Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
e-ISSN: 2395-3454

Vol. 18 | No. 3 | pp. 735-746 | 2019

Original Research Paper | Open Access

Land Evaluation by Integrating Remote Sensing and GIS for Rainfed Agriculture in Koranahalli Subwatershed

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 13-02-2019
Accepted: 29-03-2019

Key Words:
Remote Sensing
GIS
Land resource assessment
Crop suitability

ABSTRACT

In the present study, an assessment of land suitability potential for agriculture in the Koranahalli subwatershed area has been conducted through a close examination of the different indicators of land characteristics and qualities. The objective of this study is to assess the land resource and generate a potential map of the study area. The database on soil resources and land use/land cover data was generated by using remote sensing satellite data and soil survey to perform an integrated analysis in the GIS environment. Fourteen 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 4.36 percent of area is highly suitable for sorghum, followed by 36.92, 35.20, 34.89, 33.60, 31.75 percent and 31.11 percent of area is moderately suitable for chilli, chickpea, ragi, pomegranate, sorghum and sunflower respectively. About 37.44, 31.33, 30.07, 29.81 and 29.76 percent of area is marginally suitable for cultivating tomato, redgram, ragi, sunflower and sorghum or chickpea. However, 30.94, 25.39, 5.89 and 4.95 percent of the area is not suitable for cultivating castor, sapota, pomegranate and redgram or sunflower due to the limitation of soil depth and gravelliness or stoniness.

INTRODUCTION

Land evaluation using a scientific procedure is essential to assess the potential and constraints of a given land parcel for agricultural purposes (Rossiter 1996). In the recent past, the adverse effects of land use on the environment and the sustainability of agricultural production have become an issue of concern. The problems of declining soil fertility, static yield level and unfettered soil erosion are associated with intensive agriculture in industrialized countries, while over-exploitation of natural resources, and scarcity of inputs like chemical fertilizers denote intensive agriculture in the developing areas (Fresco 1990, Lanen Van et al. 1992). 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 & Gaikawad 1993), and 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. Remote sensing data are used for estimating biophysical parameters and indices besides cropping system analysis, and land-use and land-cover estimations during different seasons (Rao et al. 1996, Panigrahy et al. 2006). Therefore, the present study of land resource assessment was taken up using remote sensing and GIS in the Koranahalli subwatershed of Chikkamagaluru district, Karnataka.

MATERIALS 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 of 5820.710 ha. The study area comprises of 12 micro watersheds, *viz.* A.K. colony, Chattanahalli1, Chattanahalli 2, Gollarahalli, Jodi Bokikere, Koranahalli, Mundre1, Mundre2, Mundre3, Rajanahalli1, Rajanahalli2 and Rajanahalli3 (Fig. 1). The mean annual rainfall for the last three decades in study area was 750-900 mm. The region receives rainfall mainly from

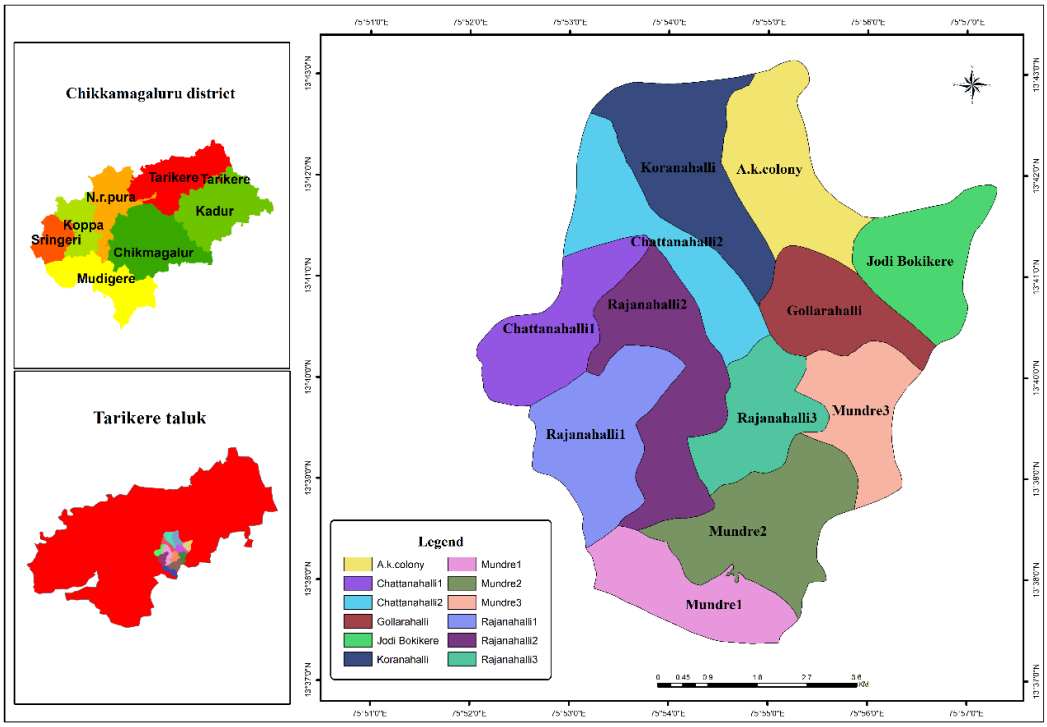

Fig. 1: Location map of Koranahalli subwatershed.

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 percent of the rainfall. Average relative humidity is about 65 percent.

