ARPN Journal of Agricultural and Biological Science

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LAND CAPABILITY CLASSIFICATION FOR INTEGRATED WATERSHED DEVELOPMENT BY APPLYING REMOTE SENSING AND GIS TECHNIQUES

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ABSTRACT

Land is the most valuable natural resource, which needs to be harnessed according to its potential. Due to over exploitation and mismanagement of natural resources coupled with socio-economic factors, the problem of land degradation is on the rise. Land resource is one of the limited resources. The use of land is not only determined by the user but also by the land capability. The land capability is governed by the different land attributes such as the types of soil, its depth and texture, underlying geology, topography, hydrology, etc. The study region selected for the present study is Dudhganga basin of southern Maharashtra which is facing severe land degradation problems. Here, an attempt has been made to apply RS and GIS for integrated watershed development of the study region. The parameters like slope, soil depth, texture and land use/ land cover are assessed by applying remote sensing and GIS techniques for the land capability classification of Dudhganga basin. Slope analysis has been carried out by using SRTM data. To assess Land use/ land cover conditions, Lands at ETM image of 2006 year is assessed by supervised classification techniques. Finally, Intersect overlay technique of GIS is used to integrate spatial information and to create Land capability classification of the Dudhganga basin. The analysis reveals that Class II, III, IV and VI are present in the study region. Out of that Class II which is much suitable for agriculture accounts 16.30 per cent. Class IV is a dominating class as far the areal extent is concerned with 34.05 per cent. The Class VI is most susceptible to land degradation which accounts for 28.61 per cent.

Keywords: land capability classification, GIS, Intersect overlay technique, supervised classification.

INTRODUCTION

Land is the most valuable natural resource, which needs to be harnessed according to its potential. Due to over exploitation and mismanagement of natural resources coupled with socio-economic factors, the problem of land degradation is on the rise. However, management of land resources is inevitable for both continued agricultural productivity and protection for the environment. Land is a limited resource and with increasing population, the demands for land become more competitive. Any given area of land can have a multitude of potential uses and all may need to be considered in planning and the management of a land resource. Uses of the land to humankind are multi-facet. As a source for primary production system, it serves as a store of water and nutrients required for plants and other living organisms. Land resource is one of limited resources. The use of land is not only determined by the user but also by the land capability. The land capability is governed by the different land attributes such as the types of soil, its depth and texture, underlying geology, topography, hydrology, etc. These attributes limit the extents of land available for various purposes. To get the maximum benefit out of the land, proper use is inevitable. Sustainable development occurs only when management goals and actions are ecologically viable, economically feasible and socially desirable.

The common way of determination of land quality from land characteristics is mainly by assessing and grouping the land types in orders and classes according to their aptitude. The order of suitability ranges from suitable, that characterizes a land were sustainable use and will give good benefits to not suitable which indicates a land qualities do not allow the considered type of use, or are not enough for sustainable outcomes (IAO, 2003). Land capability is the basis of sustainable watershed development. The basic principle of soil and water conservation is to use the land according to its capability and treat the land according to its needs. Land capability classification indicates the hazards of soil and water erosion, water logging, land degradation etc. and these hazards limit the use of land for particular purposes only.

United States Department of Agriculture (1973) has provided specific guidelines for Land Capability Classification. Here, for the present study USDA's LCC system has been adopted which includes eight classes of land designated by Roman numerals from I to VIII. The first four classes are suitable for agriculture in which the limitation on their use and necessity of conservation measures requires a careful management increase from I to IV. The remaining four classes, V to VIII, are not to be used for agriculture, but may have uses for pasture, range, woodland, grazing and wildlife purposes. The criteria for placing a given area in a particular class involve the landscape location, slope of the field, depth; texture and land use /land cover (Tide man, 1990). Thus, the capability units are groupings of soils that have common responses to pasture and crop plants under similar systems of farming. Ekanayake, G. *et al.*, (2003) has also made an attempt to identify land suitability by applying GIS technique for forest.

ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science
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Study region

The region selected for the present study is Dudhganga basin of Kolhapur district (Figure-1). This basin drains south western part of Radhanagri, northern part of Kagal and southern part of Karveer tahsil of Kolhapur district comprising eighty villages. It is located between 16° 7' to 16° 37' north latitudes and 73° 53' to 74° 20' east longitudes. The region has diversified physiography, whose western border is demarcated by Western Ghats. The soil vary from laterite patches in the west to deep medium black alluvial of the river tracts in the central part and poor grey soil in the east. The monsoon climate dominates the region. The region receives rainfall mainly from south west monsoon, ranging between 3700 mm in the west to 1000 mm in the east. The total area of the study region is 528.49 sq. km.

