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RESEARCH PAPER

Assessment of land suitability and capability by integrating remote sensing and GIS for agriculture in Chamarajanagar district, Karnataka, India

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Abstract To reduce the human influence on natural resources and to identify an appropriate land use, it is essential to carry out scientific land evaluations. Such kind of analysis allows identifying the main limiting factors for the agricultural production and enables decision makers to develop crop managements able to increase the land productivity. Objectives of this study were to develop a GIS based approach for land use suitability assessment which will assist land managers and land use planners to identify areas with physical constraints for a range of nominated land uses. Georeferenced soil survey data and field work observations have been integrated in a GIS based land use suitability assessment for agricultural planning in Chamarajanagar district, Karnataka, India. Also, GIS has been used to match the suitability for main crops based on the requirements of the crops and the quality and characteristics of land. Different land quality parameters, viz. soil texture, depth, erosion, slope, flooding and coarse fragments under various land units were evaluated for the crops. Subsequently all of them were integrated using a sequence of logical operations to generate land suitability and capability maps. Suitability and capability maps for each land use were developed to illustrate these suitability degrees and display the spatial representation of soils suitable for agriculture. It was also found that better land use options could be implemented in different land units as the conventional land evaluation methods suffer from limitation of spatial analysis for the suitability of various crops.

1. Introduction

The land capability evaluation characterizes and appraises land development units from a general point of view without taking into consideration the kind of its use. There are defined classes ranging from I to VIII (Landon, 1991). This classification is useful as some soils can be suitable for specific crops

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and unsuitable for another's; therefore precision of land utilization types is necessary. It cloud be expressed not only in terms of types of crop productions, but also how these specific crops are produced (Sys et al., 1991).

Land suitability refers to the ability of a portion of land to tolerate the production of crops in a sustainable way. Its evaluation provides information on the constraints and opportunities for the use of the land and therefore guides decisions on optimal utilizations of resources, whose knowledge is an essential prerequisite for land use planning and development. Moreover, such a kind of analysis allows identifying the main limiting factors for the agricultural production and enables decision makers such as land users, land use planners, and agricultural support services to develop a crop management able to overcome such constraints, increasing the productivity. Land could be categorized into spatially distributed agriculture potential zones based on the soil properties, terrain characteristics and analysing present land use (Bandyopadhyay et al., 2009).

Production could be met through systematic survey of the soils, evaluating their potentials for a wide range of land use options and formulating land use plans which were economically viable, socially acceptable and environmentally sound (Sathish and Niranjana, 2010).

Remote sensing (RS) data are used for estimating biophysical parameters and indices besides cropping systems analysis, and land-use and land-cover estimations during different seasons (Rao et al., 1996 and Panigrahy et al., 2006). However, RS data alone cannot suggest crop suitability for an area unless the data are integrated with the site-specific soil and climate data. RS data can be used to delineate various physiographic units besides deriving ancillary information about site characteristics, viz. slope, direction and aspect of the study area. However, detailed information of soil profile properties is essential for initiating crop suitability evaluation. Hence, soil survey data are indispensable for generating a soil map of the given region, which helps in deriving crop suitability and cropping system analysis.

RS data coupled with soil survey information can be integrated in the geographical information system (GIS) to assess crop suitability for various soil and biophysical conditions. The present study was undertaken to demonstrate the usefulness of RS and GIS technologies coupled with soil data to assess crop suitability in order to implement sustainability for crops in the study area. The potential of the integrated approach in using GIS and RS data for quantitative land evaluation has been demonstrated earlier by several researchers (Beek et al., 1997 and Merolla et al., 1994). Therefore, the objective of this study was assessment of land evaluation using RS and GIS environments.

2. Materials and methods

2.1. Description of the study area

Chamarajanagar district, (Fig. 1) is situated in the south part of Karnataka state, geographical area of Chamarajanagar district is about 5101 km^2 and lies between the North latitude 11 o 40′58″ and 12 o 06′32″ and East longitude 76 o 24′14″ and 77 o 46′55″. It falls in the southern dry zone. Topography is undulating and mountainous with north south trending hill ranges of Eastern Ghats. Salem and Coimbatore districts of Tamilnadu in the east, Mandya and Bangalore districts in the north, parts of Mysore district in the west and Nilgiris district of Tamilnadu in the south, bound the Chamarajanagar district (Central Ground Water Board, 2008) (see Fig. 1).

2.2. Remote sensing data and ancillary data

Data used in this study are Indian Remote Sensing satellite (IRS P-6) LISS III and LISS IV sensors (Table 1) and Hyperion. Remotely sensed data provide timely, accurate and reliable information on degraded lands. Also length and degree of slope were derived from SRTM (downloaded from http://www.usgs.gov) and Topographic maps. Ancillary data: Topo sheets used (1:50,000) and (1:2,50,000). Toposheets (1:50,000) used in this study were (i) 57 H/7, (ii) 57 H/4, (iii) 57 H/8, (iv) 57 H/12, (v) 57H/16, (vi) 58A/9, (vii) 58A/13 (viii) 58E/1, (ix) 58E/5, (x) 58E/9, (xi) 58A/6, (xii) 58A/10, and (xiii) 58A/14, where Topo sheets scaled (1:250,000) used in this study were xiv) 57 A, (xv) 57 E, (xvi) 57 D, (xvii) 57H.

2.3. Digital image processing

Digital image processing techniques were carried out for Indian Remote Sensing satellite (IRS) LISS III and LISS IV sensors and Hyperion. Radiometric correction, Geometric corrections and image geo-referencing, image enhancement and color composites, were carried out to change and alter the original raw spectral data to increase the information availability, and to provide the best possible product for analysis and interpretation for information extraction (unsupervised classification, supervised classification), normalized difference vegetation index (NDVI). GIS was also used to build the soil properties, the land resource database and to work out the spatial model to produce the different maps.

2.4. Software used

ENVI 5.0 and GIS 10.1 package was used for integration between RS and GIS to arrive at the capability and suitability final spatial map decision. Map interpretation was done using Geographic information system (GIS).

2.5. Land evaluation classification

Land evaluation classification was undertaken according to the FAO (1976, 1983, 1985 and 2007) system to assess the suitability of the studied area soils for agriculture and development.

Land capability classification was also undertaken based on the capability or limitations according to the U.S. Soil conservation service (1958, 1959, 1963 and 1992). The methodology flow chart for both land capability and land evaluation classification is shown in Fig. 2.

2.6. Generating of thematic maps using geostatistics techniques

For this purpose ArcGIS Geostatistical analyst was used which provided a suite of statistical models and tools for spatial data exploration and surface generation. Using ArcGIS

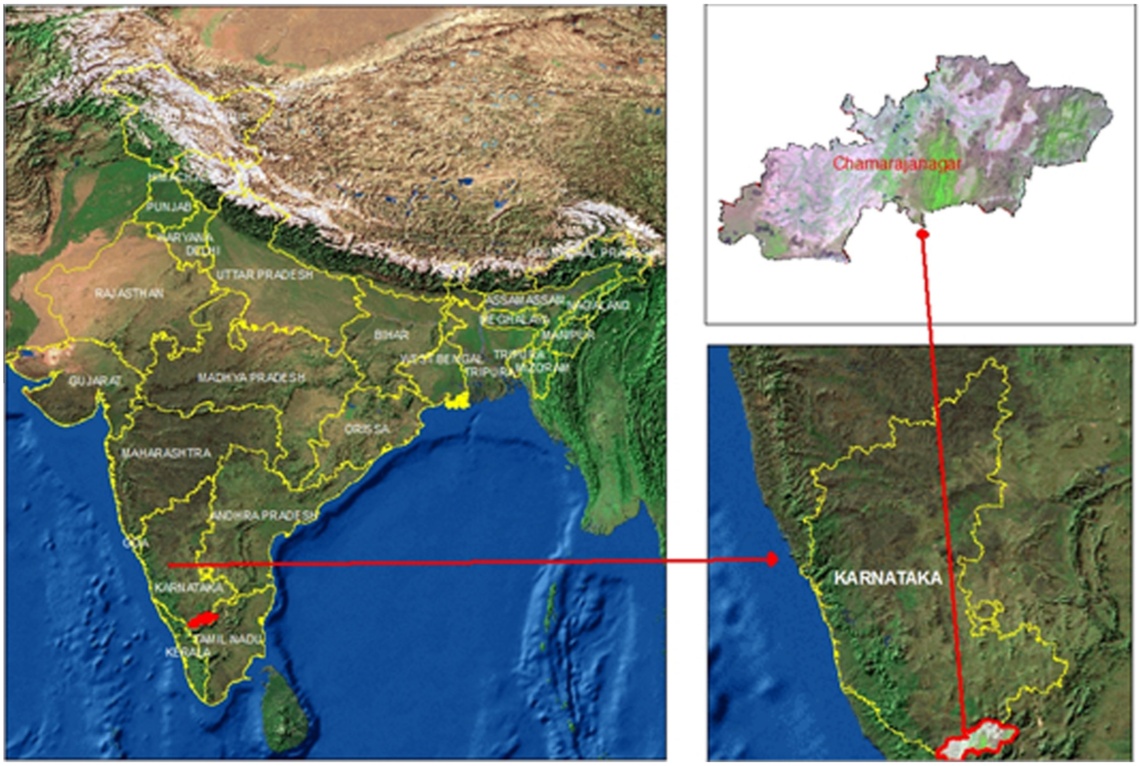

Figure 1 Location of study area.

Geostatistical analyst was created a statistically valid prediction surface from eighteen profiles of data measurements.

For mapping or estimating, the variogram is used to interpolate between the data points, this is the kriging.

For characterizing the uncertainty on estimates (degree of surface runoff, risk of different land degradation types), the same variogram can be used in a different way for making simulations of the unknown reality.

