National Seminar on
Applications of Geoinformatics in National Development
(29th & 30th Nov. 2010)
Department of Applied Geology
Dr. H. S. Gour Central University, Sagar

Dr. Rajendra K. Rawat,
Director & Org. Secretary,

Subject: Acceptance of abstract of research paper.

Dear Author(s),

I am pleased to inform you that your abstract of research paper **Land Capability based Sustainable Development and Management in Sonar Basin - a Case Study** -has been reviewed and accepted for publication in abstract-cum- souvenir volume

The acceptance of Abstract paper and its publication is subject to the following:

1) Full matter not move than 8-10 pages neatly typed on A-4 size paper (two copies) in 1.5 spacing (in MS-Word, Time New Roman font) with appropriate margins on all sides, for direct inclusion in Proceeding volume should reach to Director & Org.Sec.before 15th Nov. 2010.

2) The paper should be presented by the author/co-author in the Seminar.

3) Registration fee along with revised abstract/paper should reach on/before 10th Nov. 2010.

You are requested to submit your research paper along with CD (an advance copy through email) before presentation during the seminar.

Your cooperation is solicited.

Yours sincerely,

R.K. Rawat

(R. K.Rawat)

thomas_nih@yahoo.com

LAND CAPABILITY BASED SUSTAINABLE DEVELOPMENT AND MANAGEMENT IN SONAR BASIN - A CASE STUDY

T. Thomas[1*], R.K. Jaiswal[1], R.V. Galkate[1], N. C. Ghosh[2] & S. Singh[2]

[1]Scientist, National Institute of Hydrology, GPSRC, Manorama Colony, Sagar (M.P.)
[2]Scientist, National Institute of Hydrology, Jal Vigyan Bhavan, Roorkee (Uttarakhand)
*e-mail: thomas_nih@yahoo.com

ABSTRACT

Sustainable development occurs only when management goals and actions are ecologically viable, economically feasible and socially desirable. The ever increasing human and livestock population is continually exerting pressure on the natural resources whereby the consumption of natural resources is more than the natural regeneration capacity. This has led to various environmental issues like massive deforestation, accelerated rate of soil erosion, productivity decline, depletion of groundwater and other such resource degradation issues have been on the rise. Rapidly deteriorating natural resources emphasizes the urgent need for effective resource management approaches integrating resource conservation and resource development. The integrated basin development approach is an effective mechanism for efficient management of local resources and the key for sustainable development in the region. This approach plays a significant role in increasing the productivity of the resources.

The land capability classification serves as the basic information and tool for preparation of management plan for a basin. As soil and water are the two important natural resources in the basin, an integrated approach for sustainable development of the basin should be envisaged, and management plan prepared considering the land capability of each unit of soil with proper conservation measures based on the limitation of soil. A highly degraded sub-basin of Sonar basin with high rate of soil erosion, undulating topography, low ground water availability, soil depth limitation and considerable barren area is selected for the study. Using land capability classification, an effective sustainable management plan has been prepared, in which land use changes have been suggested according to the land capability. For determination of land capability classes detailed surveys for soil type distribution, soil depth classes, erosion classes, slope classes and permeability classes have been conducted in the study area and maps generated in ILWIS 3.0 – a GIS software. All maps have been integrated and suitable capability class assigned according to standard rating tables and suggested guidelines. Based on the land capability classification, the study area comprises of eleven land capability classes with about 82% area falling in classes II to IV and remaining 18% area falling in classes V to VII. The maximum area of 762.21 hectares falls in IVes class. A modified land use pattern has been suggested for the study area based on the land capability classification.

