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Land Use Planning by Using GIS Techniques for Land Resource Inventory (LRI)- Northern Dry Zone of Karnataka, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A study was conducted to determine land capability and to develop suitability map based on soil characteristics and climatic factors of watershed area. Detailed soil survey was carried out for Donur-2 micro watershed which comes under Basavana Bagewadi taluka of Vijayapura district, Karnataka to acquire the comprehensive data related land resources. From the study area, it was observed that based on soil-site characteristics four soil series were identified such as Dadamatti, Karjol, Nidoni and Rampur series and mapped into eight mapping units using GIS techniques. Donur-2 watershed area has been grouped into three land capability classes (LCC) *viz.,* II, III and IV

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with four subclasses IIes, IIIs, IIIse and IVe. Subclass 'e' is due to major limitation of soil property group 'e' *i.e* erosion and slope, subclass 's' is due to major limitations group 's' having parameters like texture, depth and gravelliness. Subclass 'se' and 'es' are due to limitations of both soil parameters group above mentioned, however se and es are different classes which are based major limitation one of the group and followed by other group. Land capability map was developed using GIS techniques which indicates that out of 324.3 ha study area, LCC class IIIs covering major area *i.e.* 179 ha (55.12%), followed by class IIs *i.e.* 109 ha (33.51%), class IVe *i.e.* 23 ha (7.15%) and minor area of 7 ha (2.15%) area is covered by class IIIse. Soil suitability assessment indicates that majority of land is moderately suitable for agriculture. Class III soils are designated as moderately fertile agricultural land with significant constraints. However, with special conservation practices soils under class III can be used for cultivation of different crops. Class IV soils are categorized as reasonably fertile for intermittent cultivation, characterized by significant restrictions that limit crop options but with careful management practices these can be used for cultivation of arable crops. Therefore, the utilization of a land use planning approach (LUP) is instrumental in formulating tailored land resource management strategies to enhance land productivity, mitigate land degradation and attain sustainability goals.

Keywords: Land resource inventory; land capability classification; soil mapping unit; land assessment and land use planning.

1. INTRODUCTION

"In India rainfed areas cover about 52% of net cultivated area contributing more than 40% to India's total food production. Most of small and marginal farmers are found in rainfed area only. These areas are characterized by severe low productivity, land degradation along with adverse climate change impacts. To achieve sustainability in rainfed areas it necessitates watershed development by conserving and regeneration of natural resources which help in protection of land resources like fertile soil and available soil moisture. Establishment of land capability class (LCC) plays vital role in development of watershed. LCC is established based on existing problems for which depending on the future potentials alternative land management practices are planned. Land capability classification is a system of grouping soils primarily based on their capability to produce common cultivated crops and pasture plants without deteriorating over a long period of time. Land capability is assessed based on the native characteristics and its suitability for agriculture, forestry, grazing, recreation and wildlife. Hence land is categorized into different capability classes which provide guidelines for rational use of land, Singh and Dhillon" [1]. Conducting an in-depth, site-specific analysis of soil and land resources will enable the identification of both constraints and potentials within the limited available resources. This analysis will aid in the development of appropriate, site-specific land use options, thereby facilitating sustainable management of these finite resources, Mini et al. [2]. "The soil survey and soil classification provide information on soil and related properties which can be further used for delination of soil and land suitability for irrigation, coupled with effective irrigation water management techniques", Mohan et al. [3]. Land suitability classification primarily relies on physical soil properties such as depth, drainage, texture, among other as conditioned by climate and topography and soil chemical properties. Pillai and Natarajan [4] and Sehgal [5]. Given this context, the current study focused on soil-site characterization to forecast the agricultural productivity of the area by land suitability assessment to prepare an integrated Land Capability Class (LCC) map, identify and suggest suitable soil and water conservation measures based on land class for effective land water resource management in a watershed area.

