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AN ASSESSMENT OF LAND CAPABILITY AND SUITABILITY: A SUSTAINABLE PLANNING APPROACH FOR THE SINA RIVER BASIN, MAHARASHTRA (INDIA)

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ABSTRACT

Land capability classification serves as a vital method for judicious land use planning, which balances usage and minimizes adverse environmental effects. The Present investigation is associated with assessment of the land potential and suitability of the Sina River Basin using a geospatial approach, combining soil properties, topography, and hydrological variables. An extensive land classification was created through ArcGIS 10.3 using secondary data of IRS P-6 LISS-III satellite imagery, SRTM-DEM elevation models, and soil maps from NBSS & LUP. The results classify the land according to its capabilities (I to VIII), identifying areas that are viable for agriculture, pasture, forests and conservation. Class III, accounting for 49.01% of the study area, is the most extent of arable land, but requires moderate conservation due to soil and slope limitations. Classes IV, VI and VII (36.63% of the land area) is most suited for conservation, grazing or forestry, whereas Class VIII (0.38%) is not fit for any productive use. Finally, the land suitability assessment (LSA) is used to analyze the land use strategies, which categorizes the terrain according to soil depth and slope gradient. The results indicate that 35.35% of the area is very suitable for agricultural use provided adequate soil and water conservation measures are employed, while 53.05% would require measures to be kept productive. Such measures involve adopting more sustainable land management practices including contour plowing, terracing, agroforestry, and afforestation to alleviate soil erosion. The findings of this research reiterate the importance of combining remote sensing and GIS in land capability evaluation for informed decisions in resource management and environmental sustainability. Dynamic land-use modeling to account for variable climate to maximize land use in the long-term should be the focus of future studies. This evidence gives scientific grounds for decision makers and land managers to adopt sustainable strategic planning approaches at the local and regional levels in the Sina River Basin, and also for similar ecosystems worldwide.

Keywords: Geospatial Analysis, Land Capability, Sustainable Land Use, Geoinformatics, Soil Conservation

INTRODUCTION

When utilizing land, assess its potential and suitability. Neglecting land potential may result in environmental challenges that adversely affect the ecosystem. Social health. Effective land use planning necessitates a comprehensive grasp of the opportunities and limitations presented by land resources. Climate and soil play crucial roles in assessing the appropriateness of a location for agricultural practices in any given area. The potential of land is shaped by various soil characteristics, including depth, texture, structure, permeability, pH, electrical conductivity, as well as the underlying geology and physiography. Optimal management of current land resources can enhance advantages while ensuring that future degradation is not compromised. Soil surveys must take into account all characteristics that influence their utilization and management, necessitating interpretations for diverse objectives. The classification of soil into capability units, classes, and subclasses is essential for farmers and land users in developing effective conservation plans.

Land Capability Classification in Sina River Basin

Land classification refers to the categorization of particular land areas based on their attributes or potential for utilization. A system for classifying natural land is one that organizes various land types into categories based on their intrinsic features (Fenton, T. E. 2020).

The land capability classification method categories the entire land into eight distinct classes, ranging from class I to class VIII. The initial four classes are considered appropriate for cultivation based on the level of associated risk, whereas the final four classes are regarded as unsuitable for crop cultivation but are suitable for grazing and forestry activities (Pali, A. K., et. al., 2012). The capability of the land is assessed based on various characteristics, including soil types, which play a crucial role in productivity, as well as fundamental geology, topography, and hydrology. The identified characteristics constrain the availability of land for diverse applications (Girmay, G., et. al., 2018).

Initially, the United States Department of Agriculture (1973) recommended appropriate requirements for Land Capability Classification. The classification progresses through arable land, which is further classified based on its potential and limitations for agricultural crops into four primary categories, ranging from I to IV, and non-arable land into four classes, ranging from V to VIII. The intensity and scope of recommended conservation measures are increasing from Class I to Class IV. The classes V through VIII are not suitable for agriculture; nonetheless, they can be used efficiently for pasture, range, woodland, grazing, and wildlife management. The key parameters that define the classification and subdivision of LCC are topographic elements such as slope or gradient, as well as soil pedological features like as soil depth, texture, permeability, and drainage status, which have been used by many scholars. (USDA 1973).

One of the most significant concerns with regard to the utilization of land in a sustainable manner is the classification of land capabilities. A great number of land capability classifications have been established and implemented, particularly in industrialized nations like the United States of America, the United Kingdom, and France. There is a significant amount of land capability classification methods and maps that are derived from the method utilized by the United States Department of Agriculture. The topography, particularly the inclination of the slope, and the properties of the soil, in general, are the elements that have been taken into consideration up until this point in the land capability classification (Atalay, I. 2016).