KEYWORDS: *GIS, Land capability, Sustainable development, Resource management, Soil potential, Soil Limitations*

1.0 INTRODUCTION

The balance between the economic viability and destruction of a region due to massive degradation often depends on how well the land resource base is managed. The concept of land capability is useful because it is a composite assessment of land and soil, which incorporates the key physical characteristics that limit sustainable land management. The basic principle of soil and water conservation is to use the land according to its capability and treat it according to its limitations. The land capability classification indicates the hazards of soil and water erosion and difficulties to be encountered in land use, involves the most intensive, profitable and safe use on available land, provides technical data and indicators for application to land use planning, and enables the cultivators to make the use of techniques and inputs available to each class of land. Such an approach is simple and logical, and has been applied widely (Klingebiel and Montgomery, 1961; USDA, 2000; CLI, 1965; Bibby et al., 1991). To prevent and reverse further land degradation, sustainable land management is crucial to minimizing land degradation, rehabilitating degraded areas and ensuring the optimal use of land resources for the benefit of present and future generations. Sustainable agriculture would be achieved if lands are categorized and utilized based on their different use such that the land is not degraded and is used according to its capacity to satisfy human needs for present and future generations.

Tegene (2003) suggested a framework for soil conservation planning by combining land capability evaluation, geographic information systems (GIS) and indigenous conservation technologies for use in a agricultural micro-watershed in Northern Ethiopia highlands. Esther et. al. (2004) used GIS for land capability evaluation in a part of Sahaspur block of Dehradun district, in Uttaranchal state of India and classified the study area into six major land capability classes (II, III, IV, VI, VII, VIII). Sinclair & Dobos (2006) demonstrated the application of land capability classification for development of guidelines for evaluating the quality of soil reclamation after surface mining for coal and compared the capability of the reclaimed soils with the pre-mined soils for producing crops.

Oluwatosin et. al. (2006) carried out the land capability classification and soil quality assessment in Nigeria based on the USDA land capability classification and Multiple Variable Indicator Transform technique for soil quality assessment and found that the soils range from medium to high quality for crop production and land capability ranged from II – VI, indicating fairly good value for arable use, with limitations of low fertility, high gravel content and shallow soil depth. Ahmed et. al. (2010) identified the major classes and sub-classes along with the growing period for Guila Abena watershed in Ethiopia. Bobade et. al. (2010) conducted a land evaluation study for agricultural planning in Seoni district of Madhya Pradesh based on the soil survey data within a GIS framework and interpreted the land use suitability and fertility assessment. Kushwaha et. al. (2010) demonstrated the application of remote sensing, GIS and GPS for preparation of sustainable land and water resources development action plans for Pathri Rao sub-watershed in Haridwar district of Uttarakhand. A set of decision rules were applied and data layers integrated in GIS environment for preparation of the scientific and sustainable land and water resources development action plans.

2.0 THE STUDY AREA

The study area falls in the Sonar basin of the Ken river system and is located in Kesli block of Sagar district in Madhya Pradesh covering a catchment area of 2391 ha. The sub-basin is located between latitudes 23° 23′ 25″ and 23° 27′ 05″ N and longitude 78° 42′ 30″ and 78° 46′ 39″ E. The index map of the study area is given in Fig. 1. River Chamak Dhol, which traverses 11.50 km within the sub-basin, is one of the main tributaries of river Sonar and joins near Berar Veeran. The climate is semi-arid and the average annual rainfall is about 1182 mm; 90% of which occurs during the monsoon period (June through October). The topography of the study area is highly undulating comprising of steep hills with dense forests on ridges and few barren flat top hillocks. The geology comprises of basaltic formations and boulder-strewn plains are commonly seen in the basin. Red soils mostly on the hills and black soils in the agricultural fields, mostly located near foothills, valley, and riverbanks form the general soil textures of the basin.

3.0 METHODOLOGY

For determination of land capability classification, the land is classified into various capability classes according to classification criteria as given.

