Research Article

Land Evaluation and Development of Optimum Land Use Plan of Watershed Using Remote Sensing and GIS Techniques

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Abstract
Land evaluation enables better understanding of the soils in terms of their potentials and limitations for agricultural production. In the present study, land evaluation was done for Dagala watershed, Katchch district of Gujarath state by adopting USDA land capability classification. Parameters considered for assessing the land capability were topography, wetness, physical soil condition and fertility status of the soils. By taking the consideration of all these parameters soils of the study area were categorized in to five land capability classes and three land capability sub classes. Land capability map was prepared using GIS (Arc/info) techniques. Out of the fourteen soil series established, soils of one series *i.e.* Amruthanagar series were placed under class III. Three series were classified under IV class, another six series were placed in VI class, remaining four series were categorized under class VII. Soils were classified under land capability subclass of *sc*, *esc* and *sec*. Optimum land use plan was suggested based on the potentials and limitations of different soil series of present study area of Dagala watershed.

Keywords: Land evaluation, USDA land capability classification, remote sensing, GIS techniques, soil series, land capability class and subclass, watershed, optimum land use plan and National Remote sensing Centre-Hyderabad

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Introduction

For the prosperity of the country, it is essential that the land is so managed as to get the best out of it. Proper land utilization and soil management using modern agricultural technology for optimum crop production should be adopted in such a way that the productivity of the soil per unit area is increased and maintained without environmental degradation so as to safeguard the interest of future generation. Soil survey and land use planning is a basic pre-requisite for extension of agriculture to new areas or improving productivity of the area already under cultivation or amelioration of deteriorated soils. In earlier days, scientific inventory of soil resources was obtained through conventional soil survey methods. Even though the acquired data are reliable and accurate, the field work was frequently handicapped by consideration of time, distance, weather and diversity of area. The recent advancements in space and information technology especially remote sensing plays an important role in soil resource inventory by reducing the above constraints. The use of computers for analyzing large quantities of data can be applied to agriculture in general, and soil surveys in particular. GIS is a powerful tool for storing voluminous spatial and non-spatial data and for an integrated analysis of resource data to develop sustainable action plans. Remote sensing and GIS are being increasingly used for resource inventory studies as they reduce the time required for survey, evaluation of resources for variety of applications and data transfer.

Methods and Materials

Present study area was Dagala watershed, Kutchch district of Gujarath state. This watershed lies between 23^{o}15'-23^{o}20'N latitude and 69^o 54'-70^o E longitude with a spatial extent of 7908.64 ha. This area is covered by Survey of India topographic map No. 41E/15. It is located in north-western agro-climatic zone of Gujarat. The study area comprises of six villages *i.e.* Dagala, Mokhana, Kanyabe, Amrutanagar, Dhaneti and Yoginagar.

Land evaluation was done by adopting the USDA Land capability classification [1]. Quantification of criteria for Land capability classification is given in **Table 1**. The land capability classification is widely used categorical system for evaluating land on broad agricultural systems and not for specific crops (or) practices. It is interpretative grouping of the soils mainly based on the (1) inherent soil characteristics (2) External land features and (3) Environmental factors that limit the use of the land.