2. METHODS

2.1 Description of Study Area

Donur-2 micro-watershed encompasses an area of 324.29 hectares (Fig. 1) and situated within the hot semi-arid agro-ecological region of India, the watershed spans between latitudinal coordinates in $16^0$42' 0" to $16^0$44' 0" North latitudes and 75^0 57' 0" to 75^0 59' 0" East longitudes, Basavan Bagewadi taluk of Vijayapura district in the Northern Dry Zone of Karnataka. This area has a low to medium available water content with a length of growing period of 161 days with characterized by hot and

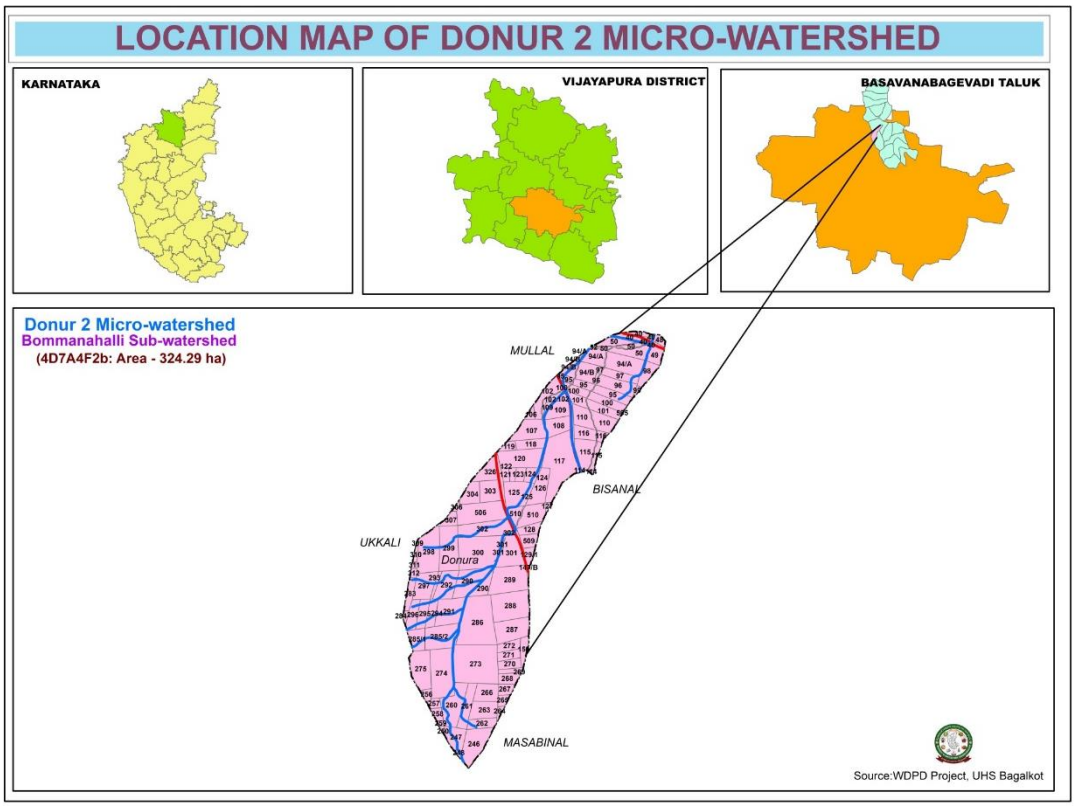

Fig. 1. Location map of study area

arid climate. The area experiences an average annual rainfall of 662 mm, occurring predominantly between June and October. Additionally, it ranges in elevation from 583 meters above mean sea level, with gently sloping relief. The general slope is towards southwest direction. The drainage pattern is parallel. Soils are derived from basaltic flows of Deccan traps, chlorite schist with shale as dominant parent material. The soils are medium to very deep black clay in major areas, sand loams in remaining areas. The major cultivating crops during kharif season are Jowar, Maize, Greengram, Pigeonpea, Cotton, Sugarcane while during *rabi* season Bengalgram, Wheat and rabi Jowar. The natural vegetation predominantly consists of trees and shrubs, including species such as Acacia (*Acacia auriculiformis*) and Neem (*Azadirachta indica*).