3.1 Land Use Suitability classification

The major land utilization groups designated in the basin may be forest *(F)*, pasture and range (P), crop land for annual and perennial crops *(C)*, upland *(U)*, low land /level lands (L_o), and waste lands *(W)*. The main two orders of land suitability include: *[S]* - land found suitable

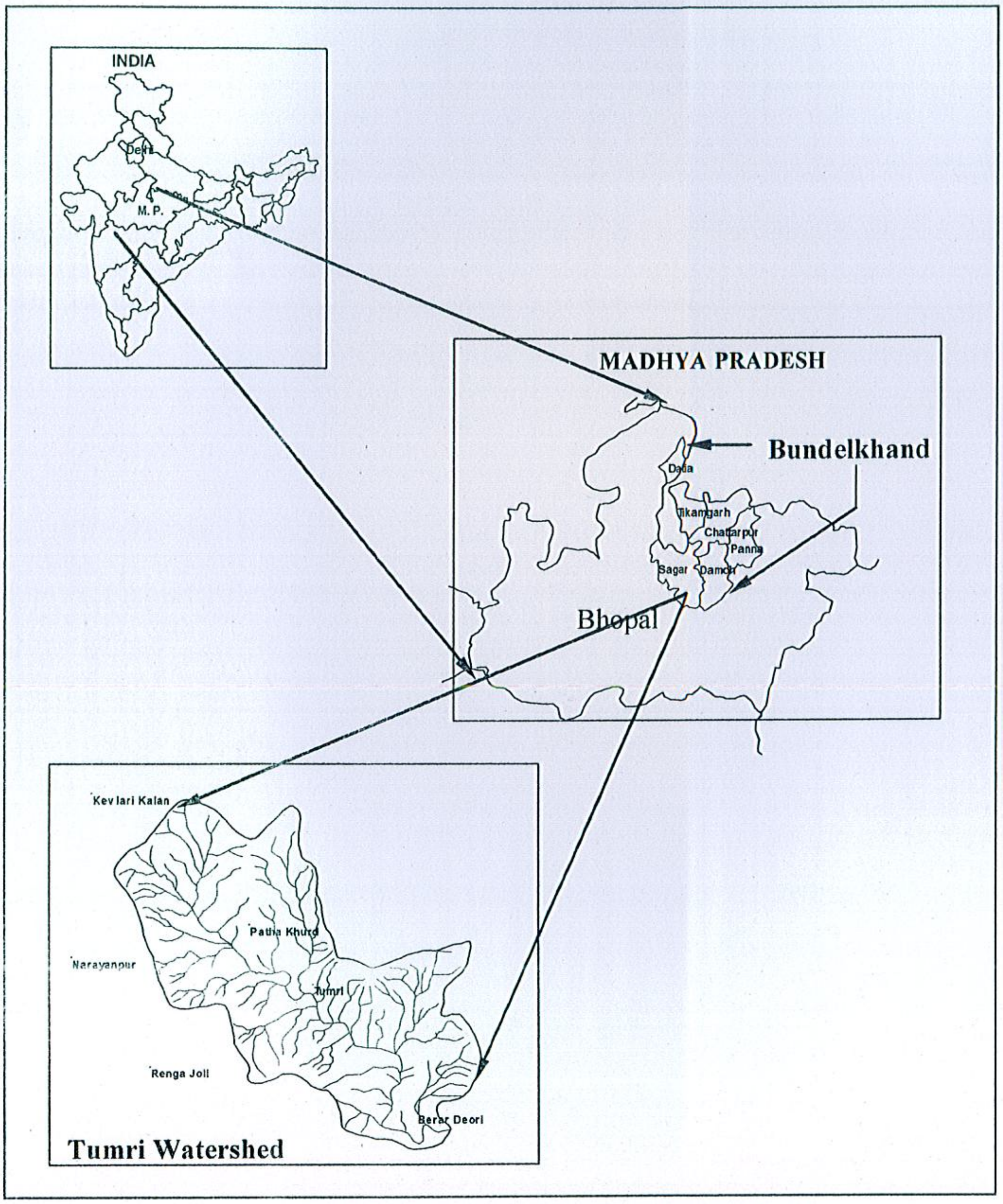

Fig 1: Index map of the Tumri watershed

for specific use and *[N]* - land found unsuitable for specific use. These two orders can be further sub-divided into five classes as: $\{S_1\}$ - highly suitable, no significant limitations; $\{S_2\}$ - moderately suitable, with moderate limitations; $\{S_3\}$ - marginally suitable with severe limitation; $\{N_1\}$ - currently not suitable with limitations, which may however be overcome by adopted practices; and $\{N_2\}$ - permanently not suitable due to severe limitations that make it impossible.