3. Results and discussion

3.1. Results

In this study, site, morphological characteristics, physical and chemical properties of collected Pedon's samples from soils were analysed during 2012–14 and described in detail for producing the soil map of Chamarajanagar district of Karnataka. Profiles in this study area are divided into seven transects and collected based on the landform (High, Medium and Low land) of the study area. The soil map has 24 mapping units consisting of soil family associations with dominant phases based on landform analysis, field survey, laboratory investigation, field reviews and after (Prasad et al., 1998) was produced and published by AbdelRahman (2014).

3.1.1. Land capability classification

Lands are utilized for multiple purposes. They are mainly used for agriculture, pastures and forestry. Depending on the nature and properties of soils, they are suitable for one or other uses. Based on the capability or limitations, the lands are grouped into eight classes by the U.S. Soil conservation service (1958, 1959, 1963 and 1992). Among them, the first four classes of lands are used for agriculture or cultivation of crops. These four classes are differentiated based on the extent of soil slope, erosion, depth, structure, soil reaction and drainage. The classes from V to VIII are not capable of supporting cultivation of crops. They are for growing grasses, forestry and supporting wild life. The last four classes are delineated based on

Table 1 IRS sensors used in this study.

Sensor	Resolution (m)	Swath width (km)	Sensor channels	Spectral bands (μm)
Linear imaging self-scanning system III (LISS-III)			LISS-III-2	0.52–0.59 (green)
	23	142	LISS-III-3	0.62–0.68 (red)
			LISS-III-4	0.77–0.86 (near IR)
	50	148	LISS-III-5	1.55–1.70 (mid-IR)
	6	70	PAN	0.5–0.75
High resolution linear imaging self-scanning system IV (LISS-IV)	5.8	24–70	LISS-IV-2	0.52–0.59 (green)
			LISS-IV-3	0.62–0.68 (red)
			LISS-IV-4	0.77–0.86 (near IR)

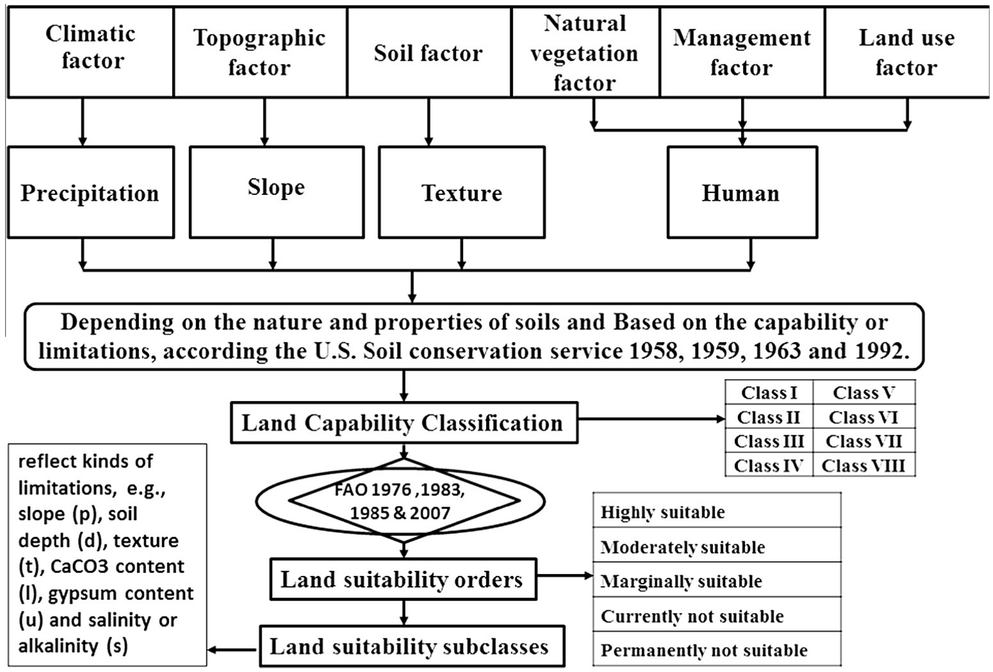

Figure 2 Flowchart for generating land evaluation maps.

problems like stream flow, flooding, ponding, rocky nature, short growing season, snow cover etc.

Classification of soils based on land capability helps in estimating soil resources available for different purposes and for appropriate use of soils without deterioration. The percentage of each class is shown in Table 2 and Fig. 3.

3.1.2. Land suitability evaluations

Land evaluation is the process of estimating the potential of land for alternative kinds of use. Its basic features are the comparison of the requirements of land use with the resources offered by the land. Land evaluation involves the collection and interpretation of very large amounts of data. Also, land evaluation predictions will be changed with the changes in technology and economic factors. Thus, data concerned with land evaluation must be stored in a way that re-evaluation can readily be made when any or all of these factors change significantly, as techniques improve, and more data become available.

In this connection, the approach for land evaluation in the studied area is carried out through two steps; diagnose and rate land limitations and applying the system in view of type, number and degree of limitations.

According to this system (suitability classification, FAO (1976, 1983, 1985 and 2007)), soils of the study area could be classified from the suitability view point as shown in Table 3 and Fig. 4 into five classes recognized within two orders (*S* and *N*) and according to this system land suitability units of subclasses could be identified as shown in Table 4 and Fig. 5.

3.1.3. Land suitability for crops and orchards

Assessing the extent and degree of capability and suitability of the land resources in the district for various crops and orchids is necessary to choose the right crop, orchid and variety suitable for the area. In carrying out this assessment, the specific requirements of a crop are compared with the characteristics of land and based on the extent of matching; the suitability of the area for the crop.

The classification is based on the inherent soil characteristics, external land features and environmental factors that limit the use of the land for various uses.

Soil depth of Chamarajanagar district (Fig. 6) is varied from very shallow (10–25 cm), shallow (25–50 cm), moderate shallow (50–75 cm), moderate deep (75–100 cm) and deep (>100 cm). Soil texture of district is varied from sandy, loamy and clayey. Most of the district soil is loamy, small area is clayey and very small area is sandy soil (Fig. 7). Soil gravelliness of district is occupied by a large area of strongly gravel class having between 35% to 80% most of crop fields is covered by non gravel or slight gravel class having less than 15% gravels, and a small part of the district soils is covered by a moderate gravelly class having between 15% to 35% of gravels as shown in Fig. 8. Slope classes of soil of district are distributed as; steeply sloping (>30%), Mod. steeply sloping (15–30%), and moderately sloping (8–15%) which are covering the eastern part of the district which is the hilly and forest areas. Gently sloping (3–8%), very gently sloping (1–3%), and level to nearly level (0–1%) are covering the western parts of the district which are the agriculture area as shown in Fig. 9. Soil drainages of the district are falling under the class of well drained soil and clayey soil is moderately well drained and there is a small area of somewhat excessive drained as shown in Fig. 10. Rainfall distribution in Chamarajanagar district ranges from less than 400 mm to more than 1500 mm as shown in Fig. 11. Chamarajanagar district depends heavily on monsoon for agricultural operations. The normal rainfall in the district is 751 mm.

The soil and land resource units of Chamarajanagar were assessed for their suitability for growing of different crops and orchards. The result showed the area that are suitable

Table 2 Land capability of soil of Chamraganajar.

Land capability classes	Percentage of area	Description
Class I	10.53	Deep well drained level lands with high water holding capacity, good response of crops to fertilizers, irrigated by a permanent irrigation system
Class II	3.40	Gentle slope (1–5%), moderate erosion hazard, (sheet and rill), inadequate soil depth, less than ideal soil structure and workability, slight to moderate alkali or saline condition, and somewhat restricted drainage
Class III	51.40	Moderately steep slope (5–10%), high erosion hazard, very slow water permeability, shallow depth band restricted root zone, low water holding capacity, low fertility, moderate alkali and salinity and/or unstable soil structure
Class IV	11.77	Severe erosion susceptibility, severe past erosion, shallow soils, low water holding capacity, poor drainage, and severe alkalinity and salinity
Class V	0.43	Interference from stream flow, short growing season, stony or rocky soils, and ponded areas where drainage is not possible
Class VI	2.31	Steep sloppy lands, < 25% slope
Class VII	8.81	Very severe limitations which restrict their use to limited grazing, woodland, or wild life. Improvement of pasture is not possible due to physical limitations
Class VIII (Rock land)	11.34	Soils of this class are not useful for any kind of crop production. Their use is restricted to recreation, wildlife, and aesthetic purposes

for selected crops and orchards (Cotton 14.72%, Finger millet 21.56%, Groundnut 13.45%, Rice 9.56%, Sorghum 26.40%, Soyabean 19.11%) and (Banana 19.11%, Cashew 25.82%, Coconut 27.83%, Mango 25.82%) in the district.

The suitability assessment for soyabean in Chamarajanagar district showed that nearly 19.11% of area is highly suitable and nearly 7.96% area is moderately suitable (Fig. 12 and Table 5). The main constraints are eroded soils, slope, and texture in moderately suitable areas. Deficiency of major nutrients and micronutrients needs to be addressed in the district through suitable fertilizers.

Soyabeans are a globally important crop, providing oil and protein. Cultivation is successful in climates with hot summers, with optimum growing conditions in mean temperatures of 20–30 °C (68 to 86 F); temperatures of below 20 °C and over 40 °C (68 F, 104 F) stunt growth significantly. They can grow in a wide range of soils, with optimum growth in moist alluvial soils with a good organic content. Soyabeans, like most legumes, perform nitrogen fixation, and take 80–120 days from sowing to harvesting.

Successful cultivation of cotton requires a long frost-free period, plenty of sunshine, and a moderate rainfall, usually from 600 to 1200 mm (24–47 in). Soils usually need to be fairly heavy, although the level of nutrients does not need to be exceptional. In general, these conditions are met within the seasonally dry tropics and subtropics in the Northern and Southern hemispheres, but a large proportion of the cotton grown today is cultivated in areas with less rainfall that obtain the water from irrigation.