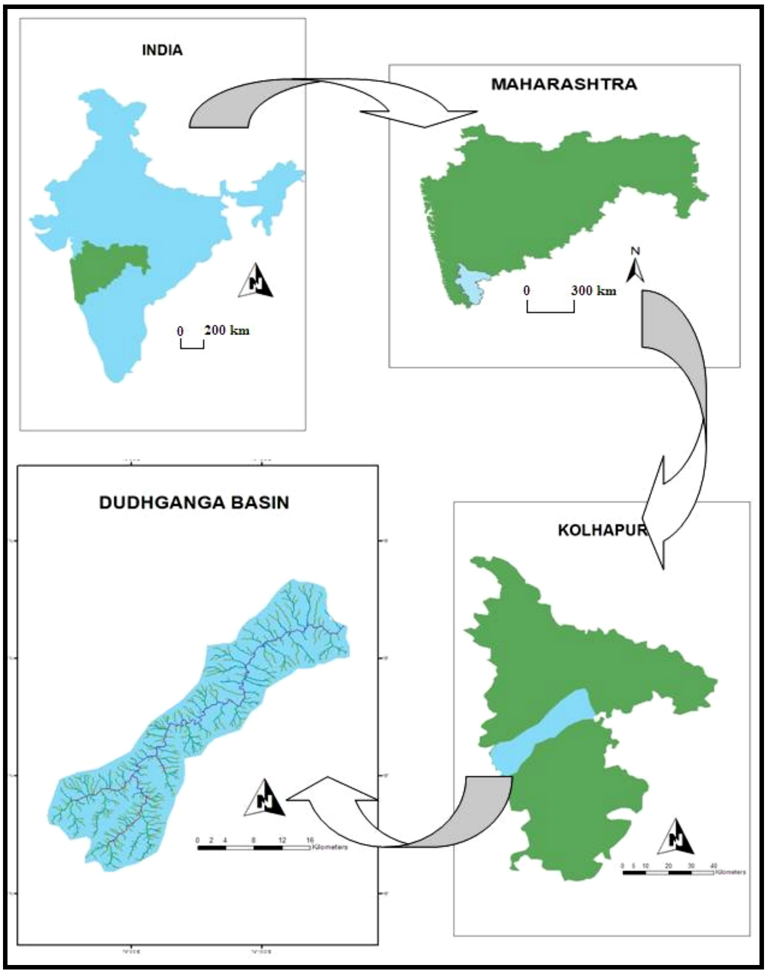

Figure-1. Study region.

MATERIALS AND METHODS

The generalized methodology for LCC using GIS is depicted in the form of a flow chart (Figure-2). The geospatial techniques help in generation of a reliable spatial and non-spatial information database.

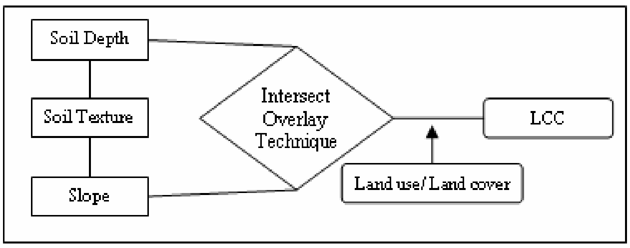

Figure-2. Methodology to derive LCC.

Such a database helps immensely in the efficient and scientific decision-making. It is clear from Figure-2 that the procedure essentially consists of 2 stages. (i) To map the controlling and indicative parameters with the existing information and (ii) integration of the controlling and indicative parameter layers digitally through GIS. The land capability classification has been carried out by applying parameters like soil depth, soil texture, land use /land cover and slope of land. This information is used as a basis for placing lands in capability classes and subclasses. The information related with soil depth and soil texture about study region has been used from National bureau and soil survey and land use planning (NBSS and LUP) and thematic maps of the study region (Figures 4 and 5) are created in Arc GIS 9.0 software. Shuttle Radar Topographic Mission (SRTM) data of the study region is

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used to assess the terrain conditions. 90m data is resampled to 30m by using 3D surfacing utility of Erdas 9.0 software to get better accuracy. Landsat ETM image was used to assess the land use/land cover categories by applying Supervised Classification technique. Here, the advance navigation technique like GPS has been used to collect training site data and to field check classified datasets. These parameters are integrated in GIS environment by using intersect overlay technique. Moreover the surface and overlay analysis capabilities in GIS can effectively facilitate in handling vast amount of spatial information (Ekanayaki and Dayawansa, 2003). The Intersect tool calculates the geometric intersection of input feature classes. The features or portion of features that are common to (intersect) all inputs will be written to the output feature class (Final LCC map).

RESULTS AND DISCUSSIONS

For LCC, slope, soil depth/ texture and land use/ land cover conditions are assessed in remote sensing and GIS environment. As these parameters have greater influence on capability of land.

Slope

Slope is a basic element for analyzing and visualizing landform characteristics. It is important in studies of watershed units, landscape units, and morphometric measures (Moore *et al*., 1992). When used with other variables slope can assist in runoff calculation, forest inventory estimates, soil erosion, wild life habitat suitability and site analysis (Wilson and Gallant, 2000). Slope is a very crucial element for LCC.