2.2 Soil survey and Mapping

A comprehensive soil survey of the study area was conducted utilizing data from IRS-LISS IV and Cartosat-1 satellite images (1:7920 scale) and Vijayapura district toposheet as per procedure outlined by Land resource inventory (LRI) for surface study during which the area was intensively traversed, surface characteristics like texture, slope, erosion, gravelliness, calcareousness and stoniness were recorded. Surface soil samples were collected at 320m grid intervals and were analyzed for macro and micronutrients status, salinity, soil reaction and organic carbon. Based on soil heterogeneity, pedon locations were marked to carry out sub surface study. At each pedon location, a new profile was excavated and a detailed horizon-wise examination was conducted. Soil samples were then collected and analyzed for essential physical and physicochemical properties following standard analytical procedures. Following the correlation of these soil properties, classification into four series was carried out according to the guidelines provided in the Field Guide for LRI Sujala-III project, ICAR-NBBSS & LUP [6]. Subsequently, these soils were mapped into eight distinct mapping units based on variations in texture, depth, slope, and erosion characteristics.

2.3 Land Capability and Soil Suitability Assessment

The soil-site characteristics of various soil units were determined by calculating the weighted

Table 1. Parameters and their ratings to be used for grouping parcels into land capability classification units/classes

Characteristics	LCC Classes							
	I	II	III	IV	V	VI	VII	VIII
Climate	Humid with well distributed rainfall	Humid with occasional dry spells/Sub humid yields frequently reduced by droughts	-	Semi-arid/Arid	-	-	-	-
Slope (%)	<1%	1-5% (Red soils), 1-3% (Black soil)	5-10%	10-25%	-	25-50%	>50%	-
Erosion	Slight	moderate		severe		very severe		
Drainage	Well to moderately drained	Imperfect to poor	Very poor	-	-	-	-	-
Soil depth	>100 cm	50-100 cm	25-50 cm	10-25 cm		<10 cm		
Texture	sl,scl,cl,l,	sc, si, c	c	ls	s	-	-	-
Gravels (%)	<15	15-35	35-60	>60		-	-	-
Rock out Crops (%)	<2	2-10	10-50	50-90	50-90	-	-	>90%
Salinity (EC)	<2	2-4	4-8	8-16	-	-	-	-
pH	6.5	-	5.5-6.5 & 7.5-8.5	<4.5, 4.5-5.54 & 8.5-9.5	-	-	-	-
Permeability	Very slow	Moderately slow	Slow	Very slow				

Source; Ref. 6.: Texture classes denoted in the table indicate: sl - sandy loam, scl - sandy clay loam, cl - clay loam, l - loam, sc- sandy clay, si - silt, c - clay, ls - loamy sand and s - sand

average of each soil property, which was then interpreted to assess land capability. The properties were compared with the criteria outlined for land capability classification (Table 1). The land capability classification is organized into three primary categories of soil, namely: i) Capability unit, ii) Capability subclass, and iii) Capability class.

I. Land capability unit is a categorization of soils with similar responses to cultivated crops and pasture plants, often determined by their respective yields.
II. Capability subclass is a classification of capability units that share similar types of limitations and hazards.
III. Land capability refers to a group of soils with the same degree of limitations, which escalate from class I to class VIII. Classes I to IV are suitable for cultivation, while classes V to VIII are not suitable for cultivation but may be suitable for grazing, forestry, wildlife maintenance, recreation, or watershed protection, ICAR [7].

In the present study the land capability classification is followed as per third category(III) of above mentioned classes which is mainly based on the inherent soil characteristics, external land features and environmental factors. The land capability classes and subclasses were determined according to the guidelines provided in the LRI Field Guide, REWARD project, ICAR-NBSS & LUP [8]. With the advancements in remote sensing and Geographic Information System (GIS), thematic layers were generated, integrated, and subjected to spatial analysis to create land capability maps and soil-site suitability maps. This process was conducted using the ArcView Interface within ArcGIS 10.8.2 software. (Suryawanshi et al. [9], Mishra et al [10], Mishra and Babu [11], Mary Silpa and Nowshaja [12].