Cotton is a medium to long duration crop and as such it is an ideal crop for the district. The suitability assessment for cotton in Chamarajanagar showed that nearly 14.72% of area is highly suitable and nearly 21.04% area is moderately suitable (Fig. 13 and Table 4). The main constraints are eroded soils, slope, texture and gravelliness in moderately suitable areas. In 3.53% of areas due to the severe constraints of erosion, slope and texture, cotton is marginally suitable. Deficiency of major nutrients and micronutrients needs to be addressed in the district through suitable fertilizers.

The suitability assessment for Finger millet in the Chamarajanagar district showed that nearly 21.56% of area is highly suitable and nearly 13.14% area is moderately suitable and nearly 19.27% area is marginally suitable (Fig. 14 and Table 4). The main constraints are eroded soils, texture and gravelliness in marginally suitable areas.

Finger millet is a promising and well adopted crop for the area. It is highly drought tolerant crop and can be grown throughout the year in India where the temperature is above 15 °C with rainfall ranging from 400 to1000 mm or even more. It can be cultivated in all types of soils ranging from poor to highly fertile soils, though it performs well in fertile and well drained loamy red and lateritic soils. Even alluvial and black soils are suitable if drainage is not a problem. It is highly salt tolerant and can be grown even in strongly alkaline soils.

The suitability assessment for groundnut in the Chamarajanagar district showed that nearly 13.45% of area is highly suitable and nearly 17.68% area is moderately suitable (Fig. 15 and Table 4). The main constraints are eroded soils, slope, texture and gravelliness in moderately suitable areas. In nine percent of the areas groundnut is marginally suitable due to the severe limitations of slope, erosion and texture. Deficiency of major nutrients and micronutrients needs to be addressed in the district through suitable fertilizers.

It is the traditional and number one oilseed crop of India as well as the world. It is predominantly a crop of tropical and sub-tropical climates. It comes up well in tracts receiving 625–1250 mm of fairly well distributed rainfall. Alternate spells of dry and wet weather are ideal for this crop. Loose/friable soils facilitate good pod development. Therefore sandy and loamy soils with fairly rich in organic matter are very well suited for this crop. Waterlogging, alkalinity and soils poor in lime greatly affect the pod filling.

Rice is a major food staple and a mainstay for the rural population and their food security. It is mainly cultivated by small farmers in holdings of less than 1 hectare. Rice is also a wage commodity for workers in the cash crop or non-agricultural sectors.

The suitability assessment for rice in the Chamarajanagar district showed that nearly 9.56% of area is highly suitable and nearly 7.26% area is moderately suitable. The main constraints are eroded soils, slope, texture and gravelliness in moderately suitable areas (Fig. 16 and Table 4). In 27.78% of the

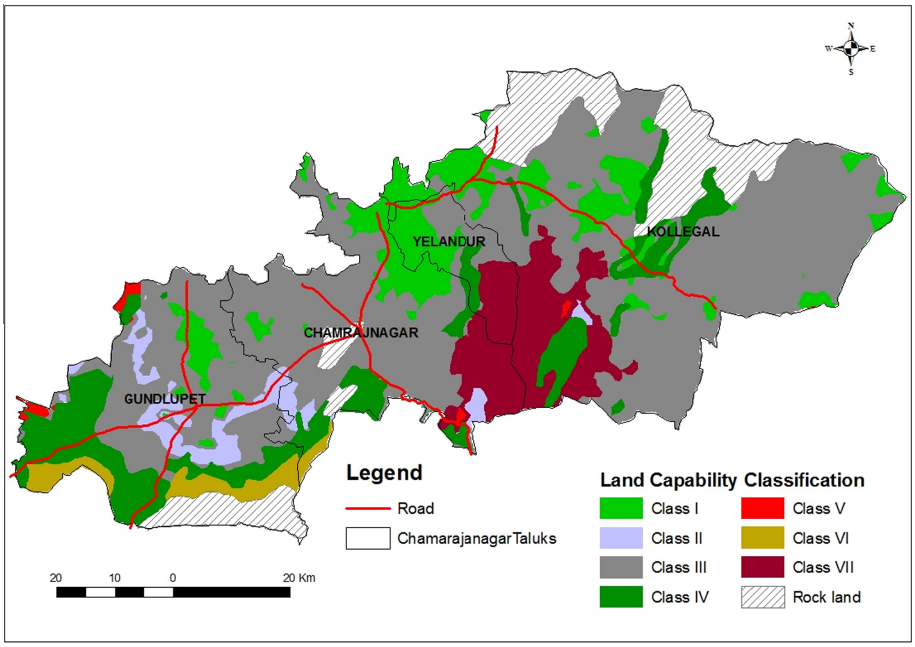

Figure 3 Land capability classification.

Table 3 Land suitability order of soil of Chamarajanagar.	
Land suitability order	Percentage of area
Highly suitable (S1)	10.53
Moderately suitable (S2)	3.4
Marginally suitable (S3)	62.52
Currently not suitable (N1)	11.77
Permanently not suitable (N2)	0.43
Rock land (N2)	11.34

areas rice is marginally suitable due to the severe limitations of slope, erosion and texture. Deficiency of major nutrients and micronutrients needs to be addressed in the district through suitable fertilizers.

Sorghum is a genus of grasses with about 30 species, one of which is raised for grain and many of which are used as fodder plants, either cultivated or as part of pasture. The plants are cultivated in warm climates worldwide.

The suitability assessment for Sorghum in Chamarajanagar district showed that nearly 26.40% of area is highly suitable, nearly 2.09% area is moderately suitable and nearly 12.15%

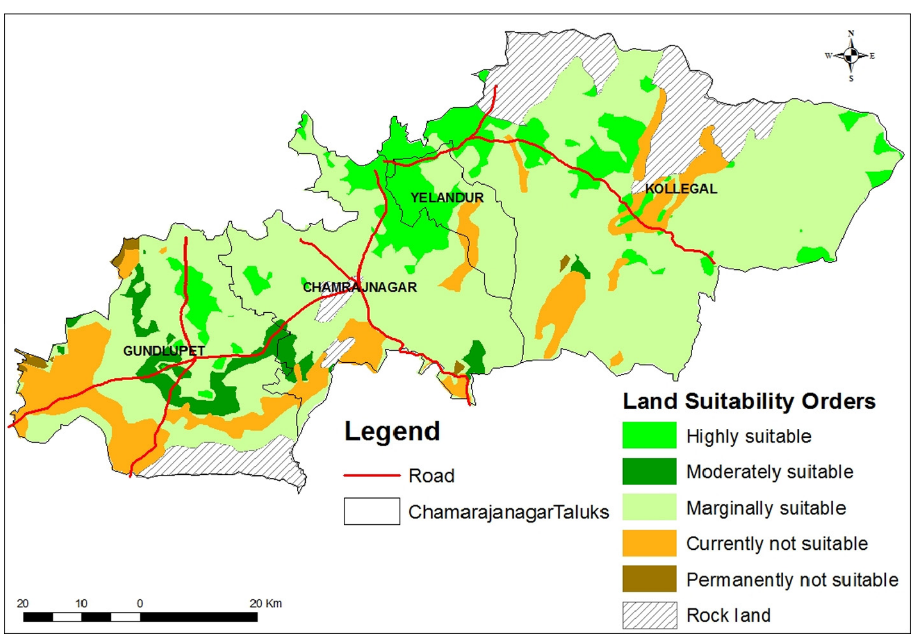

Figure 4 Land suitability orders.

Table 4 Land suitability units of subclasses of soil of Chamarajanagar.

Land suitability subclasses	Percentage of area	Land suitability subclasses	Percentage of area
S1	10.53	S3dtp	25.83
S2td	3.28	S3dt	0.21
S2t	0.13	S3dp	10.95
S3tp	2.38	N1	11.77
S3t	8.17	N2	0.43
S3sdt	14.98	Rock land (N2)	11.34

area is marginally suitable (Fig. 17 and Table 4). The main constraints are eroded soils, slope, and texture in moderately and marginally suitable areas. Deficiency of major nutrients and micronutrients needs to be addressed in the district through suitable fertilizers.

A banana is an edible fruit produced by several kinds of large herbaceous flowering plants in the genus *Musa*. The plant is allowed to produce two shoots at a time; a larger one for immediate fruiting and a smaller "sucker" or "follower" to produce fruit in 6–8 months. The life of a banana plantation is 25 years or longer, during which time the individual stools or planting sites may move slightly from their original positions as lateral rhizome formation dictates.

The suitability assessment for banana in the Chamarajanagar district showed that nearly 19.11% of area is highly suitable and nearly 27.93% area is moderately suitable (Fig. 18 and Table 4). The main constraints are eroded soils, slope, texture and gravelliness in moderately suitable areas. In thirteen percent of the areas rice is marginally suitable due to the severe limitations of slope, erosion and texture. Deficiency of major nutrients and micronutrients needs to be addressed in the district through suitable fertilizers.

The cashew tree is a tropical evergreen that produces the cashew nut and the cashew apple. Officially classed as *Anacardium occidentale*, it can grow as high as 14 m (46 ft), but the dwarf cashew, growing up to 6 m (20 ft), has proved more profitable, with earlier maturity and higher yields. The cashew nut is served as a snack or used in recipes, like other nuts, although it is actually a seed. The cashew apple is a fruit, whose pulp can be processed into a sweet, astringent fruit drink or distilled into liqueur. The shell of the cashew nut yield derivatives that can be used in many applications from lubricants to paints, and other parts of the tree have traditionally been used for snake-bites and other folk remedies.

The suitability assessment for cashew in the Chamarajanagar showed that nearly 25.82% of area is highly suitable, nearly 26.62% area is moderately suitable and nearly 17.08% area is marginally suitable (Fig. 19 and Table 4). The main constraints are eroded soils, texture and gravelliness in moderately suitable areas.