Slope analysis (Figure-3) reveals that gradient is highest in south western part and middle hilly areas and lowest gradient can be observed at the lower end of Dudhganga River towards north eastern part of the basin.

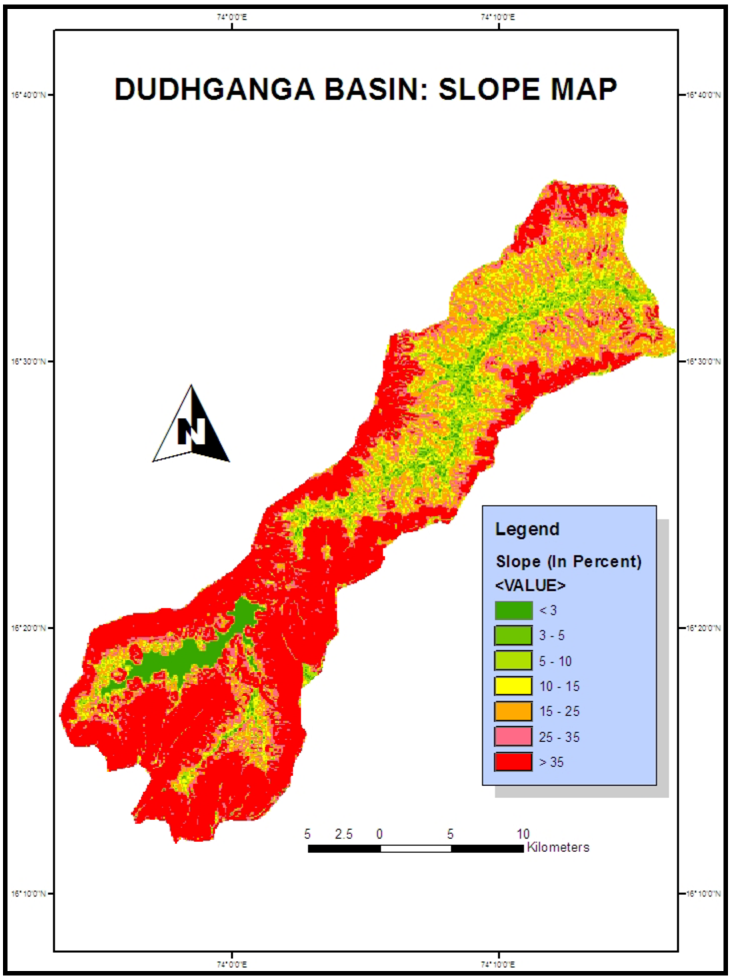

Figure-3

Soil

Soil is an important segment of our ecosystem, as it serves as an anchorage for plant and source of nutrients. Thus soil is the fundamental raw material for plant growth. The knowledge of soil resources is essential for proper watershed development and planning. Analysis of depth and texture of soil resources is very much crucial for land capability analysis and further suggesting treatment

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measures within a watershed. Soil depth (Figure-4) varies widely within Dudhganga basin.

Towards the north eastern part and along the river side, soil depth is deep as compare to south western part of Radhanagri tahsil which is shallow one. It might be a result of undulating and a rugged topography. Moderate soil depth has been observed along the piedmont plateau and plain areas of Dudhganga watershed which is lying in between shallow and deep. The texture analysis (Figure-5) reveals that basically fine and medium texture dominates the study region. The south western hilly area of Radhanagri tahsil is of medium texture and middle as well as north eastern plain areas of Kagal tahsil are of medium texture.