3. RESULTS AND DISCUSSION

3.1 Soil Map and Soil Mapping Units

A soil map is crafted to depict the spatial distribution of various soil types or other mapping units relative to prominent physical and cultural features of the Earth's surface. [13] In the identification of soil mapping units within the study area, input parameters such as soil series, soil texture, soil depth, slope, erosion and gravel content were utilized. Study area is grouped into four series namely, Dadamatti (DMT), Karjol (KRJ), Nidoni (NDN) and Rampur (RPR) series (Table 2). Dadamatti series covers 8 ha (2.33%) of the study area and they are shallow, black soils, vary from clay loam to clay texture, calcareousness which are derived from Basaltic landform. Karjol series which cover 67 ha (20.66%) area, very deem clay loam to clay soils with calcareousness in subhorizons belonged to Basaltic landform. Nidoni series covers 48 ha (14.73%) and are classified as very deep. 195 ha (60.21%) of Donur-2 watershed area belongs to Rampur series which is characterized by black soils which are deep, sandy clay to clay texture and presence of calcic horizons.

Table 2. Mapping unit description of Donur-2 micro watershed

Sl. No.	Mapping unit	Mapping Unit Description
1	DMTiB2g1	Shallow (25-50 cm), sandy clay soils developed on very gently sloping (1-3%), moderately eroded with gravelly (15-35%).
2	KRJmB2	Very deep (>150 cm), clay soils developed on very gently sloping (1-3%), moderate erosion.
3	KRJmB2g1	Very deep (>150 cm), clay soils developed on very gently sloping (1-3%), moderately eroded with gravelly (15-35%).
4	KRJmB2g2	Very deep (>150 cm), clay soils developed on very gently sloping (1-3%), moderately eroded with very gravelly (35-60%).
5	NDNmB2	Very deep (>150 cm), clay soils developed on very gently sloping (1-3%), moderately eroded.
6	RPRiB2g1	Deep (100-150 cm), sandy clay soils developed on very gently sloping (1-3%), moderately eroded with gravelly (15-35%).
7	RPRiB3g1	Deep (100-150 cm), sandy clay soils developed on very gently sloping (1-3%), severely eroded with gravelly (15-35%).
8	RPRmB2	Deep (100-150 cm), clay soils developed on very gently sloping (1-3%), moderately eroded.