The coconut palm thrives on sandy soils and is highly tolerant of salinity. It prefers areas with abundant sunlight and regular rainfall (1500–2500 mm annually), which makes colonizing shorelines of the tropics relatively straightforward. Coconuts also need high humidity (70–80% +) for optimum growth.

Coconut palms require warm conditions for successful growth, and are intolerant of cold weather. Optimum growth is with a mean annual temperature of 27 °C (81°F), and growth is reduced below 21 °C (70°F). Some seasonal variation is tolerated, with good growth where mean summer temperatures are between 28 and 37 °C (82 and 99°F), and survival as long as winter temperatures are above 4–12 °C (39–54°F); they will survive brief drops to 0 °C (32°F). Severe frost is usually fatal, although they have been known to recover from temperatures of −4 °C (25°F).

The conditions required for coconut trees to grow without any care are: Mean daily temperature above 12–13 °C (53.6–55.4°F) every day of the year, Mean annual rainfall above 1000 mm (39.37 in), and No or very little overhead canopy, since even small trees require direct sun.

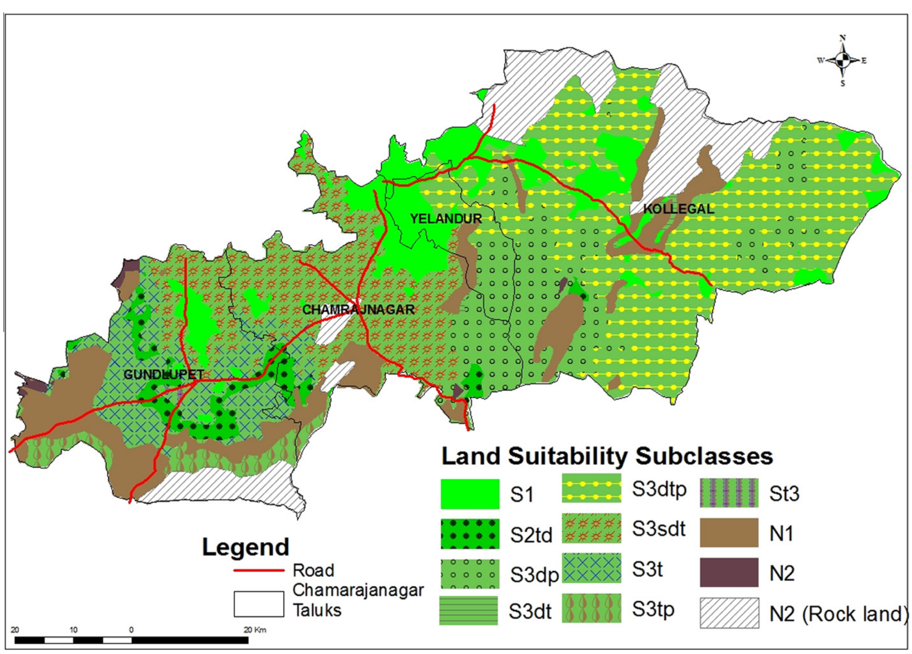

Figure 5 Land suitability subclasses.

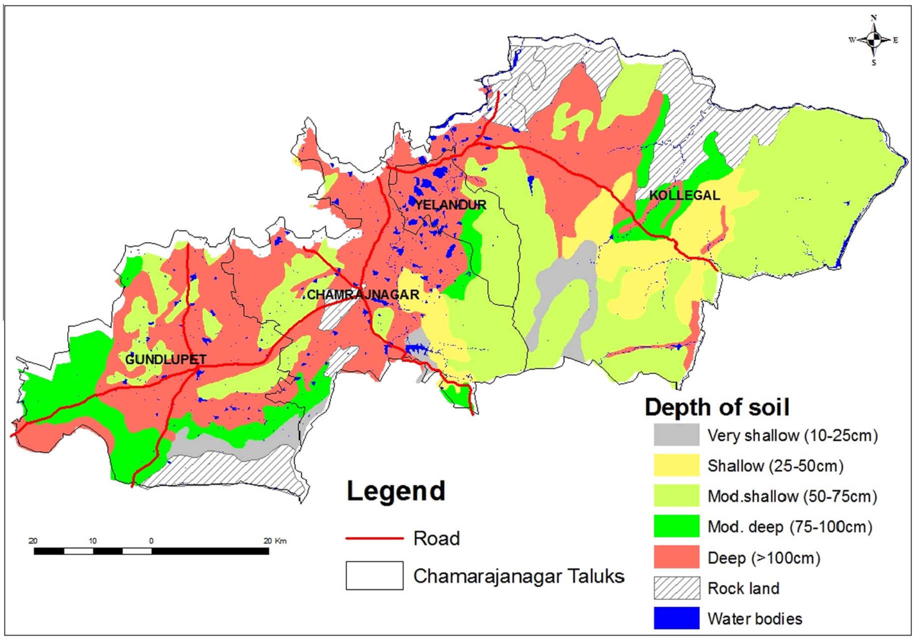

Figure 6 Soil depth of Chamarajanagar district.

The main limiting factor for most locations which satisfy the rainfall and temperature requirements is canopy growth, except those locations near coastlines, where the sandy soil and salt spray limit the growth of most other trees.

The suitability assessment for coconut in the Chamarajanagar showed that nearly 27.83% of area is highly suitable and nearly 26.62% area is moderately suitable (Fig. 20 and Table 4).

The mango is now cultivated in most frost-free tropical and warmer subtropical climates; There is very good scope for cultivating mango due to the suitable soil available in some parts of the district (Fig. 21). Deep to very deep, well drained, medium textured soils having a pH range of 5.5–7.5 are ideal for mango. It is sensitive to poor drainage, presence of free $CaCO_3$, high pH, extreme gravel and stoniness, sodicity and salinity. It can tolerate drought to a great extend and also short period of flooding.

The suitability assessment for mango in Chamarajanagar showed that nearly 25.82% of area is highly suitable and nearly 34.73% area is moderately suitable (Fig. 21 and Table 4.). The main constraints are eroded soils, slope, texture and water logging in moderately suitable areas. In another 18.59% of the area due to poor root growing conditions, the crop in marginally suitable. Deficiency of major nutrients

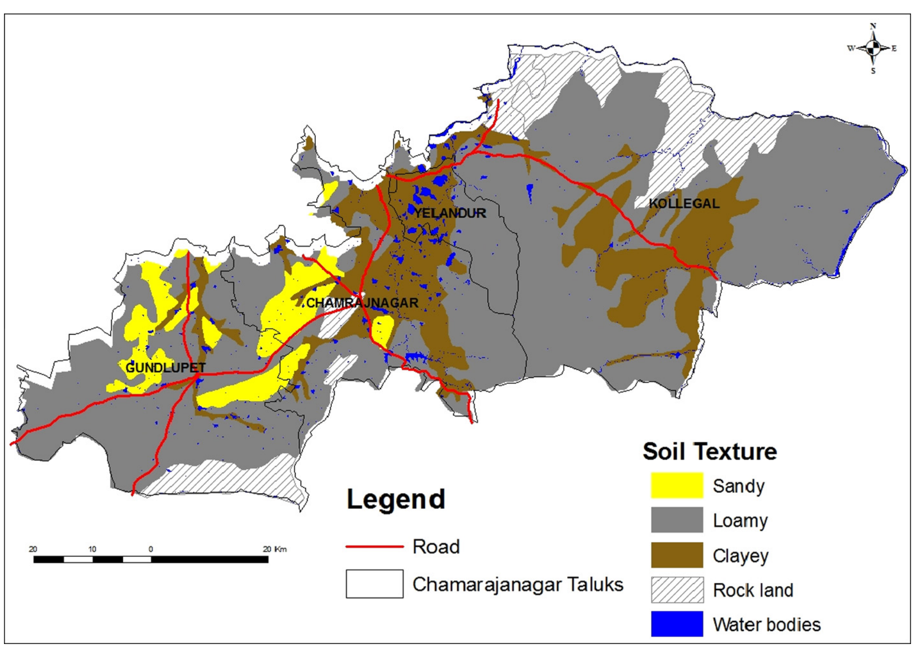

Figure 7 Soil texture of Chamarajanagar district.

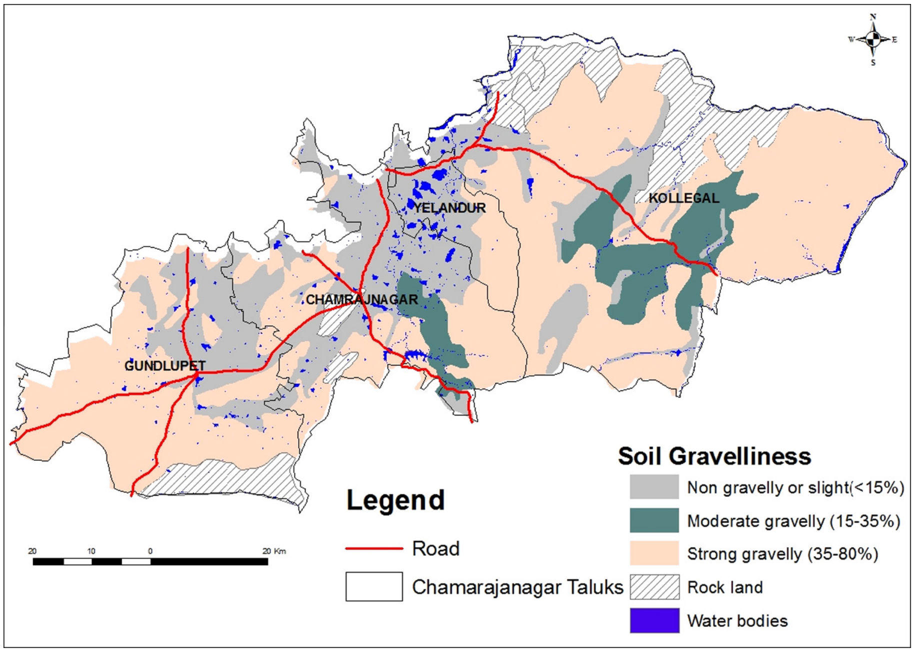

Figure 8 Soil gravels of Chamarajanagar district.

and micronutrients needs to be addressed in the district through suitable fertilizers.