The land is a valuable resource that should be used according to its potential. Overexploitation and poor management of natural resources, among other socioeconomic issues, are contributing to the worsening problem of land degradation. However, maintaining agricultural productivity while protecting the environment requires careful management of land resources. Competition for land becomes fiercer as the population keeps growing since land is a limited resource. Land resource planning and management must take into consideration the wide variety of possible uses for any given parcel of land (Panhalkar, S. 2011).

Mountains, rivers, bogs, deserts, islands, and coastal regions are all considered "land" on Earth. Mixture of mineral-rich soil and biological ingredients that enable plants grow on Earth. Environment, terrain, soil, geology, vegetation, water, and human activity shape the land's physical features. Any farmland needs initial improvements and continuing attention. Before planting, the land may need to be cleared, leveled, and laid out. Wind and water can erode it, so keep them away. Extra water or dangerous compounds must be removed from soil. The land capability classification system and watershed management allow this. Effective land use is the first and most significant water and soil conservation principle. Thus, land capacity classification is essential to watershed improvement program creation. (Tamboli, N. M., et. al., 2012).

Land capability must be regarded as a method for achieving the optimal and most effective use of land, which should be accomplished by taking into account a robust overall framework and economic sustainability (Pareta K. et. al., 2013)

Database and Methodology for LCC and LSC

For the present investigation, secondary data have been utilized to create soil characteristic maps. Satellite imagery from the IRS P-6 LISS-III sensor data has been perched from NRSC Hyderabad and SRTM-DEM (30m) elevation data has been acquired from USGS Earth Explorer. the online platforms of NRSC and USGS, specifically the Earth Explorer web data portal. Soil maps for this region have been sourced from the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) in Nagpur, and

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the Soil Grid soil database with a resolution of 250m has been employed for the creation of these soil maps.

Soil depth, texture, the presence of coarse fragments, and slope have been utilized to classify land capability classes. All these thematic maps have been incorporated into ArcGIS 10.3 software. The land capability and suitability map has been successfully prepared.

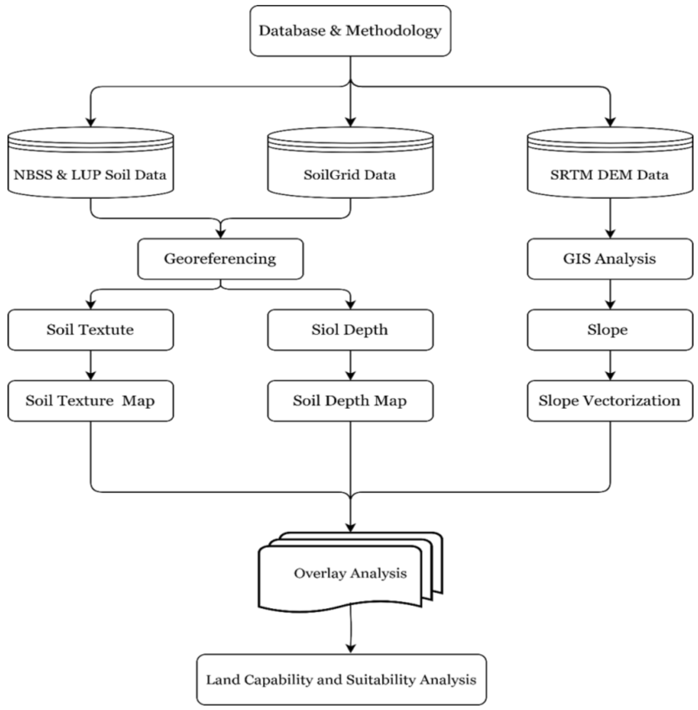

Figure 1.1 Flowchart of Database and Methodology

Result and Discussion on LCC & LSA:

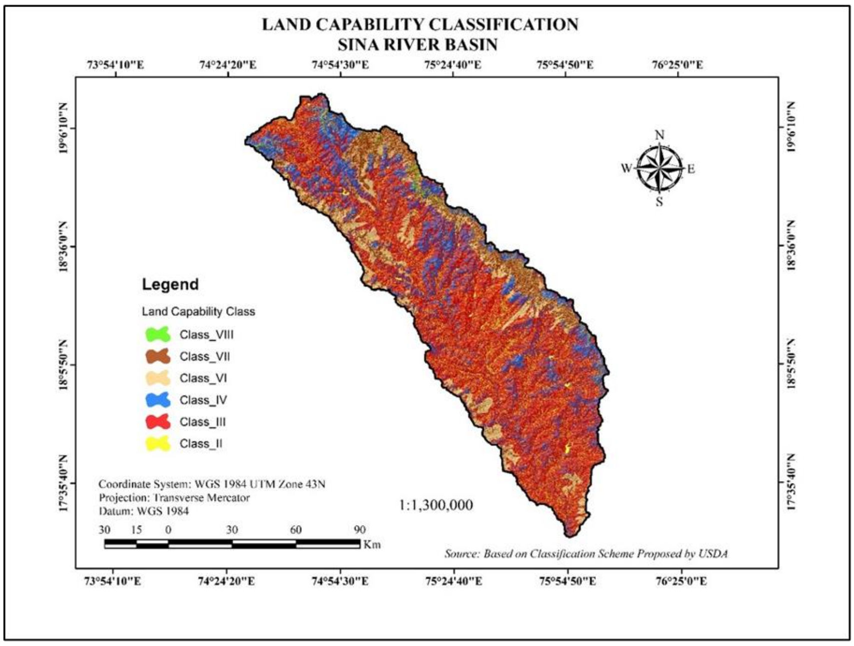

Figure 1.2 Land Capability Classification

Table 1.1 LCC & Planning Strategies in Sina River Basin

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Land Class	Recommended Use	Planning Strategies
Class II	Agriculture with minimal restrictions	Contour farming, crop rotation, and cover crops to protect soil structure.
Class III	Moderate cultivation and grazing	Terracing, vegetative strips, and conservation tillage to prevent erosion.
Class IV	Limited agriculture and grazing	Agroforestry, grass cover, and soil stabilization with check dams and bunds.
Class VI	Grazing and forestry (steeper slopes)	Controlled grazing, tree planting, and soil water conservation structures.
Class VII	Forestry and very limited grazing	Afforestation, pasture, and slope stabilization measures to prevent runoff.
Class VIII	Wildlife habitat and recreation only	Protection from any development, rewilding, and complete forest cover preservation.

Source: *Based on LCC & GIS Analysis*

Table 1.2 Land Capability Classification in Sina River Basin

Land Capability Class	Area in Sq.km	Area in Percentage
Class II	1722.74	13.94
Class III	6056.91	49.01
Class IV	2031.33	16.43
Class VI	1460.42	11.81
Class VII	1037.63	8.39
Class VIII	47.03	0.38
	12356.06	**100**

Source: *Based on GIS Intersect Analysis*

Class II: (13.94%) - Moderate Limitations (1722.74 sq.km): These areas can be farmed, although they might have some small restrictions, like mild erosion hazards, fertility problems, or gentle slopes.

Increased output is possible with the help of management strategies like as fertilization and soil conservation. With the right attention, it's perfect for growing crops.

Class III: with its severe constraints, comprises the vast majority of the land, comprising 6056.91 sq.km (or 49.01 percent of the total land area). Thin soil, steeper slopes, and insufficient drainage are among the problems that significantly limit its cultivability, despite its suitability. Some examples of the intensive management actions that are required are terracing, drainage improvement, and erosion prevention. Perfect for limited cropping or for establishing pastures.

Class IV: (16.43%) - Extremely Limited Areas (2031.33 sq.km): Apt for limited farming or pastures because of extremely limited areas, such as bad soil quality, erosion, or steep slopes. For optimal preservation, utilize with long-term vegetative cover, like bushes or grasses.

Class VI: which accounts for 11.81% of the total, is unfit for farming (1460.42 sq.km) but is good for grazing or tree planting. Included are areas with steep inclines, soils that are prone to erosion, or water that is shallow. Woodlots, wildlife habitats, or low-yielding pastures are all viable options.

Class VII: with an area of 10,37.63 sq. km and an erosion rate of 8.39%, is extremely unfit for agricultural use and can only be used for grazing, trees, or protecting animals. Could be hilly, have bad drainage, or be very rocky. To avoid soil erosion, it is best to keep it in its natural state as vegetation.

Class VIII: (0.38%) - 47.03 sq. km. of non-farm land. The land is completely unfit for farming, grazing, or tree work. These may include deserts, rocky outcrops, or wetland areas. Maintained for the benefit of animals, leisure, or aesthetics.

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Class III, which accounts for 49.01% of the land, is still arable despite the need for moderate to severe conservation measures. Approximately 36.63 percent, comprising Classes IV, VI, and VII, is better suited for conservation, grazing, or forestry than cultivation. There are very few areas that are totally unfit for productive use (0.38%, Class VIII), indicating that there are not many wastelands.