Source; *WDPD Project, UHS, Bagalkot*

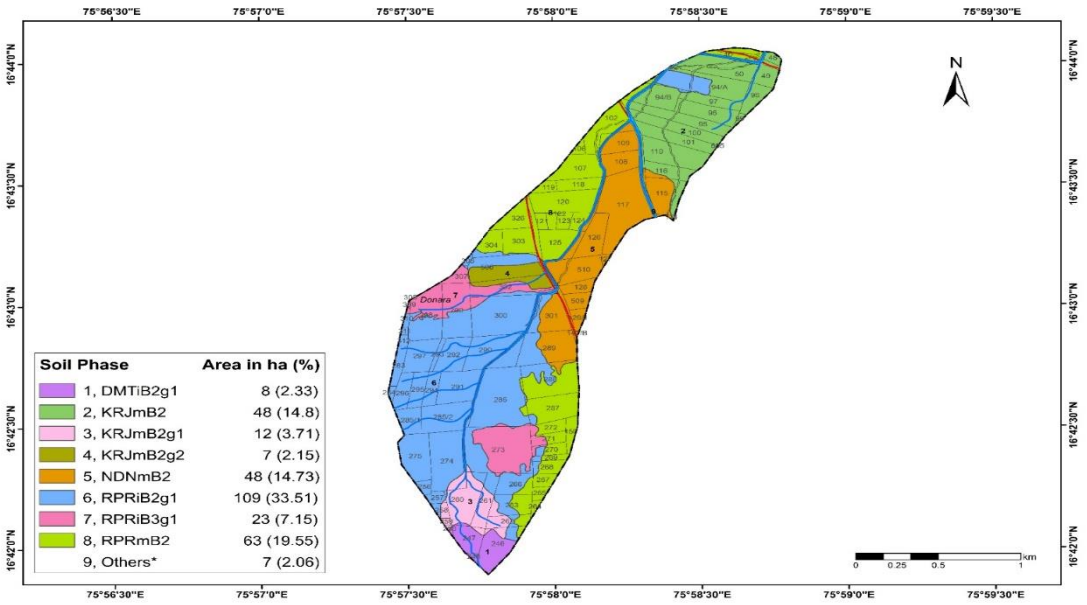

Fig. 2. Different mapping units of Donur-2 microwatershed

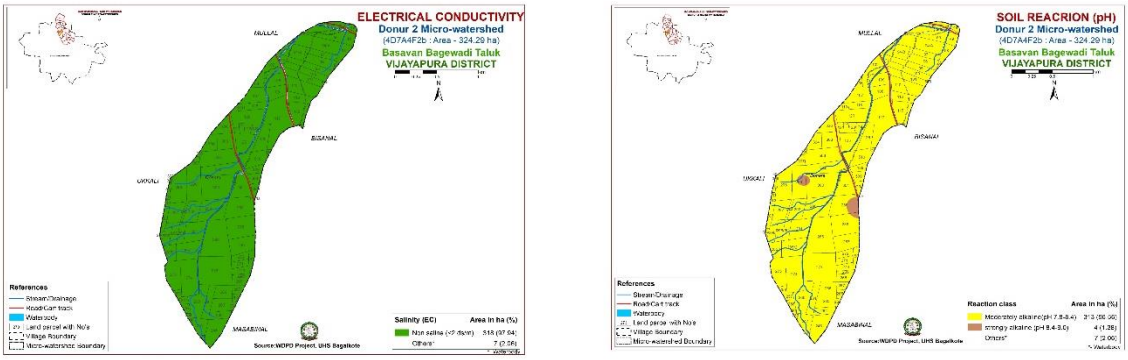

Fig. 3. (a) and (b) The EC and pH of the Donur-2 watershed area

These mapping units were delineated into eight categories during various phases of soil series using the Arc View Interface of ArcGIS 10.8.2 GIS software (refer to Fig. 2). The legend for mapping units is represented as follows: for example, "DMTiB2g1", where the first three capital letters denote the name of the series (e.g., DMT for Dadamatti), followed by a lowercase letter indicating surface texture (e.g., i for sandy clay), the subsequent capital letter denotes slope (e.g., B for 1 to 3% slope), the following numerical value signifies erosion status (e.g., 2 for moderately eroded), and finally, "g1" indicates the class of gravelliness (e.g., gravelly). The design of the legend and the types of mapping units for the study area were determined according to the procedures outlined in the LRI Field Guide for the REWARD project. Soil depth varied from shallow to very deep, slope grouped under very gently sloping class (1-3%) with moderately eroded to severely eroded soils where gravelliness ranged from no gravelly (<15%) to very gravelly (35-60 %) class. Fig. 3 (a) and (b) depict the EC and pH of the Donur-2 watershed area.

3.2 Land Capability Classification

Based on the soil-site characteristics of the study area, the soils were classified into three land capability classes (refer to Table 3). These classes are described as follows:

Table 3. Grouping of Soil-site suitability characteristics of soil mapping units of Donur-2 micro-watershed according to LCC classification

Sl. No.	Mapping unit	Depth(cm)	Texture	Slope (%)	Erosion	Gravels (%)
1.	DMTiB2g1	25-50	scl	1-3	Moderate	15-35
	LCC class	III	I	II	II	II
2.	KRJmB2	>150	c	1-3	Moderate	<15
	LCC class	I	III	II	II	I
3.	KRJmB2g1	>150	c	1-3	Moderate	15-35
	LCC class	I	III	II	II	II
4.	KRJmB2g2	>150	c	1-3	Moderate	35-60
	LCC class	I	III	II	II	III
5.	NDNmB2	>150	c	1-3	Moderate	<15
	LCC class	I	III	II	II	I
6.	RPRiB2g1	100-150	sc	1-3	Moderate	15-35
	LCC class	I	II	II	II	II
7.	RPRiB3g1	100-150	sc	1-3	Severe	15-35
	LCC class	I	II	II	IV	II
8.	RPRmB2	100-150	c	1-3	Moderate	<15
	LCC class	I	III	II	II	I