Image interpretation for physiography: Visual interpretation of satellite data covering subwatershed area 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 a base map for traversing the entire subwatershed area. Visual interpretation of false color composite 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 a relation between physiography and soils depending on the length of slope (Soil Survey Staff 1999). Soil samples collected from the typifying pedons were analysed for physical and chemical properties as per the standard procedure.

Land evaluation: Based on the soil pedon characteristics, the profiles were grouped into different soil series. 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 on field and soil analysis data was scanned and digitized using a 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) and Naidu et al. (2006). 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, 14 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 10 YR and sandy clay loam to clayey texture in subsurface and gravel content from 0 to 75 percent. 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 is presented in Fig. 2.

Land capability classification is an interpretative grouping of soil map units 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). 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 has 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 (redgram and chickpea), oilseed crops (sunflower and castor), vegetable crops (tomato and chilli) and fruit crops (pomegranate and sapota) growing in the study area by following the procedure as outlined in FAO (1976). As per FAO, land suitability classification, two orders are recognized, viz. suitable (S) and not suitable (N). The orders have classes, subclasses and units. The suitable order comprises three classes, viz. highly suitable (S1), moderately suitable (S2) and marginally suitable (S3). The not suitable order comprises two 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), as presented in Table 2.

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 (Figs. 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.

Land suitability for pulse crops: The crop requirements for growing pulse crops like redgram (*Cajanus cajan*) and chickpea (*Cicer arietinum)* were matched with the soil site characteristics of the study area and land suitability map is presented in Figs. 6 & 7. Soil site suitability for redgram and chickpea in the study area ranged from highly to marginally suitable for the cultivation. The major portion of the subwatershed area is found to be marginally suitable (1812 ha) followed by moderately suitable (1734 ha) and not suitable (288 ha) for the cultivation of redgram, whereas for chickpea cultivation maximum area is classified as moderately suitable (2049 ha) followed by marginally suitable (1732 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 sunflower (*Helianthus annus*) and castor (*Ricinus communis*) in Koranahalli subwatershed area ranged from highly to marginally suitable for the cultivation. About 1811 ha and 681 ha of study

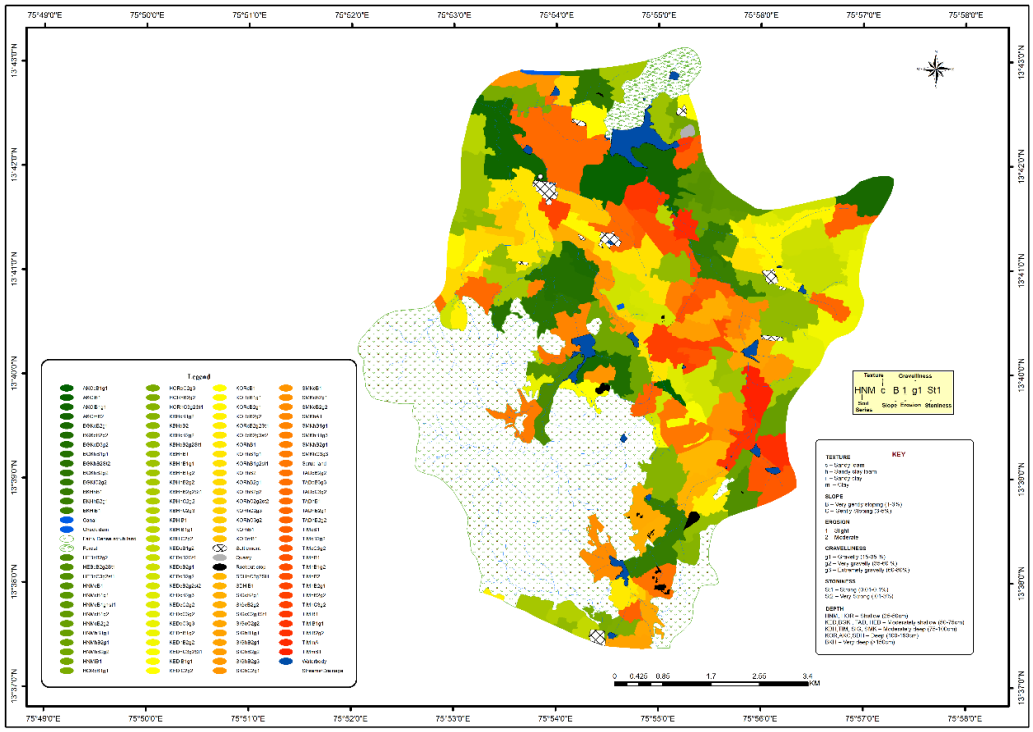

Fig. 2: Soil phase map of Koranahalli subwatershed.