Table 1 Land capability classification – quantification of the criteria

Characteristics	Class I	Class II	Class III	Class IV	Class V	Class VI	Class VII	Class VIII
Topography (t)								
1) Slope (%)	0-1	1-3	3-8	8-15	Up to 3	15-35	35-50	> 50
2) Erosion	Nil	Slight	Moderate	Severe	Nil	Severe	V. severe	
WETNESS (w)								
3) Flooding	Nil (FO)	Nil (FO) (FO/F1)	Nil to slight (F1/F2)	Slight to mod. (F3)	Mod. To severe(F 0 /F 3)	Nil to severe (F 0 to F 4)	Nil to very severe	-
4) Drainage (I)	Well	Mod. well	Imperfect	Poor	V. poor	Excessive	Excessive	Excessive
5) Permeability	Moderate	Mod. rapid	Rapid, slow	V. rapid, very slow	-	-	-	-
6) Infiltration rate (cm hr^{-1})	2-3.5	1-2.0 3.0 – 5.0	0.5 – 1.0 5.0 – 10.0	< 0.5 > 10.0	2.0	-	-	-
Physical Soil Conditions (s)								
7) Surface texture	Loam	sil & cl	sl & c	scl	s, c(m)	ls-cl	ls,s,c	ls,s,c(m)
8) Surface coarse fragments (vol.)	1-3	3-15	15-40	40-75	15-75	75+	-	-
9)Surface stoniness(%)	< 1	1-3	3-5	5-8	8-15	15-40	40-75	>75
10) Subsurface coarse fragments (%)	<15	<15	15-35	35-50	50-75	50-75	50-75	<10
11) Soil depth (cm)	>150	150-100	100-50	50-25	-	25-10	25-10	<10
12) Profile Development	Cambic/ Argillic hor. (A-(B)-C	A-B-C	Stratified A-C;A-B-C	Salic (Z)/Calcic (K) hor. A-Bz-C/A-Bk-C	Az-C, A-Bz-C	Gypsic (y) hor. A-Cy	A-C (Stony)	A-C (boundry)
Fertility (f)								
13) CEC (cmol(p^+ kg^{-1})	40-16	16-12	16-12	-	-	-	-	-
14) Base saturation (%)	80+	80+	80-50	50-35	50-35	35-50	<15	-
15) OC (0-15 cm) %	>1.0	0.75-1.0	0.5-0.75	<0.5	<0.5	-	-	-
16) Salinity EC (dS m^{-1})	<1.0	1-2	2-4	4-8	8-15	15-35	35-50	>50
17) Gypsum (%)	0.3 – 2.0	2-5	5-10	10-15	15-25	>25	-	-

hor. : horizon, V. : very

Factors considered for determining the capability are topography (slope and erosion), wetness (flooding, drainage, permeability), physical soil conditions (surface texture, surface coarse fragments, surface stoniness, sub-surface coarse fragments, soil depth and profile development) and fertility status of the soil (CEC, base saturation, OC, salinity and gypsum content). In the present study, capability classification was done up to sub class level.

Preparation of land capability map

Soils of the study area were classified up to series level and initially soil map was developed using remote sensing and GIS techniques**.** Satellite data of IRS PAN+LISS III was used for generating of soil map (**Figure 1**and **2**). Land capability for all soil units were calculated using above mentioned method and digital database was created by linking these attribute data to the soil layer. From this, derivative map (land capability map) was generated using ARC/Info software. Based on the land capability class, present land use and constraints, best optimum land use plan was suggested by adopting management practices for all the soil series of the watershed.

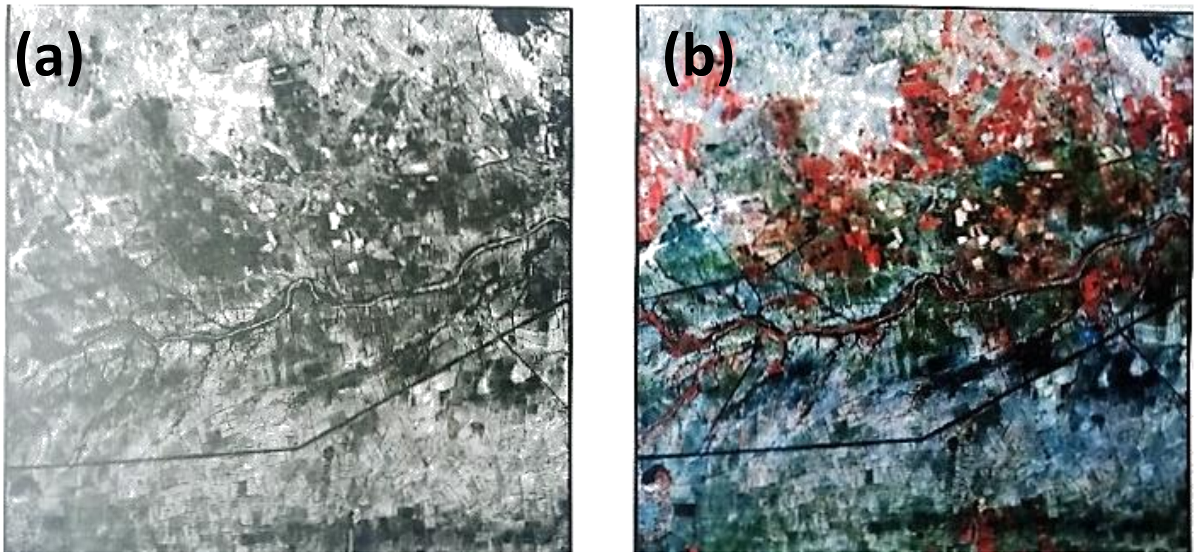

Figure 1 Satellite data of the study area used for assessing the land capability – (a) IRS-1C PAN image, (b) LISS-III image