Source; *WDPD Project, UHS, Bagalkot*

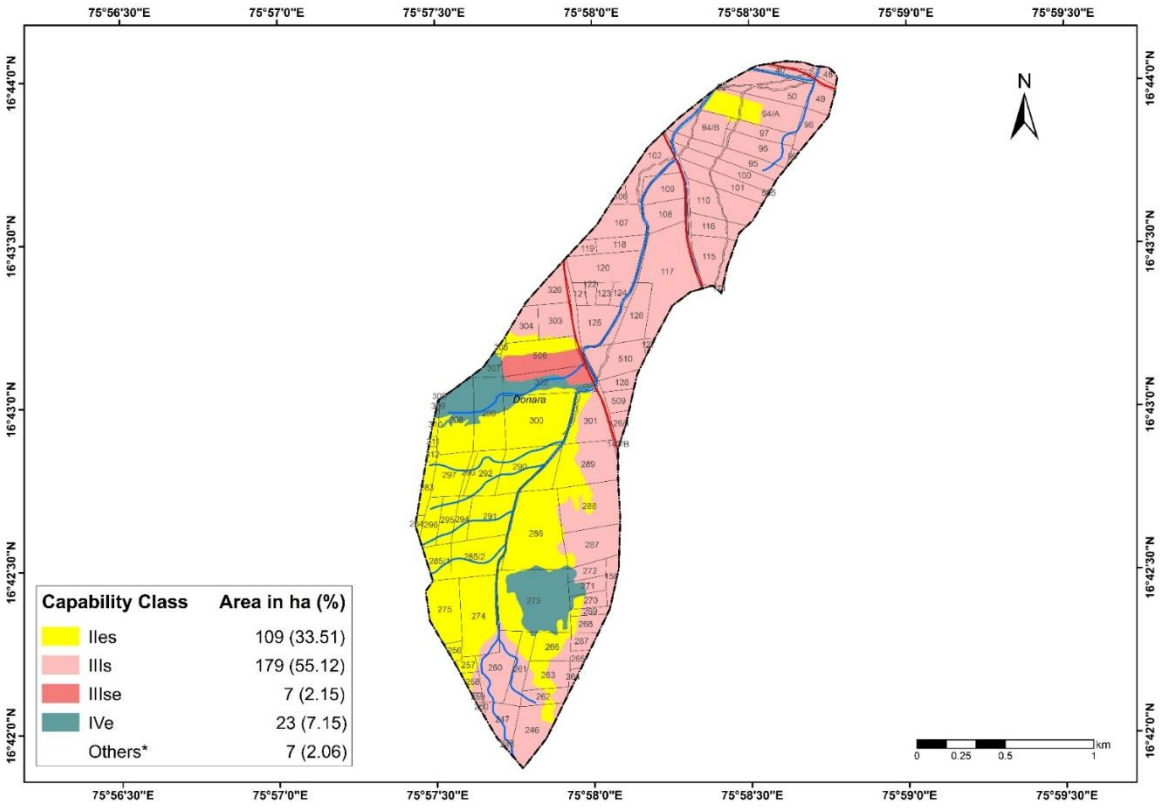

Fig. 4. Land capability classes of Donur-2 microwatershed

Class II: The analysis revealed that 109 hectares (33.51% of the study area) were categorized as land capability class II lands (see Fig. 4). Soils within this class are considered good cultivable lands, albeit with limitations that restrict their full utilization. These limitations may include one or more of the following factors: 1) restricted choice of crop, 2) gentle slope (1% to 5%), 3) moderate