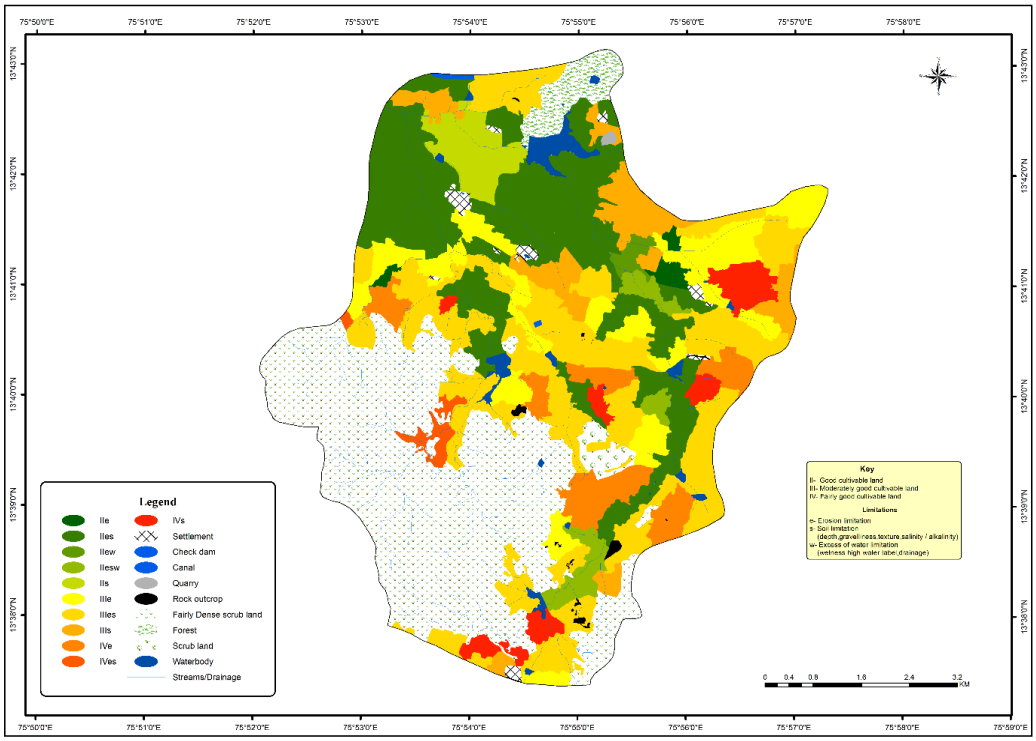

Fig. 3: Land capability classification map of Koranahalli subwatershed.

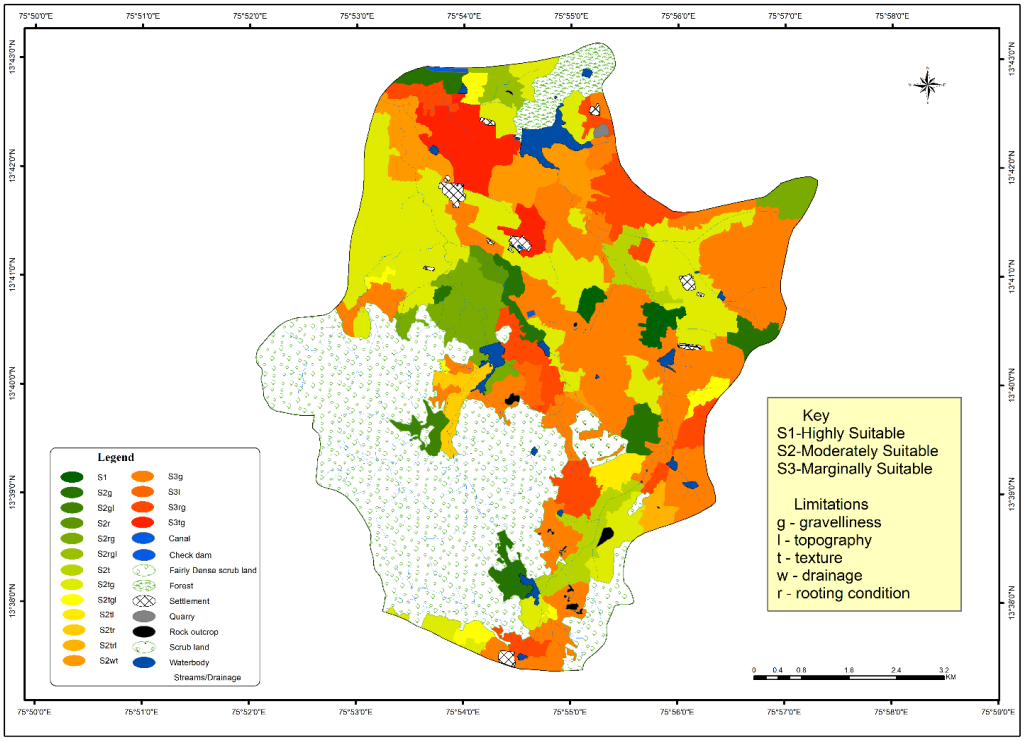

Fig. 4: Land suitability map of Ragi in Koranahalli subwatershed.