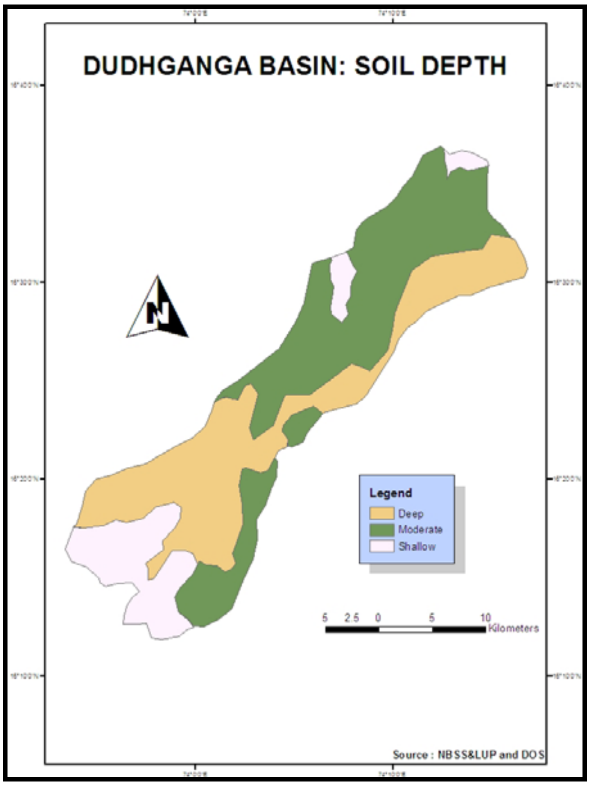

Figure-4

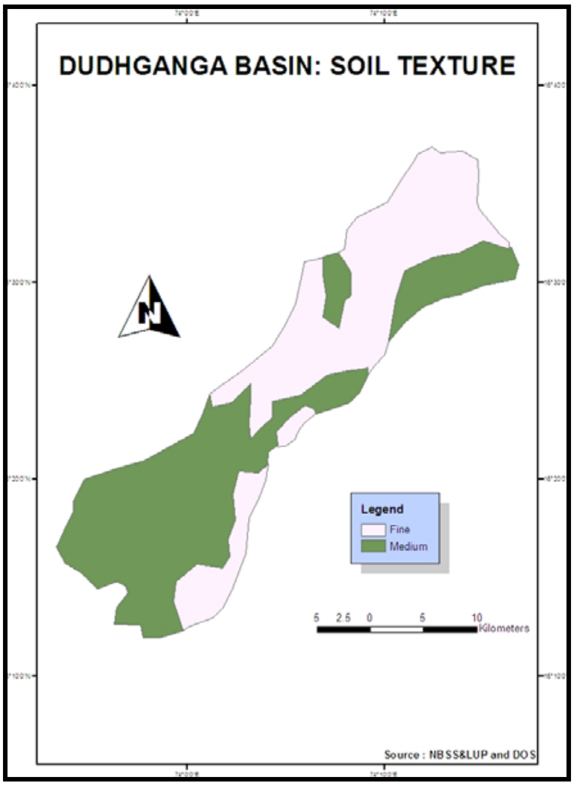

Figure-5

Land use/ land cover analysis

Knowledge of land use/land cover is prerequisite, for many planning and management activities. It is considered as an essential element for modeling and understanding the earth as a system. In order to classify land capability, it is necessary to have information on existing land use/land cover. The term land cover relates to the type of feature present on the surface of the earth and land use relates to the human activity. The study was carried out by using Landsat ETM of 14th February, 2006. Satellite images were rectified by using the SOI toposheet and further resampled by using bicubic convolution method to perform radiometric and geometric corrections.

To enhance the spatial resolution of imagery, panchromatic dataset of same sensor is used to enhance spatial resolution of Land sat ETM image by applying merge technique. Watershed boundaries were digitized and the image under the boundary extracted using the digitized boundary polygon as the mask (subset image). Field survey was performed throughout the study area using Global Positioning System (GPS). This survey was performed in order to obtain accurate location point data for each LULC class included in the classification scheme as well as for the creation of training sites and for signature generation. The satellite data was classified using supervised classification technique. Using the confusion matrix method, the accuracy of the training sets was evaluated. This method is useful to evaluate signatures that have been created from areas of interest (AOIs) in the image. Confusion matrix (Table-1) shows about 85% accuracy for supervised Land sat ETM image. Supervised classification technique classifies only the pixels in the image AOI training samples, based on the signatures. A maximum likelihood algorithm was used for better accuracy. This algorithm evaluates both the variance and covariance of the category spectral response pattern while classifying an unknown pixel. This algorithm assumes Gaussian (normal) distribution and each pixel is considered as a separate entity, independent of neighbors. Using multivariate sample mean vector and interband variance co-variance matrix, the probability of every pixel was calculated for each class and the pixels were assigned to that class which had the highest probability. GPS is again used here to verify and correct the classified LULC map with ground realities.

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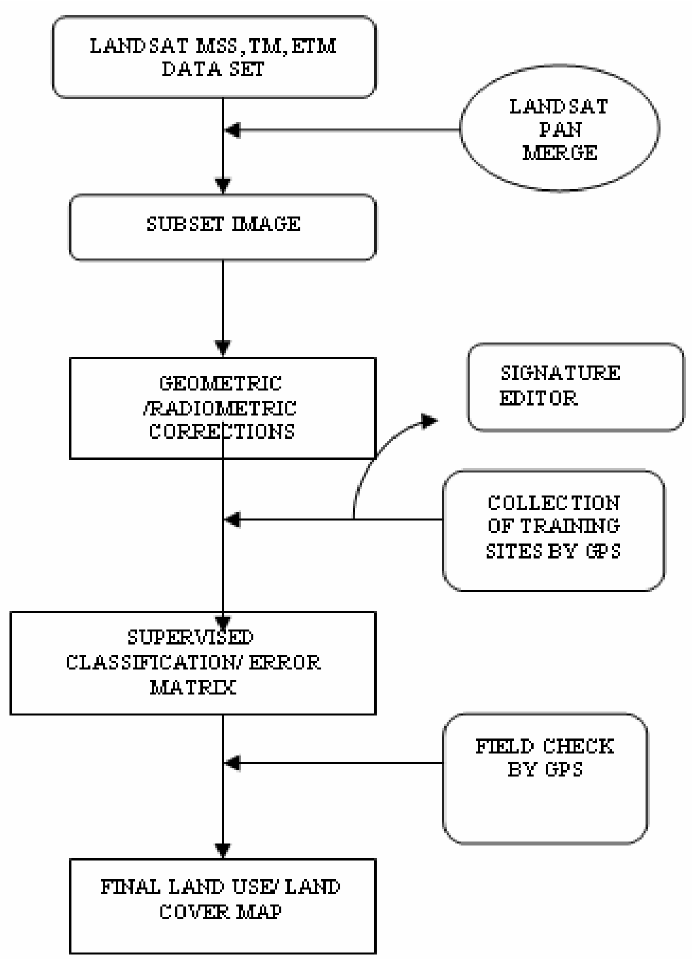