erosion risks, 4) inadequate soil depth, 5) less than optimal soil structure and workability, 6) slight to moderate alkaline or saline conditions, 7) somewhat constrained drainage, 8) necessitating moderate conservation practices to prevent degradation, and 9) capable of sustaining less intensive cropping systems. [13] These soils exhibit moderate to rapid permeability and are moderately well-drained, with minor limitations related to slope, drainage, depth, texture, profile development, soil pH, organic carbon content, and base saturation, NBSS & LUP [14]. Hence soil conservation practices like ploughing across the slope for field crops, levelling of land, ridges and furrows, providing proper drainage will help to improve the soil properties and land productivity. Similar study by Mary Shilpa and Nowshaja [12] reported that class IIe soil need protection from erosion and use of conservation irrigation methods should be done.

Class III: Our study indicates that majority of Donur-2 watershed area *i.e* 186 ha (57.27 %) belong to land capability class III, in which 179 ha area occupies IIIs subclass and 7 ha area is grouped under IIIse subclass (Fig. 4). Soils belonging to Class II soils are characterized as moderately good cultivable lands; however, their utilization is hindered by severe limitations. These limitations encompass one or more of the following factors: 1) restricted choice of crops, 2) moderately steep slope (5% to 10%), 3) high erosion risks, 4) very slow water permeability, 5) shallow depth and limited root zone, 6) low water-holding capacity, 7) poor fertility, 8) moderate alkalinity and salinity, and 9) unstable soil structure. These soils exhibit moderate to rapid permeability and are moderately well-drained, with moderate constraints related to slope, erosion, depth, coarse fragments, profile development, organic carbon content, and base saturation. Special conservation practices are required for cultivating crops on these soils, and additional management practices beyond those listed for Class III soils are necessary. Addition of organic manures, green leaf manuring, soil conservation practices like graded bunds will help to reduce the severity of different limitations. Panhalkar et al [15] opined that the conservation practices are usually more difficult to apply and to maintainin class III soils. Limitations of soils of theses soils restrict the amount of clean cultivation, time of planting, tillage, choice of crops and harvesting. Mary Shilpa and Nowshaja [12] reported that in class III soils cultivation with precautions against permanent land damage should be done. Special attention should be given to erosion control while conservation irrigation must be adopted.

Class IV: The result showed that 7.15% (23 ha) of Donur-2 watershed area has been catagorized into IV class with severe limitation of slope and erosion. These soils are categorized as fairly good cultivable lands, suitable for occasional cultivation only due to severe limitations. They are characterized by: 1) severe restrictions on the choice of crops, 2) high susceptibility to erosion, 3) steep slopes, 4) shallow soil depth, 5) low water-holding capacity, 6) poor drainage, and 7) severe alkalinity and salinity. These soils exhibit moderate to rapid permeability and are moderately well-drained, with severe limitations regarding slope, moderate to severe limitations in erosion and depth, profile development, and base saturation. They also have moderate limitations in terms of coarse fragments and organic carbon content. To achieve sustainable production of field crops and horticulture on these soils, management practices such as terracing, strip cropping, and contour tillage may be necessary. Mary Shilpa and Nowshaja [12] reported from their study that in IV th class soils cccasional cultivation is rotated with hay or pasture, or by orchards and should be protected by permanent cover crops for control of intensive erosion. Panhalkar et al [15] reported that physical conditions of in class VI soils are placed such that there is practical to apply only for range or pasture improvements, if needed, such as seeding, liming, fertilizing, and water control with contour furrows, drainage ditches, diversions or water spreaders. The present study can comparable with findings of Girmay et al [16] and LCC study in watershed area by Mishra and Babu [17].