4. Discussions

4.1. Land capability classification

The Land capability classification is one of many interpretative groupings that can be used to evaluate arable and non arable lands for limitations or hazards for producing commodity crops using soil characteristics. Land Capability Classes I, II, and III are considered suitable for croplands and class IV for haylands. LCC of V, VI, VII, and VIII are not considered arable, but can be used for permanent vegetation unless it is a miscellaneous land type.

The marginally suitable lands (Class III) occupy more than 50% of the area in the district. The major constraints for cultivation in these marginal areas are topography, erosion, soil texture, soil gravelliness, shallow depth and climate. The areas not suitable for agriculture due to steep slopes and severe ero-

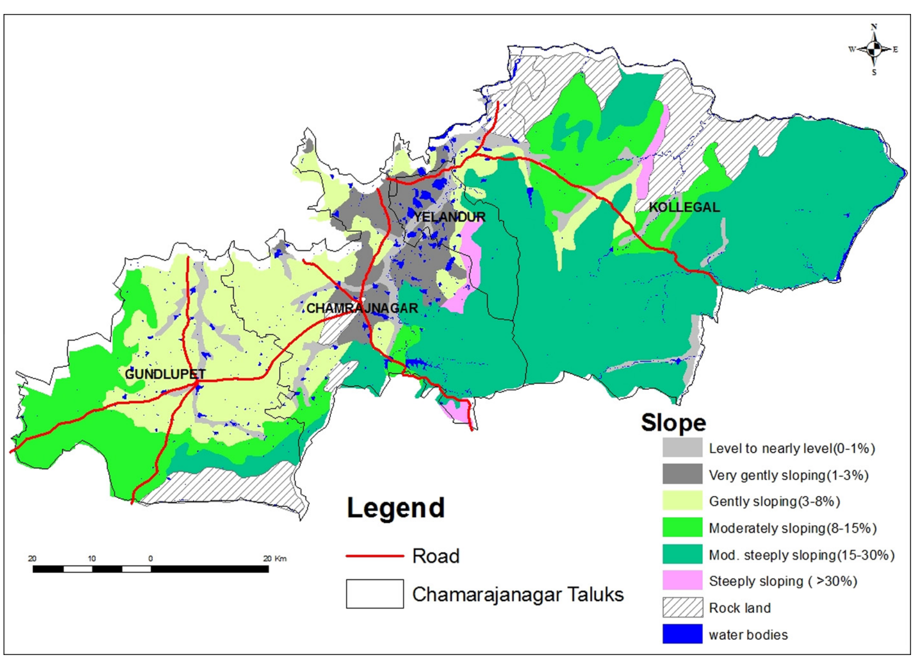

Figure 9 Slope of soil of Chamarajanagar district.

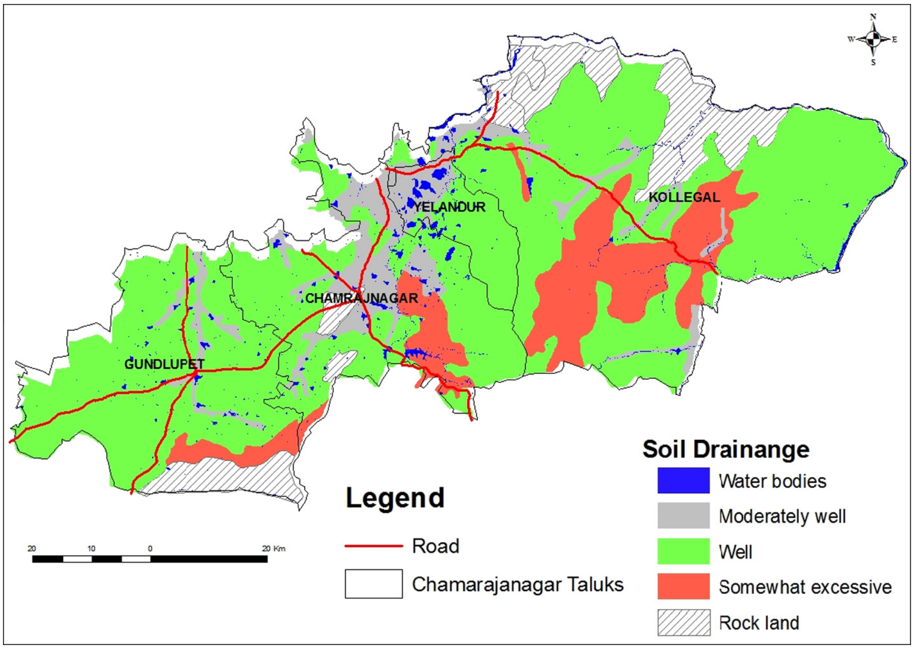

Figure 10 Soil drainages of Chamarajanagar district.

sion occur in about 23% of the area, mostly in the hilly and rocky areas of the district.

4.2. Land suitability classification

Land suitability assessment for agriculture is very important for agriculture development and future planning. Based on that, a land suitability assessment for agriculture purpose has been conducted in order to help decision makers and agriculture development planners. The results showed the suitability of the district for deferent crops in the study area. A suitability map for each land use was developed to illustrate the various degrees of suitability and their spatial representation in the area.

4.3. Limiting factors in the area

The most important limiting factors in the area are soil texture, gravel, lime, gypsum and OM. In recent years, these attributes have had influence on the land suitability and resulted in

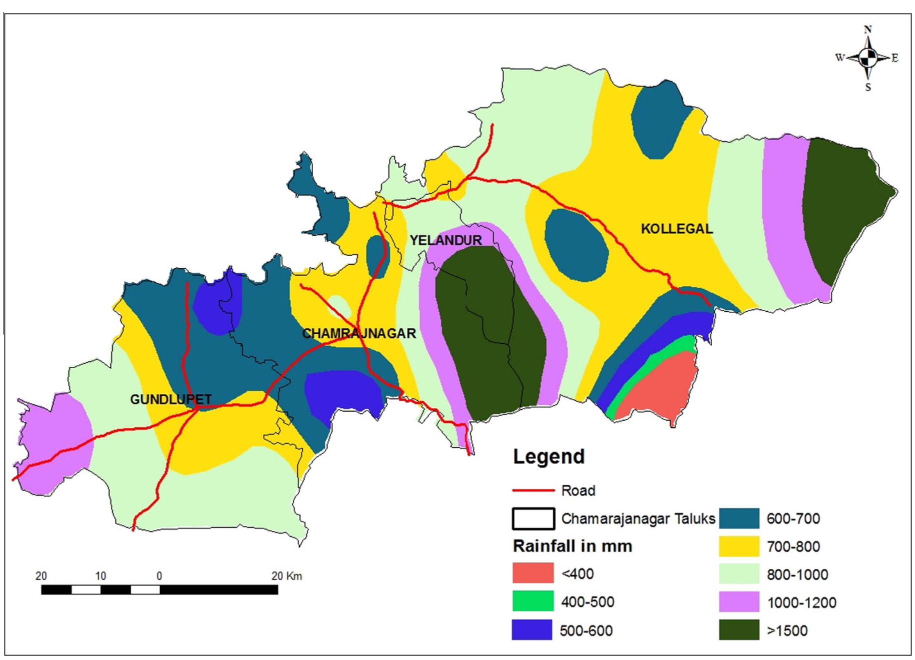

Figure 11 Rainfall distribution in Chamarajanagar district. Source: Department of Statistics, Government of Karnataka.

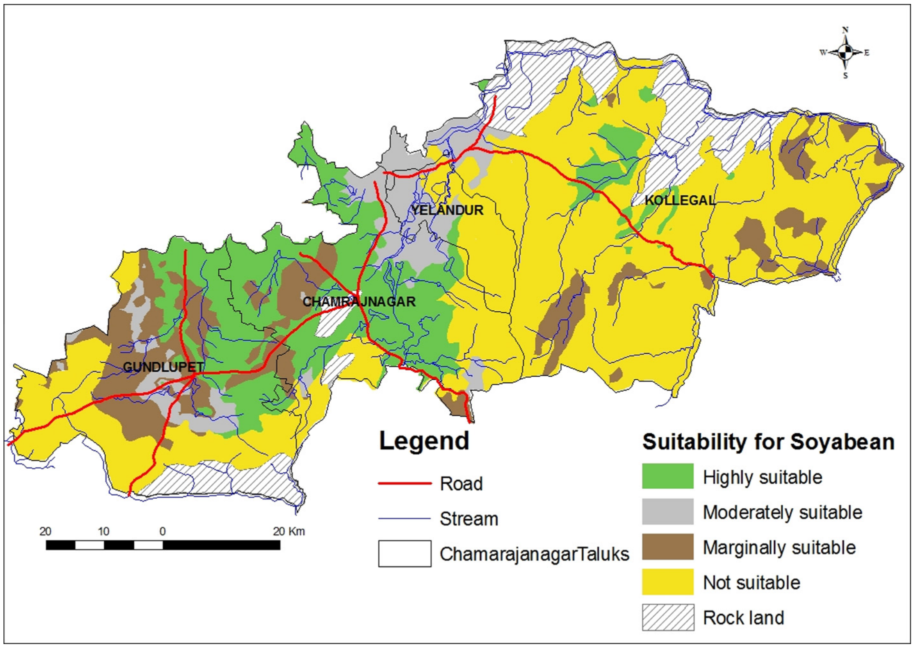

Figure 12 Land suitability for soyabean.