Figure 2 IRS-1C PAN+LISS III merged Satellite data of the study area used for assessing the land capability

Results

Land capability classification was done according to the criteria for land capability classification (Table 1). Parameters considered for assessing the land capability were topography (slope and erosion), wetness (flooding, drainage, permeability and infiltration rate), physical soil conditions (surface texture, surface coarse fragments, surface stoniness, sub-surface coarse fragments, soil depth and profile development) and fertility status of the soil (CEC, base saturation, OC, salinity and gypsum content). By taking into consideration of all these parameters, soils of the study area were categorized into five land capability classes (**Table 2**) and land capability map was prepared using GIS (ARC/Info) techniques, which is presented in the **Figure 3**.

Soils of the Amrutanagar series had less limitations compared to other soils and therefore, were placed under Class III and that of Yoginagar-2 series had very severe limitations, which were, therefore, placed under class VIII. Soils of the series Kanyabe-1, Dhaneti-2 and Dagala-1 were classified under IV class as they had moderate limitations. The soils of the series – Dhaneti-1, Dagala-2, Yoginagar-1 and Kanyabe-3 exhibited severe limitations and were placed under Class VII. The remaining six types of soils belonged to class VI.

The soils under class III and class IV were grouped under land capability sub class 'sc' which indicates the major limitation of soil followed by climate. However, climate was the limitation for all the soils of the study area as the soil temperature regime is aridic with an average annual rainfall of 350 mm. The sub-classes found in the capability class VI and VII of the soils of study area were 'sc' and 'esc', respectively. Soils of class VIII showed very severe limitations of soil factor followed by erosion and climate and so they were classified under sub class 'sec' (**Table 2**).

Table 2: Land capability classification for the soils of the study area

Pedon No.	Soil Series	Soil type	Land capability class	Land capability sub-class
1	Mokhana	Typic Torriorthents	VI	esc
2	Dagala-3	Typic Haplocambids	VI	esc
3	Amrutanagar	Vertic Haplocambids	III	sc
4	Dhaneti-1	Typic Haplocalcids	VII	sc
5	Kanyabe-2	Typic Haplocambids	VI	sc
6	Kanyabe-1	Typic Haplocalcids	IV	sc
7	Dhaneti-2	Typic Haplocambids	IV	sc
8	Yoginagar-1	Typic Torriorthents	VII	esc
9	Dagala-1	Typic Haplocambids	IV	sc
10	Yoginagar-2	Typic Torriorthents	VIII	sec
11	Dagala-2	Typic Torripsamments	VII	esc
12	Sangnadi-1	Sodic Haplocambids	VI	sc
13	Kanyabe-3	Typic Torriorthents	VII	sc
14	Sangnadi-2	Typic Haplocambids	VI	sc