Land Suitability Assessment:

Land suitability analysis (LSA) represents a fundamental component of land use planning (Yu, J., Chen, et. al., 2011). The land suitability study is the classification of observation units based on their appropriateness for a specific activity. The study delineates a region where a suitable site may be located. The explicit site search approach evaluates both site suitability and spatial attributes, including shape, contiguity, and compactness, by aggregating fundamental observational units based on certain criteria. LSA denotes a method or technique employed to ascertain the best spatially suitable configuration for the placement of present and prospective specific land uses (Malczewski, J. 2004).

The classification of land based on its suitability for specific uses, such as agriculture, grassland, and forestry, is a pertinent strategy for the sustainable development of land resources. Consequently, the treatment-oriented land suitability strategy provided by Tideman (1996) has been utilized for this purpose. This land suitability plan is predicated on soil qualities and the topographic gradient of the region, which establishes the foundational basis for land utilization. The strategy has delineated seven primary classes, of which C1, C2, C3, and C4 are deemed cultivable with escalating constraints, while the remaining three classes are not utilized for cultivation. P, FT, and F are denoted as Pasture, Fruit Trees, and Forest, respectively.

Table 1.3 A Treatment Oriented Scheme of Land Suitability

Slope / Soil Depth	Very Gently Sloping	Gently /Moderately Sloping	Moderately /Strongly Sloping	Very Strongly Sloping	Steep	Very Steep
Deep	C1	C2	C3	C4	FT	F
Moderately Deep	C1	C2	C3	C4/P	FT/F	F
Moderate/ Shallow	C1	C2	C3	P	F	F
Very Shallow	C1/P	P	P	P	F	F

Source: *Based on Tideman land Suitability Scheme (1996)*

C1: It is clear that nearly level to gently sloping terrain with deep soil is regarded as most suitable for cultivation, necessitating minimal to no treatment measures such as contour tillage or strip cropping.
C2: This category of cultivation land is defined by its moderately deep soil and a moderate slope. Enhanced conservation strategies are essential for the efficient farming practices that can be implemented with the use of compact machinery like bulldozers and similar equipment.
C3: This parcel of land is characterized by a pronounced slope, with soil depths ranging from deep to shallow. The cultivation practice presents challenges without implementing treatment measures like bench terracing and hillside ditching, which can be effectively executed using small tractors.
C4: This cultivable land exhibits a significant slope and features soil depth that ranges from deep to moderately deep. Manual labor is essential for executing farming practices; additionally, a walking tractor can be utilized

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P: This land is used for pasture and grazing due to its gradient, which ranges from moderately sloping to very strongly sloping, along with shallow to very shallow soil that does not support agricultural practices. Implementing rationalized grazing practices is strongly advised for the preservation of soil health.

FT: The land features a steep slope and possesses deep to moderately deep soil, likely utilized for the cultivation of food or fruit trees. Terracing, along with the establishment of orchards, is implemented alongside contour planting, mulching, and diversion ditching for the purpose of land conservation.

F: The land slope is characterized by very steep gradients, and the soil depth varies from deep to very shallow, which is notably indicated as a factor that could enhance forest development in this region. The land slope varies between 25 degrees and 30 degrees, making it suitable for agro-forestry applications.