Figure-6

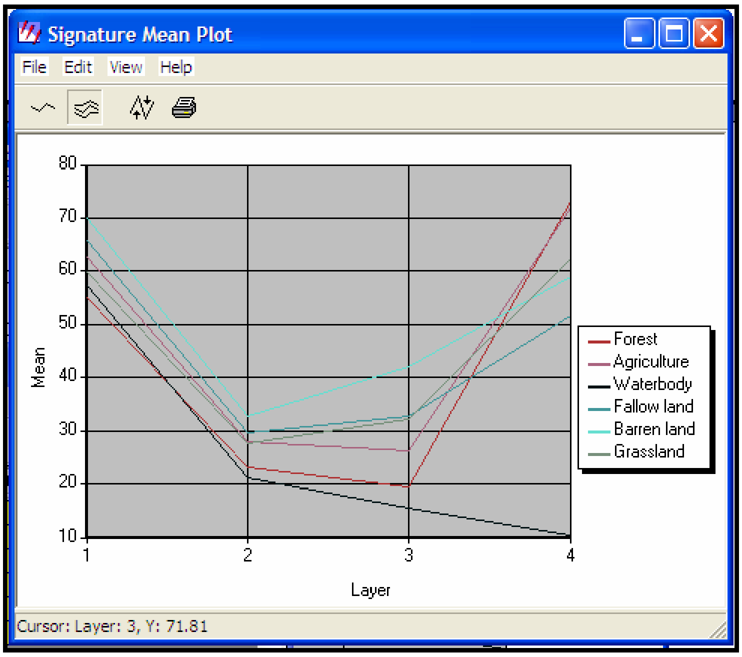

Figure-7

VOL. 6, NO. 4, APRIL 2011 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science
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The classification scheme has utilized six land use/land cover classes representing forest, agriculture, fallow land, barren land, grassland and water body.

According to supervised classified images (Figure-8), six classes were identified and the changes in land use /land cover are included in Table-2.