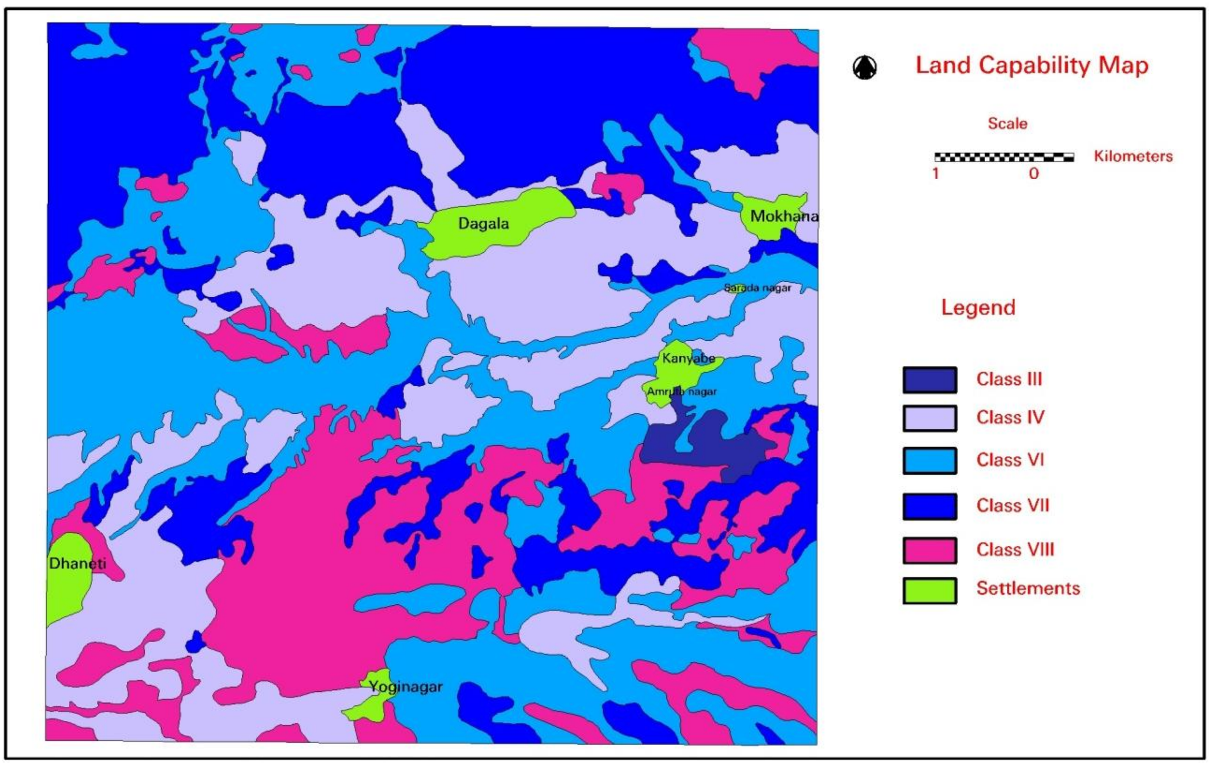

Figure 3 Land capability map generated for the study area

Discussion

Soils belonging to Amrutanagar series (Pedon-3) were categorized under land capability 'Class III' and subclass 'sc' because these soils had limitations of soil (organic matter) and climate. However, climate is the limitation for the entire study area as the average annual rainfall is 342 mm. These soils can be used for the cultivation of field crops such as all pulses, millets and oilseed crops with careful management practices.

Soils belonging to Kanyabe-1 (Pedon-6), Dhaneti-2 (Pedon-7) and Dagala-1 (Pedon-9) were grouped under class IV sc as these soils exhibited the limitations of coarse texture, calcic horizon from 50 cm depth onwards and low organic matter. In addition, Dagala-1 also showed limitations of coarse texture, surface stoniness and sub-surface coarse fragments. Hence, these are suitable for cultivation of limited crops and need intensive soil conservation and management practices such as addition of organic manures, deep tillage, addition of tank silt after stone removal by mechanical working.

Soils of pedons-1 and 2 were classified as class-VI esc and pedons-5, 12 and 14 were classified as class-VI sc. These soils of class-VI had moderate limitations of texture, surface stoniness, sub-surface coarse fragments and low organic matter. Moreover soils of Pedons-1 and 2 (Mokhana and Dagala-3 series) had the limitations of erosion with moderate to steep slopes, having shallow depth and therefore, were grouped as land capability sub class 'esc' whereas pedons-5, 12 and 14 were grouped as subclass 'sc' only. These soils are not suitable for growing crops and are only suitable for grazing (or) forestry.

Soils of Dhaneti-1 (Pedon-4), Yoginagar-1 (Pedon-8), Dagala-2 (Pedon-11) and Kanyabe-3 (Pedon-13) were classified under class-VII in which pedons-4 and 13 were kept under subclass 'sc' due to the severe limitations of texture, more surface stoniness, more subsurface coarse fragments, low organic matter, more permeability while pedons-8 and 11 were kept under sub class 'esc' because of severe erosion in addition to the above soil related constraints. These soils are fairly suitable for grazing or forestry and need careful management practices even for grazing or forestry purposes.

Soils belonging to Yoginagar-2 series (Pedon-10) were categorized as class-VIII sec (Table 2) as these soils had very severe limitations of texture (very coarse), more surface stoniness, more sub-surface coarse fragments, low organic matter, low CEC and erosion besides climate. These are suitable only for wild life or recreation purposes. [2] and [3] were evaluated the potential use of land adopting this method and suggested optimum land use plan for tribal areas of Andhra Pradesh and for upper Maulkhand catchment in mid-hills zone of Himachal Pradesh, respectively. [4] were also adopted this method for land evaluation at Goa and [5] and [6] at Tamil Nadu.