4. CONCLUSION

Donur-2 watershed land capability maps generated from information collected through LRI depicts that all the study area belongs to arable lands and it is fit for cultivation. In the study area, there were no lands categorized as Class I. The majority of the area falls under Class III lands, which are marginally suitable for crop cultivation but highly suitable for other purposes such as wildlife habitat, forestry, and grazing. However, these lands are not suitable for intensive or very intensive cultivation practices. The second-largest portion of the area is occupied by Class II lands, which can be utilized for various types of cultivation (excluding very intensive cultivation)

as well as for wildlife habitat, forestry, and grazing. Considering the limited availability of Class II lands, it is advisable to reserve them primarily for the cultivation of food crops and commercial crops. Class IV lands can be utilized for crop cultivation by adopting major soil conservation practices. Suitable soil conservation and management practices like graded bunds, terracing, strip cropping and contour-tillage should be followed to improve the soil physic chemical properties along with enhancing productivity. Hence site specific LCC study and its interpretation helps to conserve the valuable agricultural resources and to achieve the sustainability.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Singh J, Dhillon SS, Agricultural Geography, Tata Mc- Grow Hill Publishing Company. New Delhi; 1984.
2. Mini V, Patil PL, Dasog GS. Characterization and classification of soils of pilot site in coastal agro ecosystem of North Karnataka. Agropedology. 2007; 17:59-67.
3. Mohan MM, Babu MVS, Reddy M, Vijaya Sai. Characterization of soils of *Hanumankoppa microwatershed* in Northern Transitional Zone of Karnataka. Progressive Agriculture. 2013;13:4-10.
4. Pillai MY, Natarajan A. Characterization and classification of dominant soils of parts of Garakahalli watershed using remote sensing technique. The Mysore Journal of Agricultural Sciences. 2004;38:193-200.
5. Sehgal JL. Pedology-Concepts and Application. Kalyani Publishers, New Delhi; 1996.
6. ICAR-NBSS & LUP. Field guide for land resource inventory SUJALA-III project, Karnataka, National Bureau of Soil Survey and Land Use planning, Regional centre, Bangalore; 2016.
7. ICAR-Indian Council of Agricultural Research. Hand book of Agricultural (Ed.) New Delhi; 1980.
8. ICAR-NBSS & LUP. Field guide for land resource inventory REWARD Project, Karnataka, National Bureau of Soil Survey and Land Use planning, Regional centre, Bangalore; 2018.
9. Suryawanshi SL, Pathak SV, Pali AK, Das SN. Application of remote sensing and Geographic Information System in Land Capability Classification, Hydrology and watershed management, Himanshu publications, Udaipur. In: Kumar, V, Singh, PK and Purohit, R.C. (ed); 2005.
10. Mishra P, Mazumdar A, Roy D, Ravi Babu R. Land capability class map of an agricultural micro-watershed using GIS. Environment and Ecology. 2006;24(3): 485-489.
11. Mishra P, Ravi Babu R. Simulation of storm sediment yield from an agricultural watershed using remote sensing, GIS and MUSLE. Journal of Soil and Water Conservation. 2009;8(3):12-21.
12. Mary Silpa TJ, Nowshaja PT. Land capability classification of ollukara block panchayat using GIS. Procedia Technology. 2016;24:303-308.
13. Amara DM, Nadaf SA, Saidu DH, Vonu OS, Musa RM, Kamanda PJ, Sawyerr PA, Mboma JC, Mansaray SD, Sannoh MA. Studies on land resource inventory for agricultural land use planning in northern transition zone of India through remote sensing and GIS techniques. Journal of Geographic Information System. 2021; 13(6):710-28.
14. ICAR-NBSS & LUP -National Bureau of Soil Survey and Land Use planning. Proceedings of National Meet on Soil-Site Suitability Criteria for Different Crops. NBSS & LUP Publishing, Nagpur; 1994.
15. Panhalkar S, Mali S, Pawar C. Land capability classification in Hiranyakeshi basin of Maharashtra (India): A Geo-informatics approach. International Journal of Engineering and Technical Research. 2014;2(6):18-21.
16. Girmay G, Sebnie W, Reda Y. Land capability classification and suitability assessment for selected crops in Gateno watershed, Ethiopia. Cogent food and agriculture. 2018;4(1):1532863.

17. Mishra P, Babu RR. GIS based land capability classification of a watershed for land and water resource management. International Journal of Current Microbiology and Applied Sciences. 2021; 10(01):1268-1272.

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