Table 5 Percentages of selected crops and orchards suitability classes.

Suitability classes	Highly suitable	Moderately suitable	Marginally suitable	Currently not suitable	Permanently not suitable	Rock land
Cotton	14.72	21.04	3.53	11.10	38.27	11.34
Finger millet	21.56	13.14	19.27	–	34.68	11.34
Groundnut	13.45	17.68	9.25	10.59	37.69	11.34
Rice	9.56	7.26	27.78	–	44.06	11.34
Sorghum	26.40	2.09	12.15	–	48.02	11.34
Soyabean	19.11	7.96	13.02	–	48.57	11.34
Banana	19.11	27.93	13.02	–	28.60	11.34
Cashew	25.82	26.62	17.08	2.84	16.30	11.34
Coconut	27.83	44.09	5.90	–	10.84	11.34
Mango	25.82	34.73	18.59	2.84	6.69	11.34

changing their moderately suitable class to marginally suitable class. Slope, an important element of landform, plays an important role wherever mechanization is concerned. In order to avoid soil erosion and other problems derived from the use of machinery, only land with slopes below 8° should be used. Fortunately, most of the study area was found suitable with respect to topography; only 10.06% had the steepest slope category and was therefore unsuitable for full-mechanized cultivation.

Each plant species requires definite soil and site conditions for its optimum growth. Although some plants may be found to grow under different soils and extreme agro-ecological conditions, yet not all plants can grow on the same soil and under the same environment. The conspicuous absence of Pinus species in inter-tropical and of eucalyptus in the temperate (cold) regions are examples. Since the availability of both water and plant success and/or failure of any plant species, in a particular area, is largely determined by these factors. The deep rooted forest or orchard plantations respond differently to soil depth and soil texture (Mishra and Sahu, 1991) than the shallow-rooted arable crops such as rice, wheat, green gram, black gram, pigeon-pea, groundnut etc.

4.4. Suitability for different crops

Several soil-site studies for different plant species have been reported in the literature. These illustrate how soil depth, soil texture, salinity and drainage conditions are related to soil-site quality. The objective of various soil-site evaluation studies has been to predict and classify land for plant growth (Sehgal, 1996). Observations on growth inhibiting factors for certain species and tolerance of others to extremely adverse conditions have been evaluated by many scientists.

The soil and land resource units of Chamarajanagar were assessed for its suitability for growing of different crops and orchards. The result showed the areas that are highly suitable for selected crops and orchards (Cotton 14.72%, Finger millet 21.56%, Groundnut 13.45%, Rice 9.56%, Sorghum 26.40%,

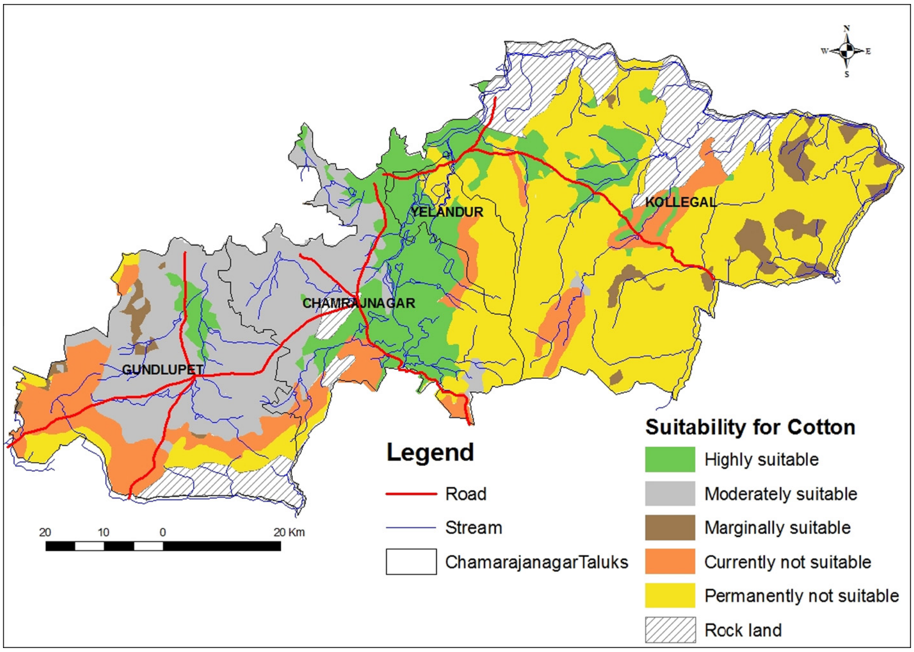

Figure 13 Land suitability for cotton.

Soyabean 19.11%) and (Banana 19.11%, Cashew 25.82%, Coconut 27.83%, Mango 25.82%) in the district.

The performance of any crop is largely dependent on soil parameters (depth, drainage, texture etc.) as conditioned by climate and topography. The study of soil-site characterization for predicting the crop performance of an area forms land evaluation. According to Van Wambeke and Rossiter (1987), land evaluation is the rating of soil and site for optimum returns per unit area. The yield influencing factors for important crops have to be evaluated and the results obtained may be applied for higher production of these crops through proper utilization of similar soils occurring elsewhere in same agro-climate sub-regions under scientific management practices (Khades and Gaikwad, 1995).

The studied soils vary in their suitability for different crops, according to the criteria for the determination of the land suitability classes.

4.4.1. Cotton

The yield influencing factors on cotton are rainfall, soil depth and free $CaCO_3$. The study area was moderately and marginally suitable for cotton. Because of severe limitations of ero-

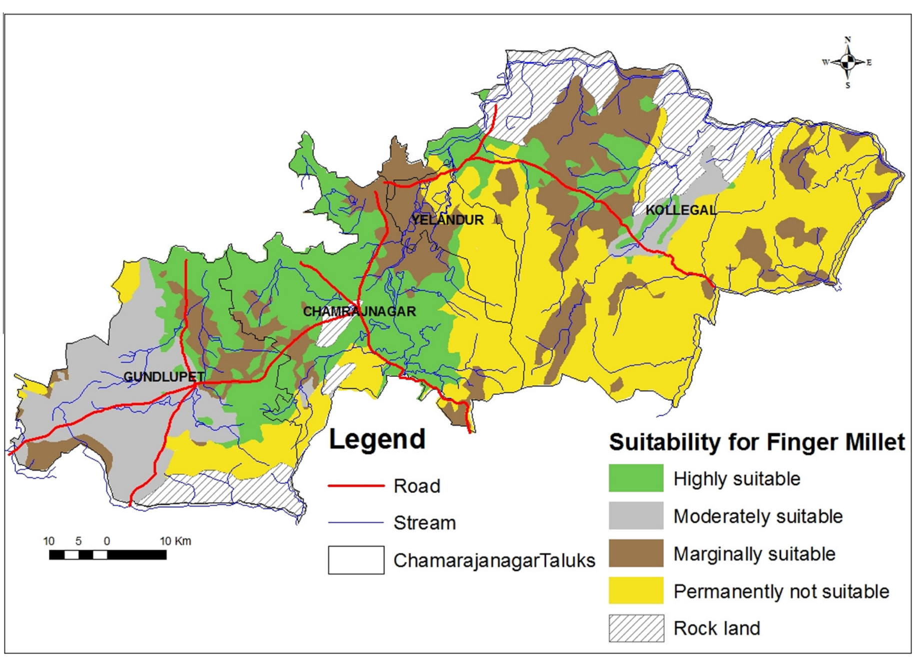

Figure 14 Land suitability for Finger millet.

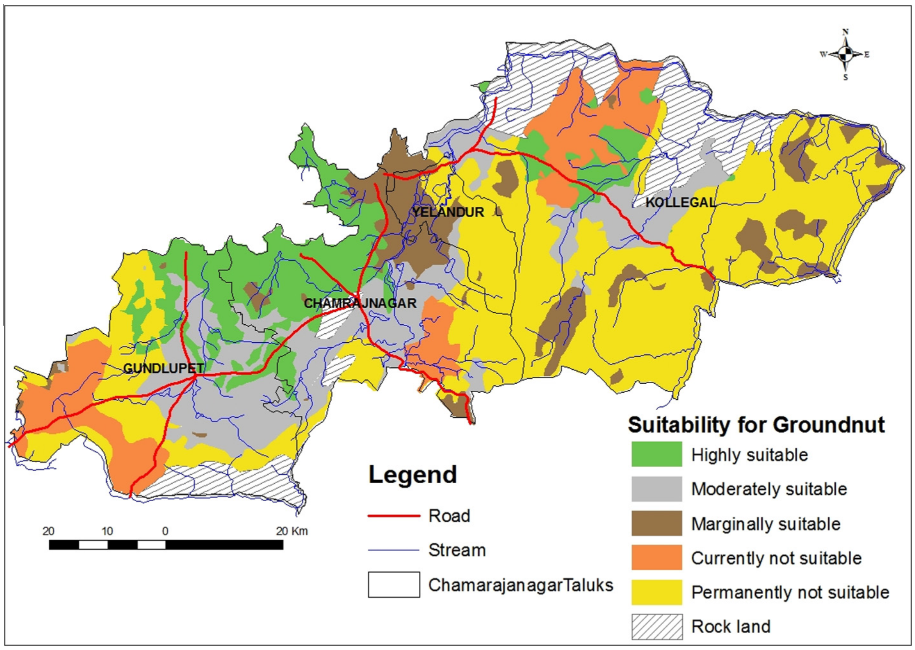

Figure 15 Land suitability for groundnut.

sion and organic matter content, the areas represented by uplands were marginally suitable for cotton. Similarly, midlands were also marginally suitable whereas, lowlands were marginally suitable for cotton because of limitations of moderate drainage (Sehgal, 1991).