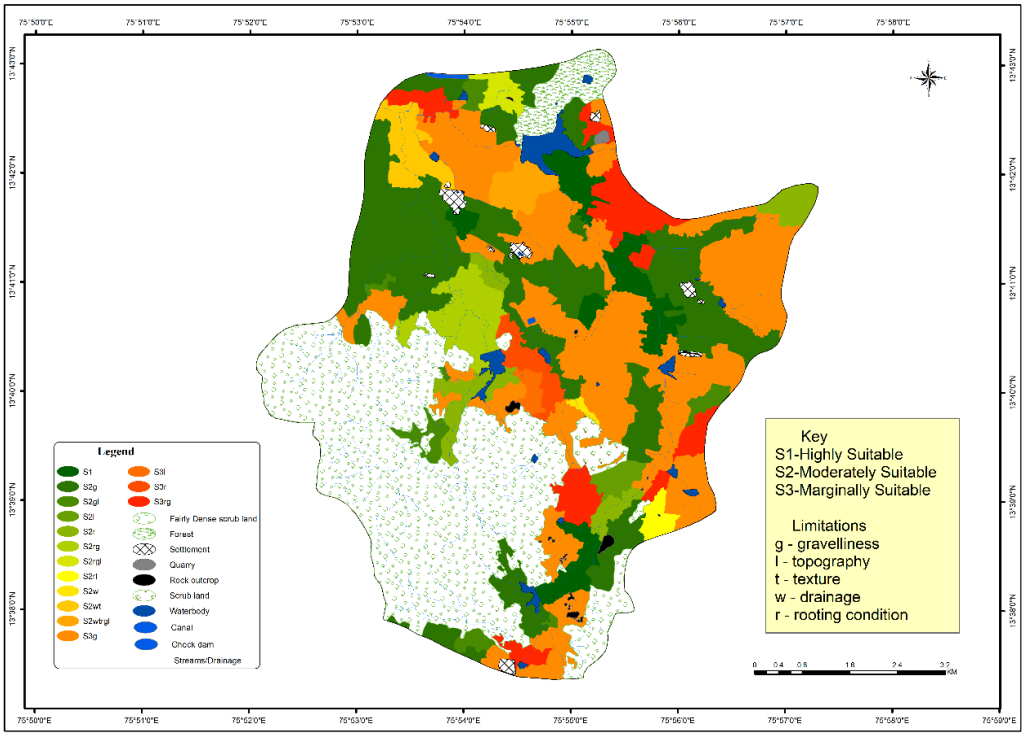

Fig. 5: Land suitability map of Sorghum in Koranahalli subwatershed.

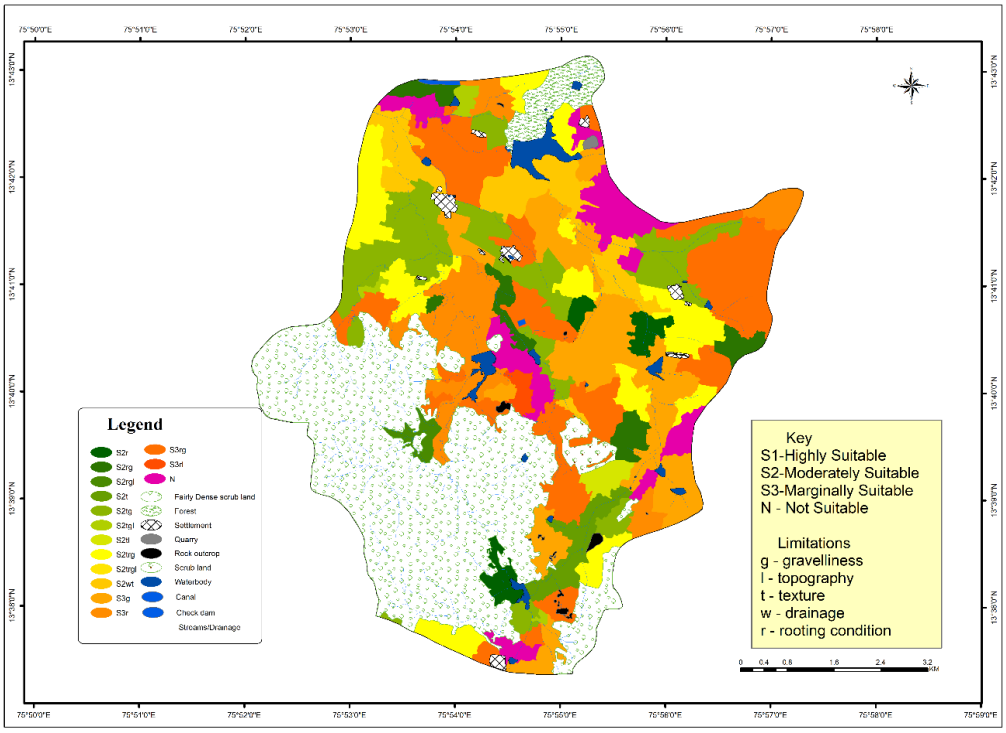

Fig. 6: Land suitability map of Redgram in Koranahalli subwatershed.