Optimum land use plan suggested

Optimum land use plan for the watershed was suggested taking in to consideration of potentials and limitations of the different soil series. Present land use of the soils classified under land capability classes III and IV *i.e.* Amruthanagar, Kanyabe-1, Dhaneti-2, Dagala-1 series is cultivated land. These are used for growing bajra, sorghum and castor. But after improving the soil by managing the constraints of texture and organic matter through the addition of organic matter, tank silt and providing good irrigation facilities by means of drip (or) sprinkler methods, these soils can be used for growing oilseeds such as groundnut, sesamum, mustard and pulses (**Table 3**).

Among the soils that are classified under LCC VI i.e. series-Mokhana, Dagala-3, Kanyabe-2, Sangnadi-1 and Sangnadi-2, present land use of Mokhana and Dgala-3 is scrub land mostly ocuupied with *Prosophis* Sp. and that of Kanyabe-2 series (pedon-5) is partially cultivated and partially waste land with *Prosophis* Sp. Soils of Kanyabe -2 had the constraints of coarse texture, more surface stoniness, more subsurface coarse fragments and low organic matter. These soils can be utilized in future for cultivation of oilseeds and pulses by adopting management practices such as addition of organic manures and provision of irrigation facilities through drip/sprinkler methods after removal of stones.

Soils of Dagala-3 had constraints of moderately shallow depth, coarse texture, more surface stoniness, moderately sloping land with erosion. But by reducing erosion and stabilizing soil scape with the help of small stone and line checks across gullies, these can be suggested for arid horticulture. [4] assessed the potential land use in the proposed irrigation command using remote sensing and GIS in Goa by developing land capability map as attribute map and suggested potential land use. A study was undertaken in a part of Solani watershed of Haridwar and Saharanpur districts in Uttaranchal and Uttar Pradesh, respectively by [7] for assessing the land capability to adopt suitable soil conservation measures and suggested land use plan through remote sensing and GIS approaches.

Even though the present land use of Mokhana and Dagala-3 is scrub land with *Prosophis Sp*., soils of Mokhana series (pedon-1) had severe limitations in addition to the limitations noticed in soils of Dagala-3 (pedon-2) such as shallow in depth with lithic contact, steep slope with erosion. It is not economical for adoption of management practices to improve these soils and hence they can be utilized for recreation and urban development purposes.

Sangnadi-1 and 2 (Pedons-12&14) were classified under class VI sc but constraints in soils are different. Sangnadi-2 series soils had the constraints such as coarse texture, presence of surface stoniness, sub surface coarse fragments and low organic matter and so were restricted for cultivation of castor crop only. The status of soils can be improved by adopting management practices i.e. stones removal by mechanical working followed by addition of tank silt, organic manures or green manures and then can be suggested for cultivation of millets such as bajra and sorghum in addition to castor crop.

Sangnadi-1 series soils had salt problems and so can be used for growing salt tolerant crops such as tomatoes, linseed, clusterbean, onion, cowpea, groundnut pearlmillet *etc.* after reclaiming the soils.

Table 3 optimum land use plan suggested for the study area based on land capability classification of soils

Soil Series	Present land use	LCC		Management practices	Suggested land use after adopting management practices
		Class	Constraints		
1) Mokhana	Scrub land (*Prosophis* sp.)	VI esc	Shallow depth with lithic contact Coarse texture More surface stoniness More sub-surface coarse fragments Low OC Steep slope and erosion	-	Recreation purpose
2) Dagala-3	Scrub land with *Prosophis* sp.	VI esc	Moderately shallow depth Coarse texture More surface stoniness More sub-surface coarse fragments Low OC Moderately sloping land Erosion	Small stone and live checks across gullies to stabilize soil scape and reduce erosion	Arid horticulture
3) Amruta nagar	Cultivated (single crop)	III sc	1) Low OC	Addition of organic manures Provision of irrigation facilities through drip/sprinkler methods	Cultivation of crops such as oilseeds and pulses
4) Dhaneti-1	Scrub land with *Prosophis* sp.	VII sc	Coarse texture More surface stoniness More sub-surface coarse fragments Calcic horizon at a depth of 47 cm Low OM 6) Depth	Addition of organic manures Deep tillage	Arid horticulture
5) Kanyabe-2	Partly Cultivated and partly waste land with *Prosophis* sp.	VI sc	1) Coarse texture 2) More surface stoniness More sub-surface coarse fragments 4) Low OM	Addition of organic manures Provision of irrigation facilities through drip/sprinkler methods Stone removal	Cultivation of oilseeds and pulses
6) Kanyabe-1	Cultivated (Single crop)	IV sc	Coarse texture Calcic horizon from 50 cm onwards Low OM	Addition of organic manures	Cultivation of millets and castor