4.4.2. Finger millet

Finger millet comes up well on soils having soil depth of 100 cm, clay content from 48% to 56%, CEC from 43 to 53 cmol (p+) per kg and organic carbon from 0.63% to 0.74% (Bhaskar et al., 1996). The areas represented by upland pedons were moderately suitable, because of moderate limitations of soil. The upland pedons were marginally suitable. The midlands were moderately suitable, because of moderate limitations of soil and climate.

4.4.3. Sorghum and groundnut

The factors influencing sorghum yield are rainfall, temperature, slope, BS, $CaCO_3$, CEC and texture. The area represented by uplands was marginally suitable, because of severe

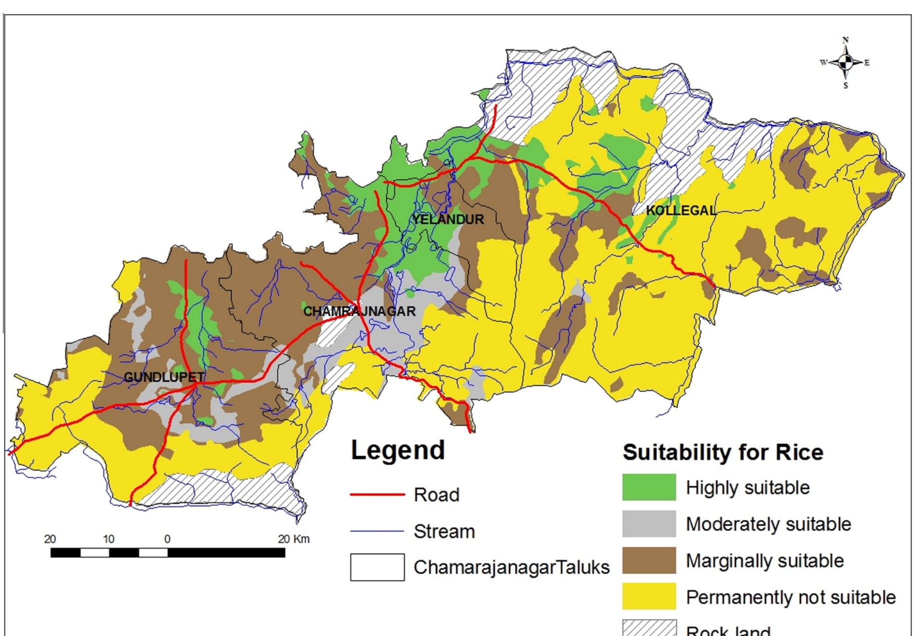

Figure 16 Land suitability for rice.

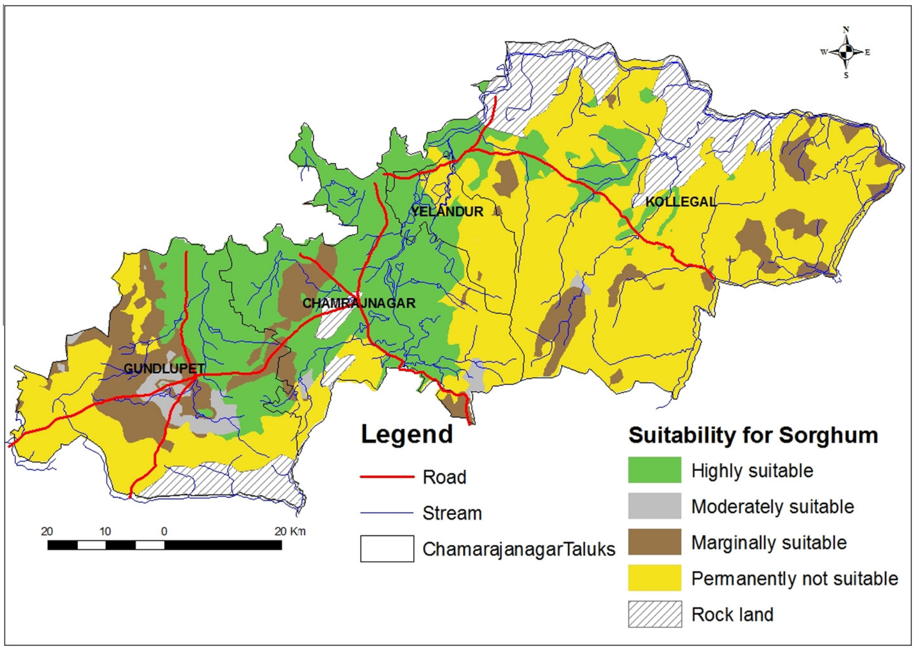

Figure 17 Land suitability for sorghum.

limitations of slope, erosion and organic carbon and the midlands were moderately suitable, whereas the lowlands were marginally suitable due to moderate drainage.

The uplands were moderately suitable for these crops owing to their severe limitations of slope; erosion and lowlands were not suitable (but potentially suitable) because of poor drainage, whereas midlands and lowlands were moderately suitable attributed due to moderate limitations of drainage and fertility. Similarly, Satyavathi and Suryanarayan (2004) reported that Typic Haplustalfs in Telangana region were moderately suitable for growing groundnuts as they exhibited similar limitations in soil fertility and physical characteristics.

4.4.4. Rice

The hilly areas and sloping upland areas were permanently not suitable due to very severe limitations of drainage and slope. The other uplands and midlands were marginally suitable, due to slope, erosion and drainage whereas lowlands were moderately to highly suitable due to moderate limitations of climate and fertility factors.

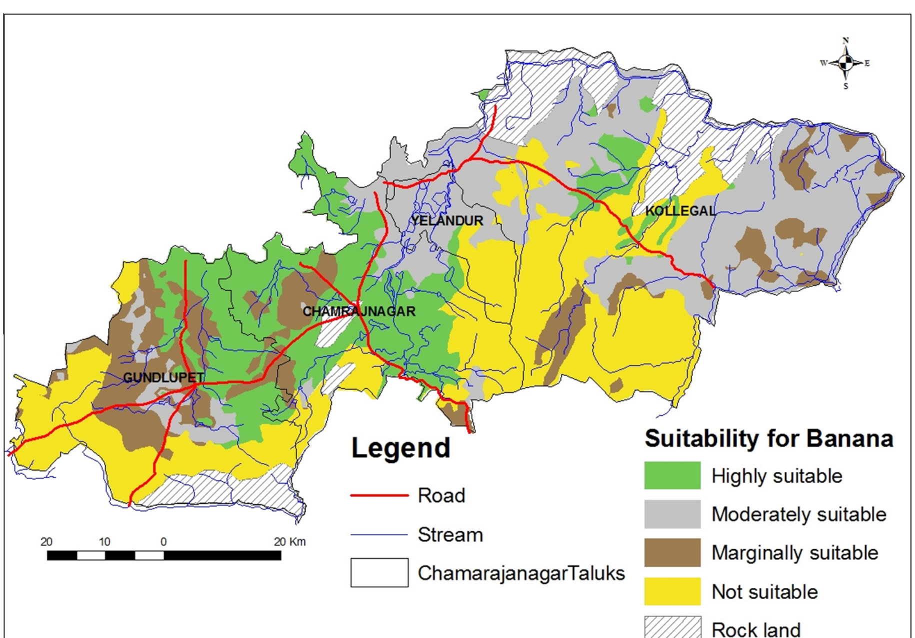

Figure 18 Land suitability for banana.

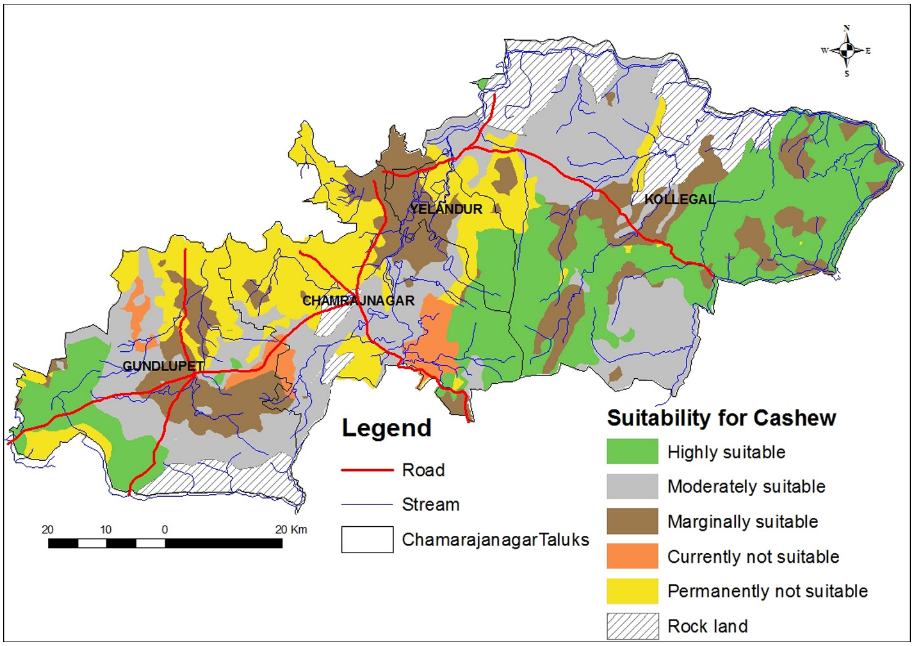

Figure 19 Land suitability for cashew.

4.4.5. Soyabean

The uplands and midlands were moderately suitable due to moderate limitations of slope, drainage and soil limitations and some upland areas were marginally suitable, whereas lowlands were not suitable but potentially suitable owing to their moderate drainage conditions.

All the land scapes of the study area except lowlands were marginally suitable for the crop due to severe limitations of slope, drainage and moderate limitations of climate and soil, whereas lowlands were permanently not suitable due to moderate drainage.