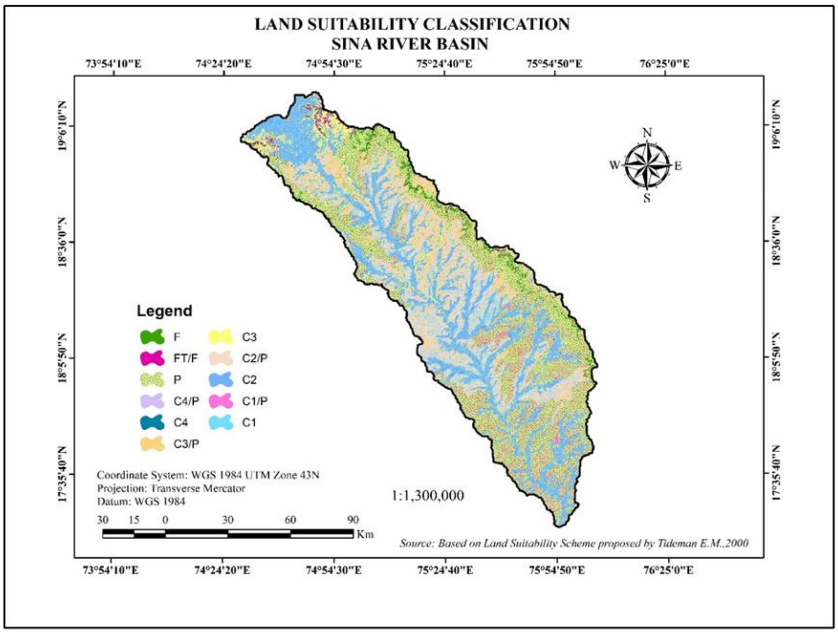

Figure 1.3 Land Suitability Classification

Table 1.4 Land Suitability Classification in Sina River Basin

Soil Depth	Slope Class	Land Suitability Class	Area in sq.km	Area in Percentage
Deep/Moderately Deep	Nearly level Slope	C1	1310.95	10.61
Very Shallow	Nearly level Slope	C1/P	646.02	5.23
Deep/Moderately Deep	Gently Slope	C2	2410.83	19.51
Shallow	Gently Slope	C2/P	2151.45	17.41
Very Shallow/ Extremely Shallow	Gently Slope	P	2330.54	18.86
Deep/Moderately Deep	Moderately/Strong Slope	C3	820.08	6.64
Shallow	Moderately/Strong Slope	C3/P	832.48	6.74
Very Shallow/ Extremely Shallow	Moderately/Strong Slope	P	1240.36	10.04
Deep	Moderately Steep	C4	24.78	0.20
Moderately Deep	Moderately Steep	C4/P	40.74	0.33
Shallow/Very Shallow/Extremely Shallow	Moderately Steep	P	206.49	1.67
Deep/Moderately Deep	Steep	FT/F	46.15	0.37
Shallow	Steep	F	29.82	0.24

Very Shallow/ Extremely shallow	Steep	F	96.75	0.78
Deep/Moderately Deep/Shallow/Very Shallow/Extremely Shallow	Very Steep	F	169.13	1.37
			12356.47	100

Source: *Based on Tideman land Suitability Scheme (1996)*

The C1–C4 classes of deep and moderately deep soils cover a wide range of slopes, from very flat to quite steep. C1–C4 varieties are often more suited for cultivation due to their higher water retention capacity.

Classified as C2/P, C3/P, or P, these soils are shallow to very shallow Because of their low water-holding capacity, which makes them susceptible to runoff and erosion, soils that are found on mild to moderately steep slopes are not ideal for intensive farming. Subterranean Soils (F and P Classes) These soils are prone to flow and erosion and are not suited for farming; they are most common on extremely steep terrain.

Slopes that are almost flat (C1, C1/P): These 15.84 percent of the land is ideal for farming because there is little chance of erosion, but low-lying portions may need drainage management to prevent flooding. Covering around 60.16 percent of the land, gentle to moderate slopes (C2, C2/P, C3, C3/P) are somewhat amenable to farming, but they do necessitate soil conservation measures owing to a considerable erosion risk. Areas with steep or very steep slopes (C4, F) make up 12.64% of the land area these slopes are prone to erosion and would be better used for agroforestry, pasture, or forestry than for traditional farming.

The land that is very suitable for agricultural, with the right soil and water management procedures, makes up about 35.35 percent of the total area. A significant portion of the land, 53.05% to be exact, is classified as either marginally suitable or restricted use, necessitating conservation activities in order to maintain productivity.

Roughly 12.64 percent is considered unsuitable or forested, and this area has to be reforested, conserved ecologically, and to reduce runoff of the study area.

CONCLUSION:

Reduce Runoff and Prevent Drought with Land Use Planning

Contour Plowing: Nearly Level and Gently Sloped Areas (C1, C2) Reduces runoff by slowing water movement across slopes. Crop Rotation and Cover Crops: Enhance soil structure, increase infiltration, and reduce erosion risk.

Terracing or Graded Bunds: Manage water flow and retain moisture in slightly sloping areas. Agroforestry Systems: Integrating trees with crops improves soil stability and reduces runoff. Moderate to Strongly Sloped Areas (C3, C3/P) Strip Cropping: Alternating crop strips with grass or legumes to minimize erosion.

Terracing and Bench Terraces: Essential for reducing slope length and runoff velocity. Grassed Waterways: Direct excess water safely off the land while minimizing erosion. Mulching: Reduces evaporation, improves infiltration, and minimizes surface runoff. Steep and Very Steep Areas (C4, F)

Afforestation and Reforestation: Promote Forest cover to stabilize slopes and reduce runoff. Pasture Development: Establish grassland or grazing areas with perennial grasses to reduce soil loss.

Check Dams and Gully Plugging: Control erosion and retain sediment in highly erodible areas. Conservation Tillage: Minimizes soil disturbance to retain soil moisture and organic matter.

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