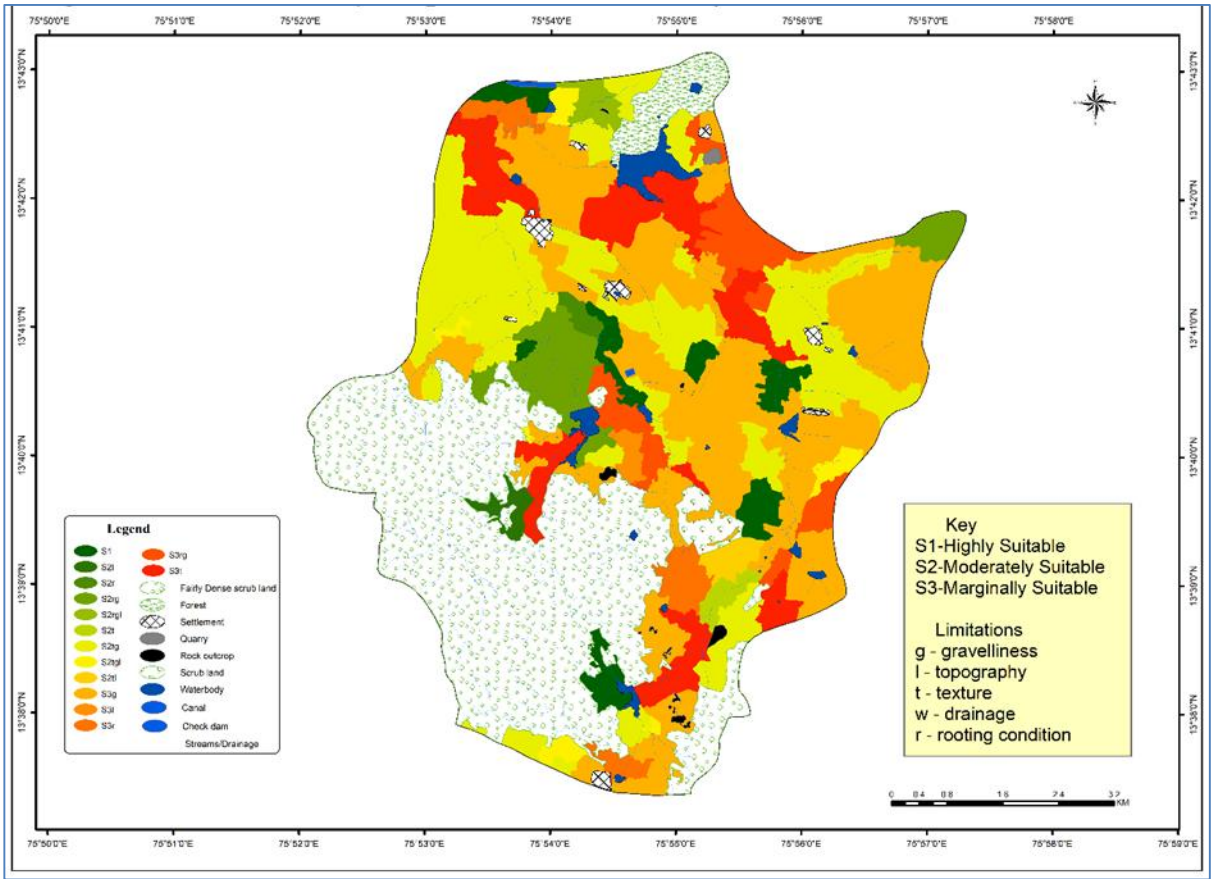

Fig 10: Land suitability map of tomato & brinjal in Koranahalli subwatershed

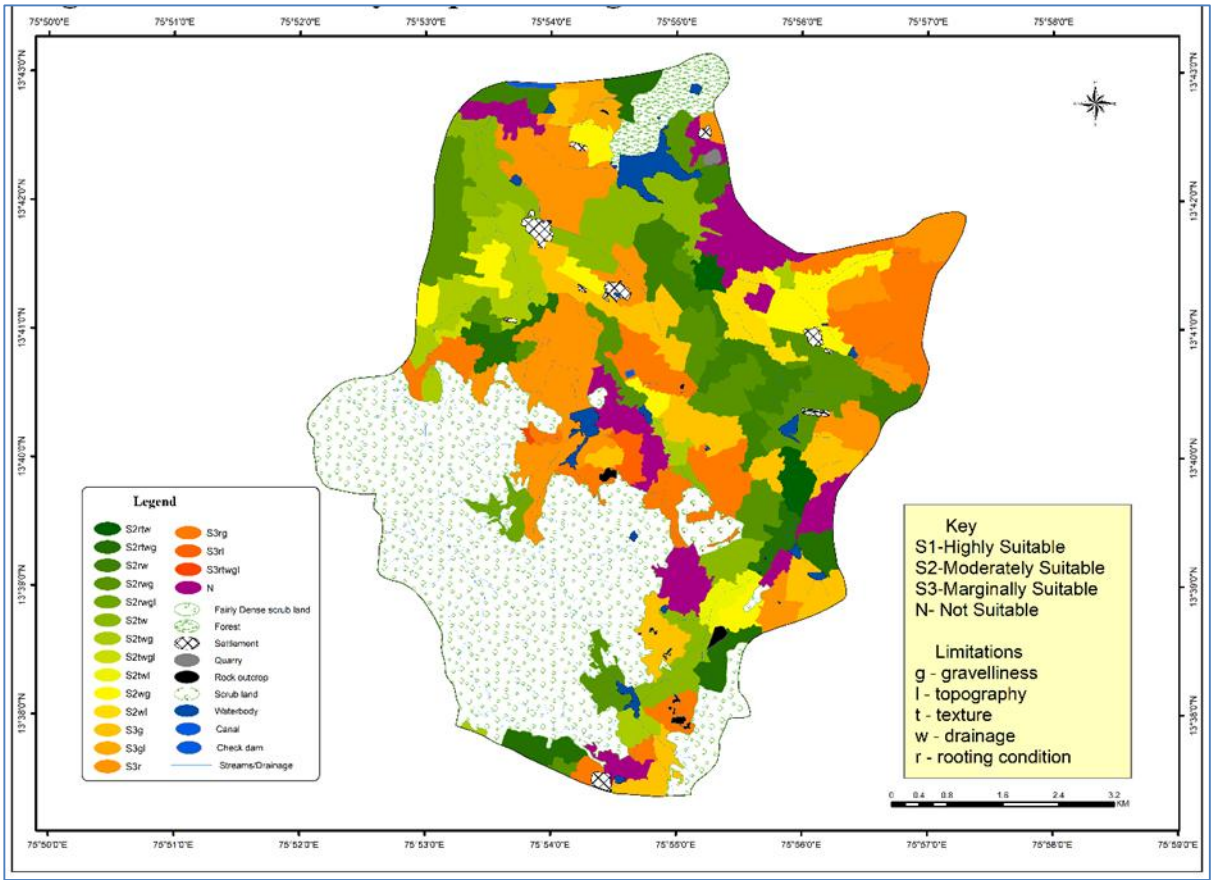

Fig 11: Land suitability map of pomegranate in Koranahalli subwatershed

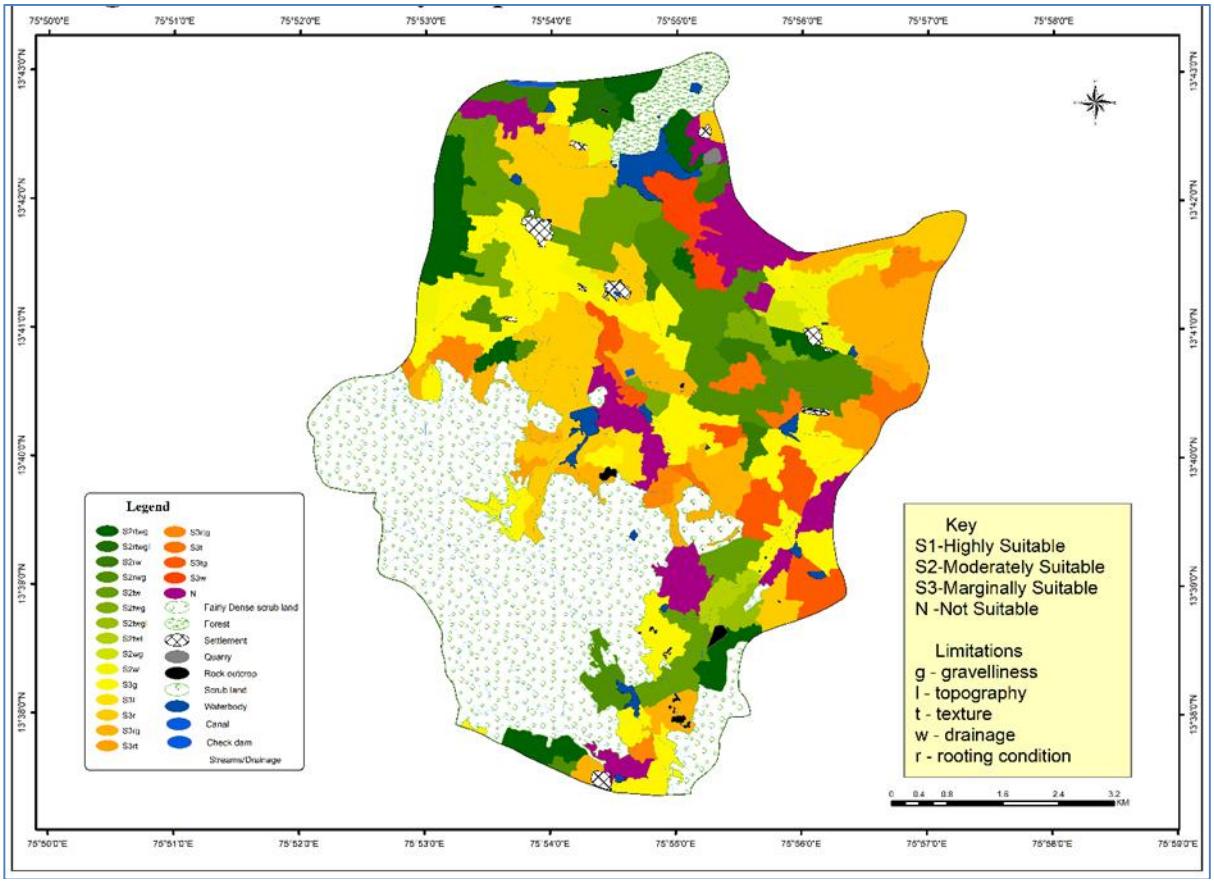

Fig 12: Land suitability map of banana in Koranahalli subwatershed

Conclusion

About one hundred and fifty soil mapping units were grouped into good cultivable land and moderately cultivable land and fairly good cultivable land. About 33.50 per cent of the Koranahalli Sub Watershed area is classified as moderately good cultivable land (III) with major limitations of erosion, soil depth and drainage, followed by 24.16 per cent good cultivable land (II) with minor limitations of soil depth, erosion and drainage and 8.20 per cent of fairly good cultivable land (III) with severe limitation of soil depth, erosion and drainage. Soil-site suitability evaluation of Koranahalli subwatershed area revealed that about 34.89 per cent and 31.75 per cent of the study area is moderately suitable for cultivation of cereals like ragi and sorghum. In case of pulse crops about 32.95 per cent of area is highly suitable for cultivation of field bean and 35.20 per cent of the area moderately suitable for growing chickpea. Among oilseed crops about 55.94 per cent and 33.74 per cent of the study area is grouped under moderately suitable for cultivation of groundnut and soybean. Whereas for vegetables 37.44 percent of the subwatershed area found to be marginally suitable for cultivation of tomato and brinjal. However, for fruit crops 33.60 per cent of the area is moderately suitable for pomegranate, 36.52 per cent of area marginally suitable for banana cultivation and 5.89 per cent of the area is not suitable for cultivating both the crops due to the limitation of soil depth and gravelliness or stoniness.

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