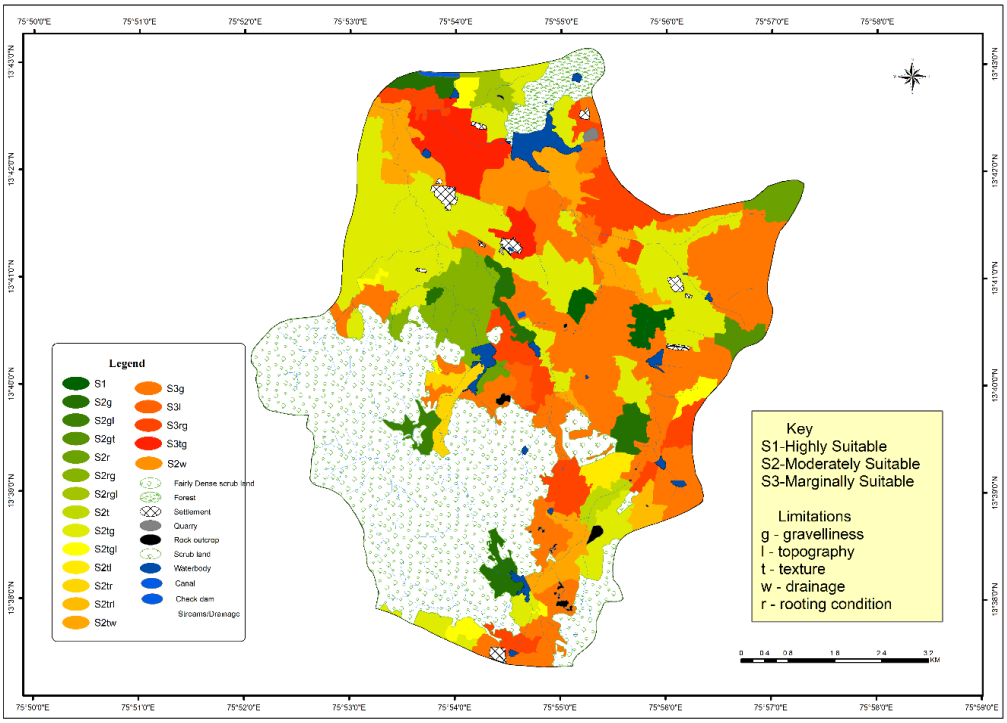

Fig. 7: Land suitability map of Chickpea in Koranahalli subwatershed.

Table 1: Soil series characteristics of Koranahalli subwatershed.

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

area is found to be moderately suitable, followed by marginally suitable of 1735 ha and 1352 ha, and not suitable of 288 ha and 1801 ha land for the cultivation of sunflower and castor due to the limitations of gravelliness, texture, topography, drainage and rooting conditions (Figs. 8 & 9).

Land suitability for vegetable crops: The suitability assessment for growing vegetables like tomato (*Lycopersicon esculentum*) and chilli (*Capsicum annuum*) 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 tomato. Whereas, for cultivation of chilli, maximum area is grouped under moderately suitable (2149 ha) followed by marginally suitable (1667 ha) and highly suitable (18 ha), this may be due to the limitations of gravelliness, texture, topography, drainage and rooting conditions (Figs. 10 & 11).

Land suitability for fruit crops: The crop suitability assessment for cultivating pomegranate *(Punica granatum)* and sapota (*Manilkara zapota*) fruit crops in Koranahalli subwatershed area ranged from moderately suitable to not suitable for the cultivation. However, the maximum area under study classified as moderately suitable is 1956 ha and 766 ha, followed by marginally suitable of 1535 ha and 1590 ha land for the cultivation of pomegranate and sapota due to the limitations of gravelliness, texture, soil depth, moisture availability and rooting conditions (Figs. 12 & 13). About 343 ha and 1478 ha of Koranahalli subwatershed area found to be not suitable for the cultivation of pomegranate and sapota fruit crops.

CONCLUSIONS

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 percent of the Koranahalli subwatershed area is classified as moderately good cultivable land (III) with major limitations of erosion, soil depth and drainage, followed by 24.16 percent good cultivable land (II) with minor limitations of soil depth, erosion and drainage and 8.20 percent 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 percent and 31.75 percent of the study area is moderately suitable for cultivation of cereals like ragi and sorghum. In case of pulse crops about 35.20 percent of area is moderately suitable for cultivation of chickpea and 31.13 percent of the area marginally suitable for growing redgram. Among oilseed crops about 29.81 percent and 23.23 percent of the

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	°C	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	°C	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
Redgram (*Cajanus cajan)*					
Mean temperature	°C	25-28	22-24	20-21	<20
Total rainfall	mm	800-1000	600-800	400-600	<400
Length of Growing period	Days	>180	100-120	80-100	<80
Effective soil depth	cm	>100	85-100	40-85	<40
Slope	%	<3	5-10	10-15	>15
Chickpea (*Cicer arietinum)*					
Mean temperature	°C	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	-
Castor (*Ricinuscommunis*)					
Mean temperature	°C	26-32	33-35;24-25	36-40;15-23	<40;>15
Total rainfall	mm	600-750	400-600	250-400	<250
Soil drainage	Class	Well drained	Moderately well drained	Imperfectly drained	Poorly drained
Effective soil depth	cm	>75	50-75	25-50	<25
Slope	%	<3	3-5	5-10	-
Sunflower*(Helianthus annus)*					
Mean temperature	°C	24-30	31-34;20-23	35-38;16-19	>38;<16
Total rainfall	mm	600-700	500-600	400-500	<400
Length of Growing period	Days	>90	80-90	70-80	<70
Effective soil depth	cm	>100	76-100	50-75	<50
Slope	%	<3	3-5	5-10	>10
Tomato (*Solanum lycopersicum*)					
Mean temperature	°C	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
Chilli *(Capsicum annuum)*					
Mean temperature	°C	25-32	33-35;20-24	36-38;<20	>38
Total rainfall	mm	750-900	900-1200	500-600;>1200	-
Length of Growing period	Days	>150	120-150	90-120	<90
Effective soil depth	cm	>75	50-75	25-50	<25
Slope	%	<3	3-5	5-10	-
Pomegranate *(Punica granatum)*					
Mean temperature	°C	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	
Sapota (*Manilkara zapota)*					
Mean temperature	°C	28-32	33-36;24 - 27	37–42;18-23	>42 ; <18
Salinity	dS/m	Non Saline	Up to 1.0	1.0-2.0	2.0-4.0
Effective soil depth	cm	>150	75-150	50-75	<50
Slope	%	<3	3-5	5-10	-