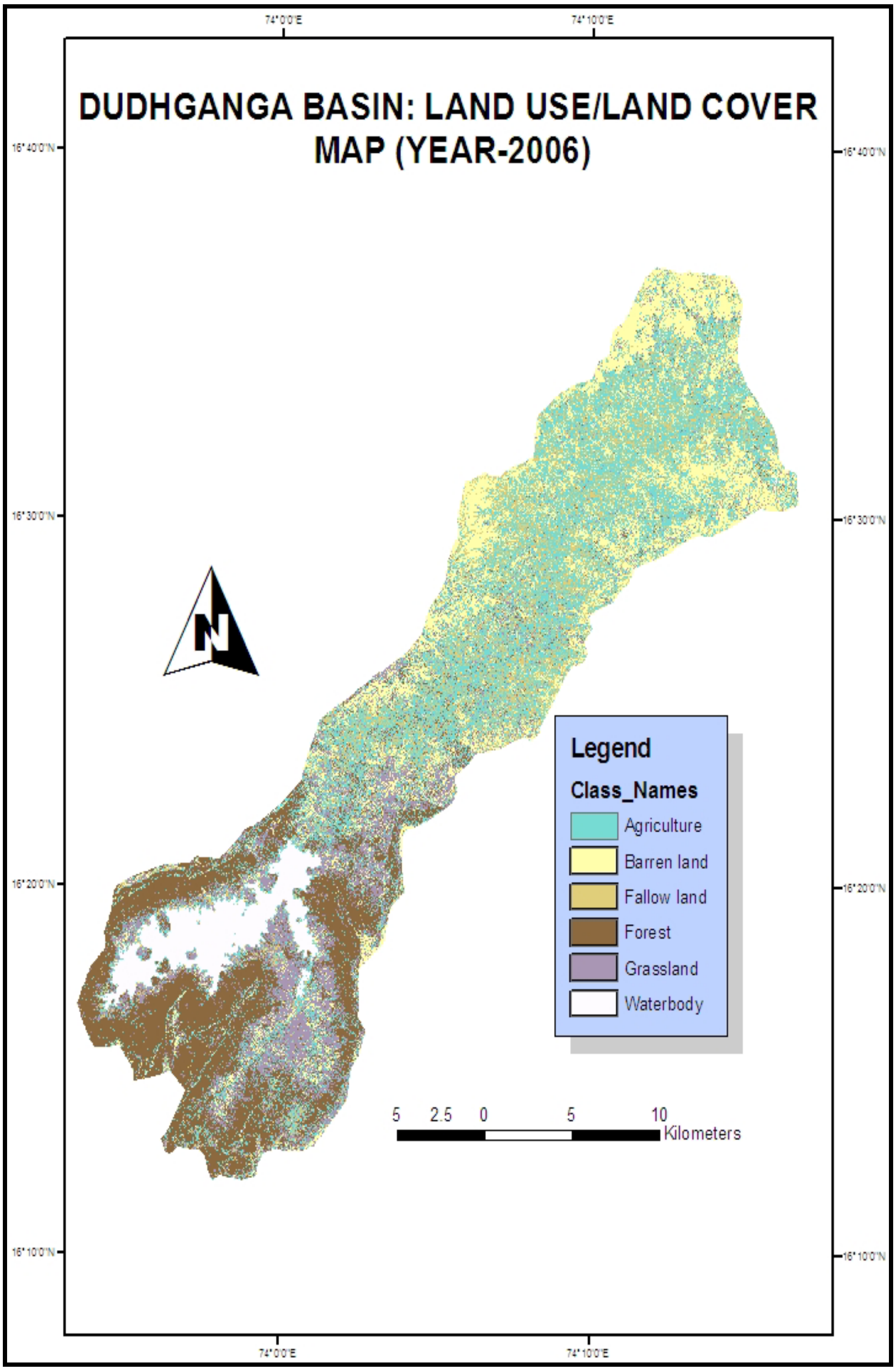

Figure-8

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Table-1. Error matrix of landsat ETM image.

Classified data	Forest	Agriculture	Barren land	Water body	Grass land	Fallow land	Row total
Forest	95.57	2.45	0.03	0.1	1.87	0.08	100
Agriculture	2.45	63.69	3.28	0.57	5.55	24.46	100
Barren land	0.03	3.28	94.14	0	0.78	1.77	100
Water body	0	0.57	0.1	99.33	0	0	100
Grass land	1.87	5.55	0.78	0	88.64	3.16	100
Fallow land	0.08	24.46	1.77	0	3.16	70.53	100
Column total	100	100	100	100	100	100	600

In the year 2006, out of the total geographical area of the basin, about 36.2 % was under cultivation (Net sown area and fallow land).The area under fallow land was 15.7 per cent. The lower reaches of Dudhganga basin is having high proportion of sown area and low proportion of fallow land and the vise versa situation is observed in the upper reaches of south western high altitude areas of the basin. The south western part of the region is dominated by Western Ghats. Forest and grassland cover play a very vital role in land and water conservation. It indicates that the natural resources of this basin are not sustainably managed as the actual dense forest remaining now is about 22.5 per cent only. Forest cover is generally observed in southwestern part of Dudhganga basin which is undulating and hilly area. The share of barren land is about 16.3 per cent**.** High proportion of this category is basically confined to hilly and plateau areas of Karveer tahsil and north eastern part of Kagal tahsil. The proportion of water bodies, which includes dam, tank and rivers account for 6.8 per cent.

Table-2. Land use/ land cover analysis.

Class name	Year 2006	
	Area in hectares	Area in hectares
Grass land	9494	17.90
Fallow land	8300	15.80
Barren land	8661	16.40
Forest	11930	22.60
Water bodies	3614	6.80
Agricultural fields(Sown area)	10850	20.50
Total	**52849**	**100**

Land capability classes

"Land capability" classifications provide a ranking of the capacity of each part of a land resource to sustain broad land use classes (Rosser, *et al*., 1974). However, four main LCC classes have been identified by considering the above mentioned parameters. Those are II, III, IV and VI.

a) Class II

The analysis reveals that class II can be seen along the Dudhganga River. This class is limited as compare to other classes. This class covers 86.05 sq. km area (16.30 %) which is dominated by gentle slope. In Dudhganga watershed, this class is identified as most suitable for agricultural crop production. Soils in this class require careful soil management, including conservation practices, to prevent deterioration or to improve air and water relations when the soils are cultivated.

Table-3. Areal extent of land capability classification.

S. No.	LCC class	Area (km^2)	Area (In per cent)
1	II	86.05	16.30
2	III	111.21	21.04
3	IV	180	34.05
4	VI	151.23	28.61
Total		**528.49**	**100**

Source: Compiled and computed by researcher

The soils may be used for cultivated crops. The soils in this class provide the farm operator less latitude in the choice of either crops or management practices than soils in class I. The limitations are few and the practices are easy to apply for this class.

b) Class III

This class is extended between class II and IV. Its spatial extent is much more in lower reaches of Dudhganga basin as compare to upper reaches. The total area covered by this class is about 111.21 sq. km (21.04 %). Soils in class III have more restrictions than those in class II and when used for cultivated crops, the conservation practices are usually more difficult to apply and to maintain.
Limitations of soils in class III restrict the amount of clean cultivation; timing of planting, tillage, choice of crops and harvesting.