4.4.6. Cashew and coconut

The upland area was marginally suitable due to severe limitations in topography and texture; midlands were also marginally suitable whereas, lowlands were suitable for both crops. The area represented by uplands, midlands and lowlands was marginally suitable due to severe climatic limitations such as rainfall and mean maximum temperature.

4.4.7. Mango and banana

The upland areas were marginally suitable due to moderate limitations in rainfall, temperature, erosion, depth, coarse

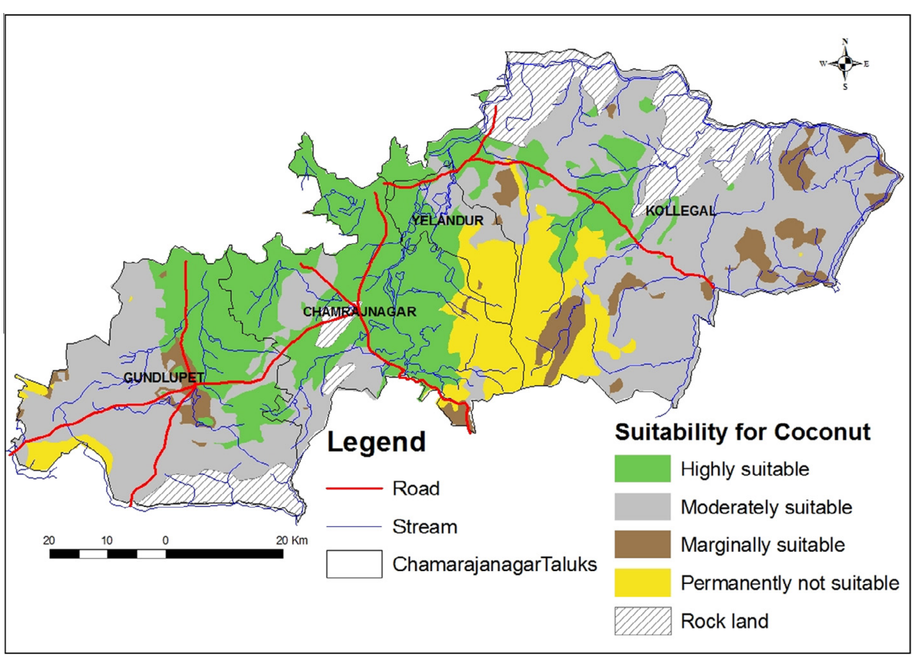

Figure 20 Land suitability for coconut.

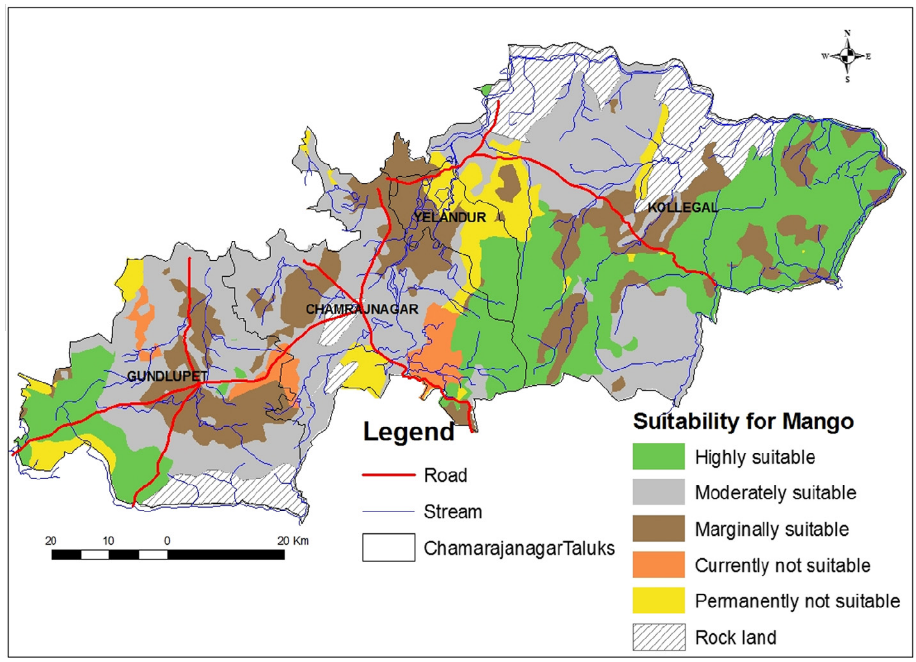

Figure 21 Land suitability for mango.

fragments and CEC. Similarly, midlands were also marginally suitable, whereas lowlands were presently not suitable but potentially suitable due to moderate drainage.

5. Conclusion

Based on the capability or limitations, the lands are grouped into eight classes; Class I occupied 10.53%, Class II occupied 3.4%, Class III occupied 51.4%, Class IV occupied 11.77%, Class V occupied 0.43%, Class VI occupied 2.31%, Class VII occupied 8.81%, and Class VIII (Rock land) occupied 11.34% of the total area. According to FAO (1976, 1983, 1985 and 2007) soils of the study area could be classified from the suitability view point to highly suitable class occupying 10.53%, moderately suitable class 3.40%, marginally suitable class 62.52%, currently not suitable class 11.77, permanently not suitable class occupying 0.43%, and rock land 11.34% of the total area in the district. The physiographic units of study area matched with the suitability for crops and orchards. The lowlands were moderately suitable for crops, whereas the upland were moderately suitable due to slope factor. The areas marginally suitable were due to limitations of slope and organic carbon. The midlands were moderately suitable, because of limitations in organic carbon and moderate drainage. Hence judicious use of organic manures in combination with inorganic fertilizers not only paves the way to achieve sustainable yields and also maintains the soil health without deterioration of future generations.

The study reveals that there is a close relationship between physiography and soils. The formation of the diverse group of soils can be attributed to the variation in topography, causing erosion, leaching, sedimentation and other pedogenic processes modified by water table.

Conflict of interest

There is no conflict of interest.

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References

AbdelRahman, M.A.E., 2014. Assessment of land degradation and land use planning by using remote sensing and GIS techniques in Chamarajanagar District, Karnataka (Ph.D. thesis) submitted to UAS, Bangalore University, India.

Bandyopadhyay, S., Jaiswal, R.K., Hegde, V.S., Jayaraman, V., 2009. Assessment of land suitability potentials for agriculture using a remote sensing and GIS based approach. Int. J. Remote Sens. 30 (4), 879–895.

Beek, K.J., De Bie, K., Driessen, P., 1997. Land information and land evaluation for land use planning and sustainable land management. Land Chatham 1, 27–44.

Bhaskar, K.S., Gaikawad, S.T., Anantha Rao, D., 1996. Soil site suitability evaluation for wheat: A case study. Agropedology 6 (1), 89–94.

Government of India, Ministry of Water Resources, Central Ground Water Board, Ground Water Information Booklet, Chamarajanagar District, Karnataka, South Western Region, Bangalore, November, 2008.

FAO, 1976. A framework for land evaluation. FAO soil bulletin no. 32, Rome.
FAO, 1983. Guidelines: land evaluation for rainfed agriculture, FAO soils bulletin no. 52, Rome.
FAO, 1985. Guidelines: land evaluation for irrigated agriculture. Soils bulletin 55. Food and Agriculture Organization of the United Nations.
FAO, 2007. A framework for land evaluation. FAO soil bulletin no. 6 Rome, Italy.
Khades, G.K., Gaikwad, S.T., 1995. Soil based agro-technology transfer: a case study. Agropedology 5, 91–96.
Landon, J.R., 1991. Booker Tropical Soil Manual. Longman Scientific and Technical, p. 474.
Merolla, S., Armesto, G., Calvanese, G., 1994. A GIS application for assessing agricultural land. ITC J. 3, 264–269.
Mishra, A., Sahu, G.C., 1991. Sisal-the strongest vegetable fiber crop. Orissa Rev.
Panigrahy, S., Manjunath, K.R., Ray, S.S., 2006. Deriving cropping system performance indices using remote sensing data and GIS. Int. J. Remote Sens. 26, 2595–2606.
Prasad, C.V., Reddy, R.S., Sehgal, J., Velautham, M., 1998. Soil of Karnataka for optimizing land use. In: Soils of India Series, 47. NBSS Publ.
Rao, D.P., Gautam, N.C., Nagaraja, R., Ram Mohan, P., 1996. IRS-IC application in land use mapping and planning. Curr. Sci. 70, 575–578.
Sathish, A., Niranjana, K.V., 2010. Land suitability studies for major crops in Pavagadataluk, Karnataka using remote sensing and GIS techniques. J. Indian Soc. Remote Sens. 38 (1), 143–151.
Satyavathi, P.L.A., Suryanarayan Reddy, M., 2004. Soil site suitability for six major crops in Telangana region of Andhra Pradesh. J. Indian Soc. Soil Sci. 52 (3), 220–225.
Sehgal, J.L., 1991. Soil-site suitability evaluation for cotton. Agropedology 1, 49–63.
Sehgal, J.L., 1996. Pedology-Concepts and Applications. Kalyani Publishers, Ludhiana.
Soil Conservation Service, Washington, DC, Soil Survey Staff, 1959, Land Capability Subclass. Soils Memorandum SCS-30. Soil Conversation Service, Washington, DC.
Soil Conservation Service, 1963. Know the Capability of Your Land. USDA-NRCS, Washington, DC, pp. 1–25.
Soil Conservation Service, 1992, Washington, DC: Soil Conservation Service, pp. 60–73.
Soil Survey Staff, 1958, Land Capability Classification. Soils Memorandum SCS-22.
Sys, I., Van Ranst, E., Debaveye, J., 1991. Land evaluation, Part I. Principles in land evaluation and crop production calculations, General administration for development cooperation, Brussels, p. 40.
Van Wambeke, A., Rossiter, D., 1987. Automated land evaluation systems as a focus for soil research. IBSRAM News Lett. 6, October 1987.