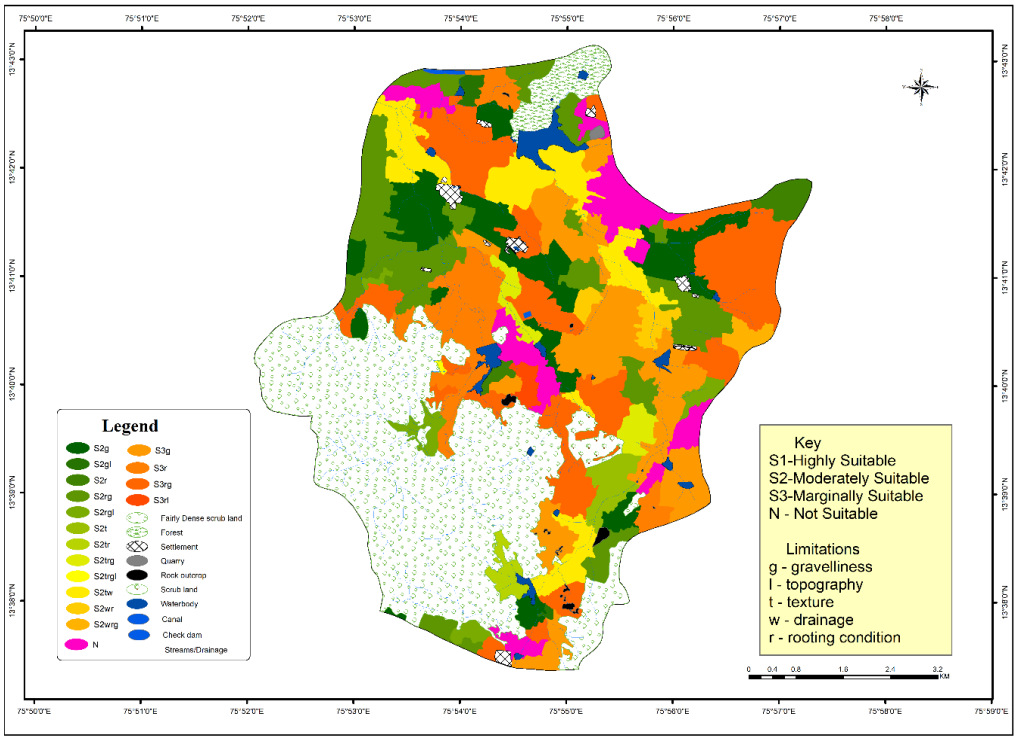

Fig. 8: Land suitability map of Sunflower in Koranahalli subwatershed.

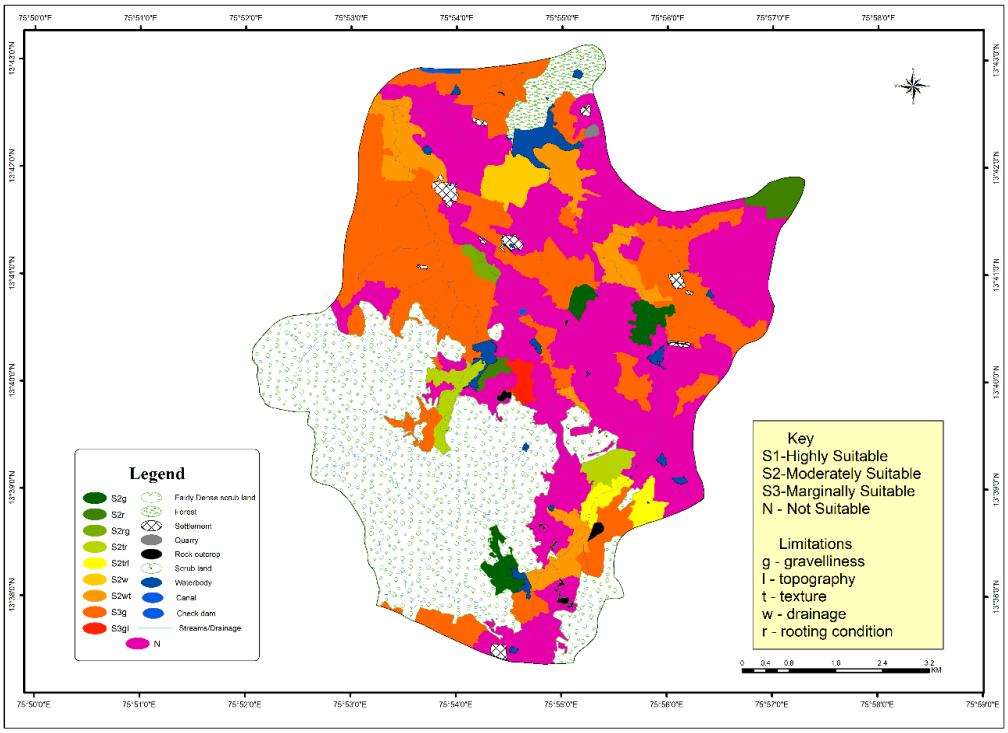

Fig. 9: Land suitability map of Castor in Koranahalli subwatershed.