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c) Class IV

This is a dominant class with respect to areal extent in the study region, which accounts for 180 sq. km (34.05 %). The restrictions in use for soils in class IV are greater than those in class III and the choice of plants is more limited. When these soils are cultivated, more careful management is required and conservation practices are more difficult to apply and maintain. Soils in class IV may be used for crops, pasture, woodland, range or wildlife food and cover.

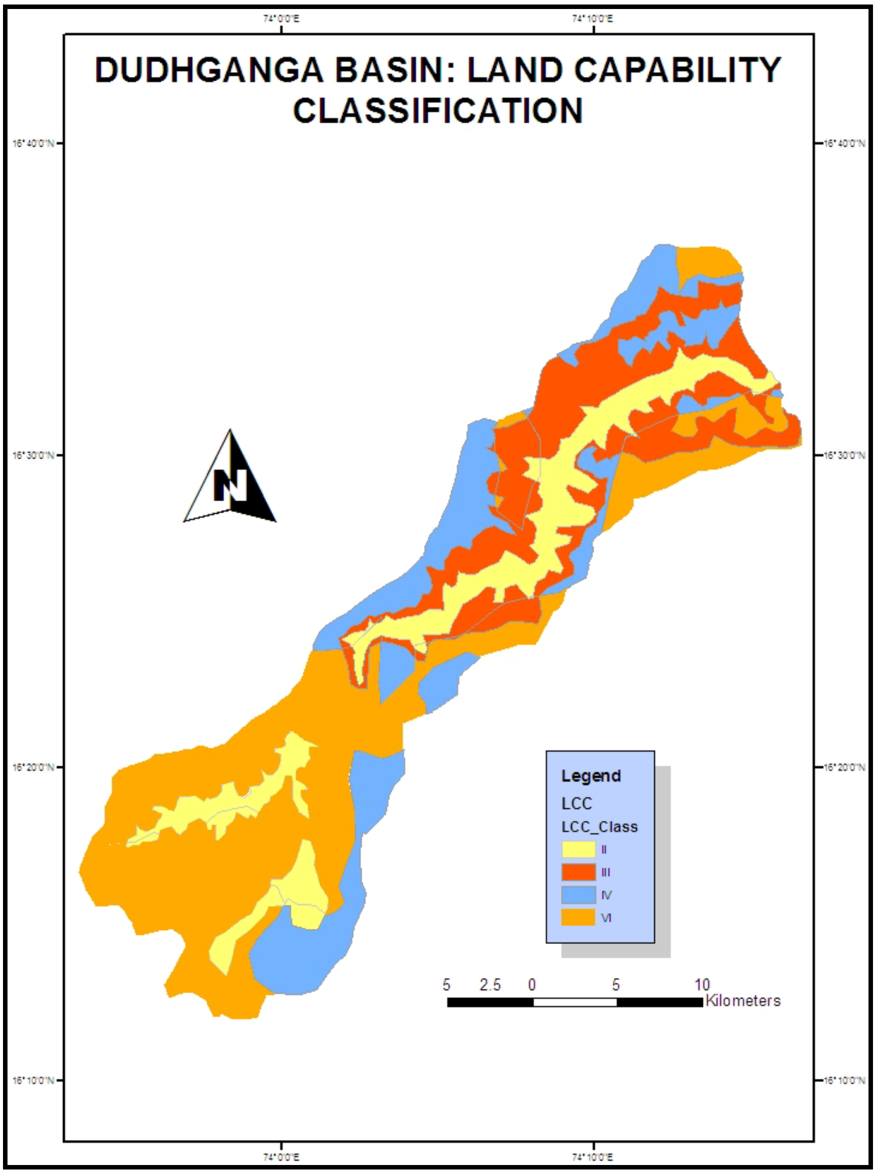

Figure-9

Soils in class IV are well suited to only two or three of the common crops or the harvest produced may be low in relation to inputs over a long period of time.Many sloping soils in class IV are suited to occasional but not regular cultivation.

d) Class VI

This class ranks second in the study region as it covers area about 151.23 sq. km. The analysis reveals that in upper reaches of Dudhganga River towards south western side this class mainly dominates. Physical conditions of soils placed in class VI are such that it is practical to apply range or pasture improvements, if needed, such as seeding, liming, fertilizing, and water control with contour furrows, drainage ditches, diversions or water spreaders.

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Table-4. Details of land capability classification.