7) Dhaneti-2	Cultivated (Single crop)	IV sc	Coarse texture Calcic horizon from 50 cm onwards Low OM	Addition of organic manures Provision of irrigation facilities through drip/sprinkler methods	Cultivation of crops such as oilseeds and pulses
8) Yoginagar-1	Degraded unculturable l and (or) waste land with *Prosophis* sp.	VII esc	Coarse texture Surface stoniness Sub-surface coarse fragments Depth Erosion	Addition of organic manures Deep tillage Small stone and live checks across rills to stabilize soil scape and reduce erosion	Arid horticulture
9) Dagala-1	Cultivated (Single crop)	IV sc	Coarse texture Surface stoniness Sub-surface coarse fragments Depth Low OC	Addition of organic manures Deep tillage Addition of tank silt Stone removal by mechanical working	Cultivation of oilseeds and pulses
10) Yogi nagar-2	Waste land with *Prosophis* sp.	VIII sec	Very coarse texture Surface stoniness Sub-surface coarse fragments Depth Low OC Low CEC	Small stone and live checks across rills to stabilize soil scape and reduce erosion	Recreation and urban development
11) Dagala-2	Scrub land	VII esc	1) Very coarse texture 2) Low fertility level 3) Low OM Erosion Depth Low CEC	Small stone and live checks across rills to stabilize soil scape and reduce erosion	Recreation and urban development
12) Sangnadi-1	Scrub land	VI sc	Surface stoniness Low OC Salinity	Application of gypsum Provision of drainage Addition of organic manures	Salt tolerant crops
13) Kanyabe-3	Scrub land	VII sc	1) Very coarse texture 2) Weak profile development 3) Low fertility level Low organic matter More Permeability More infiltration rate	Addition of organic manures Small stone and live checks across rills to stabilize soil scape and reduce erosion	Arid horticulture
14) Sangnadi-2	Cultivated (Single crop)	VI sc	Coarse texture Surface stoniness Sub-surface coarse fragments Low organic matter	Addition of organic manures, green manures Stones removal by mechanical working Addition of tank silt	Cultivation of millets and castor

The soils that were classified under LCC VII (Dagala-2) and VIII class (Yoginagar-2 series) had severe limitations and are not suitable for cultivation even though after adopting management practices. More over, it is not economical and therefore they are suggested for recreation and urban development only.

[8] studied the soil survey interpretation for land use planning in salt affected soils of Purna Valley of Vidarbha, Maharashtra by applying the methods of land capability classification. [4] assessed the potential land use in the proposed irrigation command in Goa using remote sensing and GIS techniques. They generated land capability and land irrigability maps as attribute maps and integrated to suggest potential land use map.

Conclusion

Finally to conclude, the soils of Dagala watershed that are classified under land capability classes III and IV (Soils of Amruthanagar, Dhaneti-2, Dagala-1 series) are suggested for growing oilseeds such as ground nut, sesamum, mustard and pulses. Among the soils that are classified under LCC VI (Mokhana, Dagala-3, Kanyabe-2, Sangnadhi-1 and Sangnadhi-2), Kanyabe-2 soils are suggested to grow oilseeds and pulses by managing the constraints. Soils of Dagala-3, Dhaneti-1 Yoginagar-1 and kanyabe-3 are suggested for arid horticulture. Soils of Sangnadhi-2 and Kanyabe-1 series are suggested for cultivation of millets such as bajra and sorghum in addition to castor crop. Soils of Sangnadhi-1 are suggested to grow salt tolerant crops after reclaiming soils. Soils of Mokhana (LCC VI class *esc*), Dagala-2 (LCC VII class *esc*) and Yoginagar-2 (LCC VIII class *sec*) series are not suitable for cultivation even though after adopting management practices. More over, it is not economical and therefore they are suggested for recreation and urban development only.

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