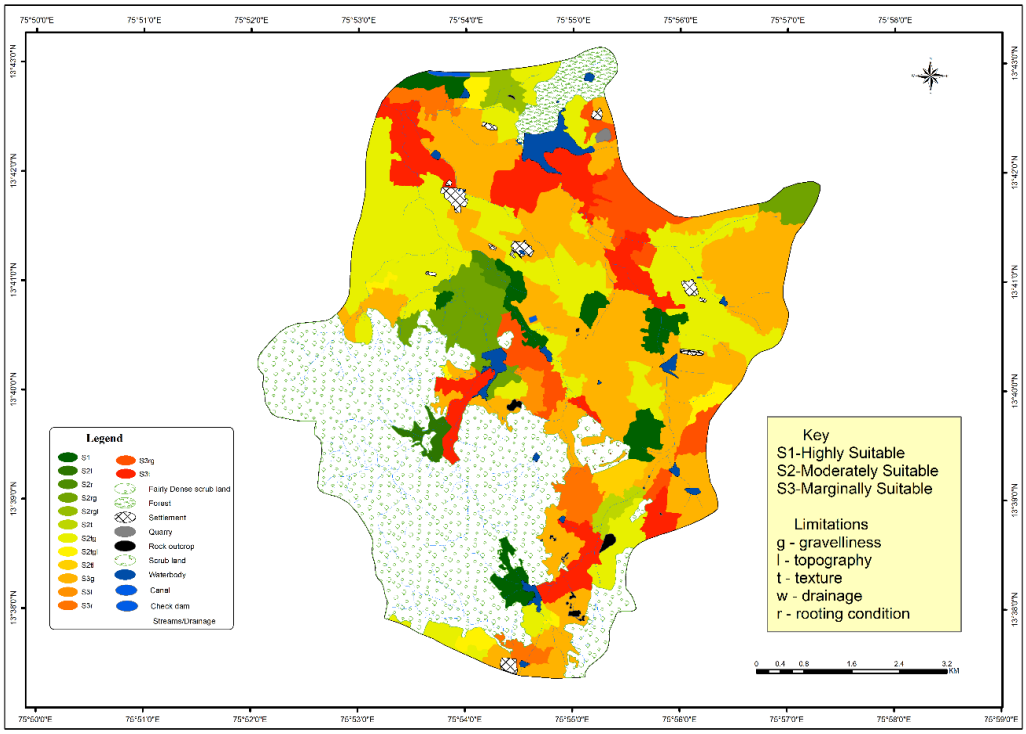

Fig. 10: Land suitability map of Tomato in Koranahalli subwatershed.

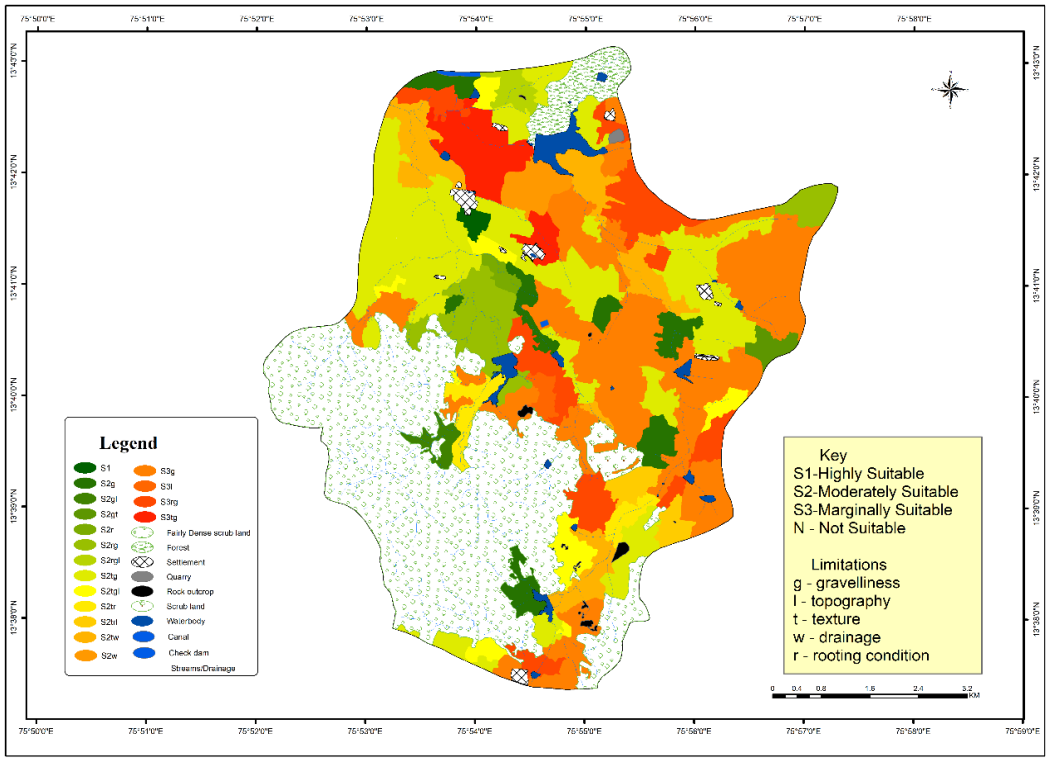

Fig. 11: Land suitability map of Chilli in Koranahalli subwatershed.