Id	Soil_depth	Soil_texture	Slope_class	LCC_subclass	LCC_class
0	Deep	Fine	Strong	IV	IV
1	Deep	Fine	Strong	IV	IV
2	Deep	Fine	Moderate	III	III
3	Deep	Fine	Moderate	III	III
4	Deep	Fine	Gentle	II	II
5	Deep	Fine	Strong	IV	IV
6	Deep	Fine	Strong	IV	IV
7	Deep	Fine	Strong	IV	IV
8	Deep	Fine	Gentle	II	II
9	Deep	Fine	Strong	IV	IV
10	Shallow	Medium	Gentle	II	II
11	Shallow	Medium	Gentle	IIs_{1*}	II
12	Shallow	Medium	Steep	VIe_{3*}	VI
13	Shallow	Medium	Steep	VIe_3	VI
14	Shallow	Medium	Moderate	$IIIs_1$	III
15	Shallow	Medium	Gentle	IIs_1	II
16	Shallow	Fine	Steep	VIe_3	VI
17	Moderate	Medium	Steep	VI	VI
18	Moderate	Medium	Moderate	$IIIs_1$	III
19	Moderate	Medium	Gentle	IIs_1	II
20	Moderate	Medium	Steep	VI	VI
21	Moderate	Medium	Gentle	II	II
22	Moderate	Medium	Gentle	IIs_1	II
23	Moderate	Medium	Steep	VI	VI
24	Moderate	Medium	Moderate	$IIIs_1$	III
25	Moderate	Medium	Moderate	$IIIs_1$	III
26	Moderate	Medium	Gentle	IIs_1	II
27	Deep	Fine	Strong	IV	IV
28	Shallow	Medium	Steep	VIe_3	VI
29	Deep	Fine	Moderate	III	III
30	Shallow	Medium	Moderate	$IIIs_1$	III
31	Deep	Fine	Strong	IV	IV
32	Moderate	Medium	Steep	VI	VI
33	Deep	Fine	Moderate	III	III
34	Moderate	Medium	Moderate	$IIIs_1$	III
35	Deep	Fine	Gentle	II	II
36	Moderate	Medium	Gentle	IIs_1	II
37	Deep	Fine	Strong	IV	IV
38	Moderate	Medium	Steep	VI	VI

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39	Deep	Fine	Strong	IV	IV
40	Moderate	Medium	Steep	VI	VI
41	Deep	Fine	Moderate	III	III
42	Moderate	Medium	Moderate	$IIIs_1$	III
43	Deep	Fine	Moderate	III	III
44	Moderate	Medium	Moderate	$IIIs_1$	III
45	Deep	Fine	Gentle	II	II
46	Moderate	Medium	Gentle	IIs_1	II
47	Deep	Fine	Strong	IV	IV
48	Shallow	Medium	Steep	VIe_3	VI
49	Deep	Fine	Strong	IV	IV
50	Moderate	Medium	Steep	VI	VI
51	Shallow	Medium	Steep	VIe_3	VI
52	Moderate	Medium	Steep	VI	VI

Source: Compiled and computed by researcher
*s_1- Limitations of effective soil depth, e_3- Severe erosion.

CONCLUSIONS

The methodology premissed here to indicate land capability classes for decision-making intervention. The analysis reveals that Class II, III, IV and VI are present in the study region. Out of that Class II which is much suitable for agriculture accounts 16.30 per cent. Class IV is a dominating class as far as the areal extent is concerned with 34.05 per cent. The Class VI is most susceptible to land degradation which accounts for 28.61 per cent. Integrated watershed development should be planned by considering land capability classification of Dudhganga basin.

REFERENCES

Ekanayake G.K. and Dayawansa N. D. K. 2003. Land Suitability Identification for a Production Forest through GIS Technique. http://www.gisdevelopment.net/application/environment/overview/mi03148.html

Environamental System Research Institute. 1988. User Guide ARC INFO. The Geographical Information System Software (Redlands. CA. USA: ESRI Inc.).

International Agricultural Organisation. 2003. Land Evaluation in the Province of Thies, Senegal. http://www.iao.florence.it/training/thies/senegal_23linked p. 11. html.

Moore I.D. and J.P. Wilson. 1992. Length-slope factors for the revised universal soil loss equation: simplified method of estimation. Journal of Soil and Water Conservation. 47(5): 423-428.

National Bureau of Soil Survey and Land Use Planning. 2005. Soil Resource Mapping Project. National Bureau of Soil Survey and Land Use Planning (NBSS and LUP and DOS), Nagpur.

Rajora R. 1998. Integrated Watershed Management. Rawat Publications, New Delhi and Jaipur.

Ramamoorthi 1991. IRS 1A Applications in Hydrology and Water Resources. Journal of Current Sci. 61 (3-4): 180-189.

Rosser J., Swartz G. L., Dawson N.M. and H. S. Briggs. 1974. A Land Capability Classification for Agricultural Purposes. Div. Land Utilization. Tech. Rep. p. 14.

Tideman E.M. 2000. Watershed Management - Guidelines for Indian Conditions. Omega Scientific Publishers, New Delhi.

United States Department of Agriculture. 1973. Soil Conservation Service, Land Capability Classification, Agriculture Handbook No. 210.

Wilson J. P. and J. C. Gallant. 2000. Terrain Analysis: Principles and Applications. John Wiley and Sons, New York. pp. 87-131.