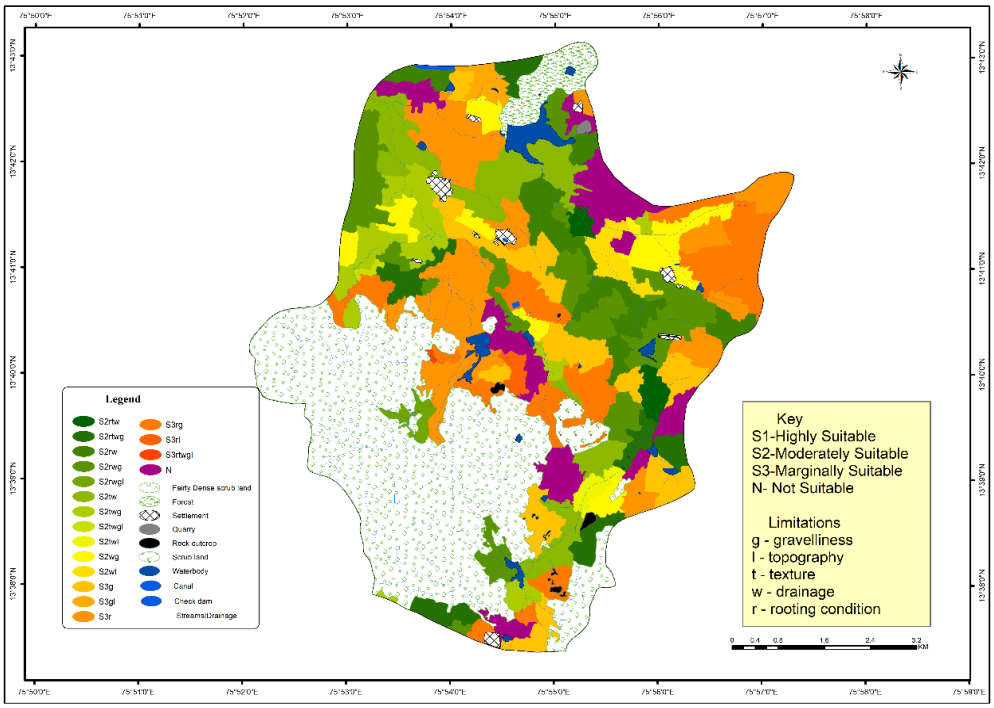

Fig. 12: Land suitability map of Pomegranate in Koranahalli subwatershed.

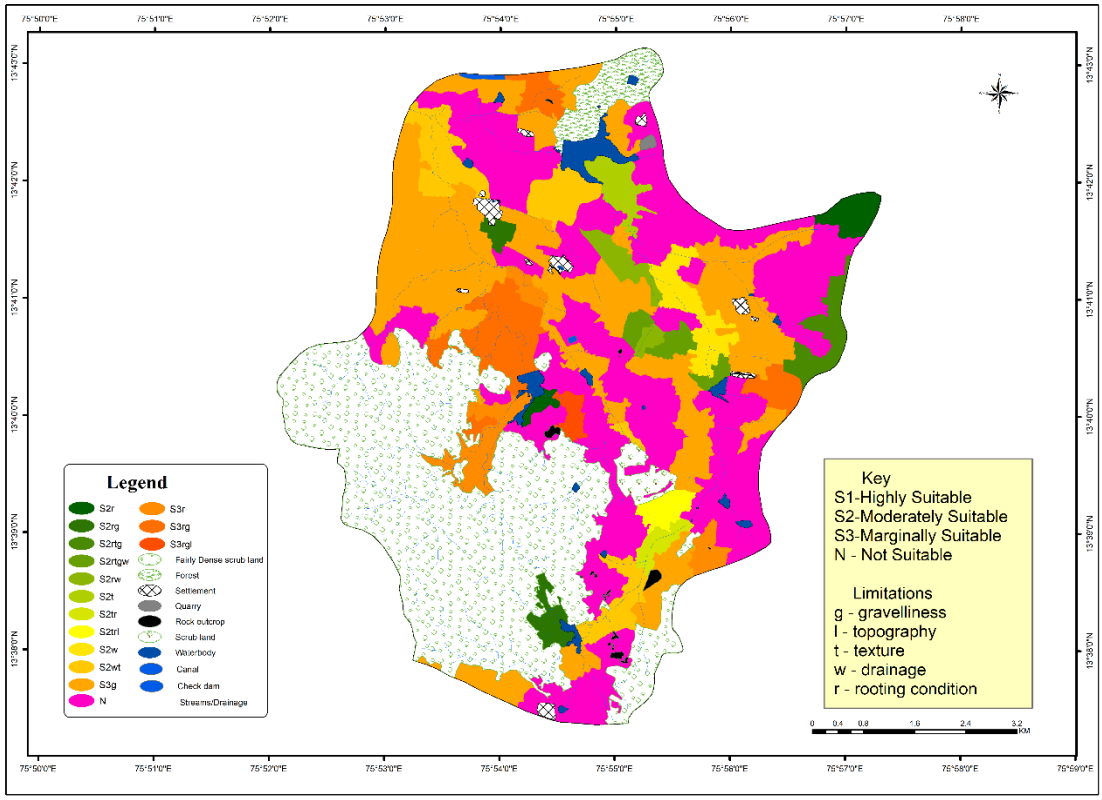

Fig. 13: Land suitability map of Sapota in Koranahalli subwatershed.

study area is grouped under marginally suitable for cultivation of sunflower and castor. Whereas, for vegetables 37.44 percent and 28.64 percent of the subwatershed area found to be marginally suitable for cultivation of tomato and chilli. However, for fruit crops 33.60 percent of the area is moderately suitable for pomegranate, 27.32 percent of area marginally suitable for sapota cultivation and 5.89 percent and 25.39 percent of the area is not suitable for cultivating pomegranate and sapota due to the limitation of soil depth and gravelliness or stoniness.

ACKNOWLEDGEMENT

The authors sincerely acknowledge "The World Bank", Watershed Development Department, Government of Karnataka,University of Agricultural and Horticultural Sciences, Shivamogga and Kuvempu University, Shivamogga for extending the facilities to carry out this research.

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