3.2 Land Capability Classification

Before deciding land capability of a unit of land, the important factors that needs to be considered include, soil profile characteristics like soil texture, effective soil depth, permeability, drainage, nutrients, soil salinity, alkalinity, toxicity, and coarse soil fragments; external features of lands like water logging, slope, and erosion; and climatic factors like rainfall, and wind velocity.

3.2.1 Land capability group

In the land capability classification, the land can be classified into two broad groups, namely: *(A)* - Land suitable for cultivation which includes *Class I to IV* lands, and *(B)* - Land not suitable for cultivation, but very well suited to forestry, grassland and wild life which includes *Class V to VIII* lands.

3.2.2 Land capability classes

These classes are groups of capability sub-classes or capability units that have the same relative degree of hazard or limitation. The land capability classes are mapped as Roman numbers from I to VIII. The risk of soil damage or limitation becomes progressively greater from *Class I to VIII.* The classes show the location, amount and general suitability of the soil for agricultural use.

3.2.3 Land capability sub-classes

Sub-classes are groups of capability units which have the same major conservation problems namely *[e]* - erosion and runoff; *[w]* - excess water; *[s]* - root zone limitations; and *[c]* - climatic limitations. Land capability sub-classes provide information about the kind of conservation problems or limitations of the land. The class and sub-class together provide the information about the type of limitation and kind of problem in view for broader planning, and conservation studies.

3.2.4 Land capability units

The soils in a capability unit are sufficiently uniform to produce similar kinds of cultivated crops and pasture plants with similar management practices and require similar conservation treatment and management practices under the same kind of vegetation cover. The land capability units are represented as ordinary numerals from *1 to 4* placed as subscripts to the sub-class letters. The numerals represent the following meanings: *{1}* - limitation of effective soil depth; *{2}* - very heavy or light texture of soil; *{3}* - nature of material restricting root zone; and *{4}* - salinity or alkalinity of soil. A land unit represented by **$[\{IV_{e1}\}]$** indicates a unit of land having severe limitation of soil erosion and effective soil depth suitable for agriculture with intensive soil conservation measures.

3.3 Soil type classification

For determination of distribution of soil types in the basin, textural analysis of different types of soil presented have been performed. The spatial distributions of different soils are determined for land capability classification.

3.3.1 Soil depth classification

According to the depth of the soil at different test sites, the basin can be divided into different zones from d_1 *to* d_5 and depth range of various classes is given in Table 1.

Table 1: Soil depth classes for land capability classification

S.N.	Symbol	Name of class	Depth range (cm)
1.	d_1	Very Shallow	0.0 to 7.5
2.	d_2	Shallow	7.5 to 22.5
3.	d_3	Moderately deep	22.5 to 45.0
4.	d_4	Deep	45.0 to 90.0
5.	d_5	Very Deep	Greater than 90.0

3.3.2 Slope classification

Slope classification is important in deciding the land capability classification. With the help of contour map of the basin, a slope map may be prepared. Using the slope map, the basin can be divided into different slope-class zones from *A to H*. The slope range for different classes has been given in Table 2.

Table 2: Slope classes for land capability classification

Symbol	Name of class	% Slope	Symbol	Name of class	% Slope
A	Nearly level	0 to 1	E	Moderately steep	10 to 15
B	Gently sloping	1 to 3	F	Steep	15 to 25
C	Moderately sloping	3 to 5	G	Very steep	25 to 33
D	Strongly sloping	5 to 10	H	Very very steep	> 33

3.3.3 Soil erosion classification

The erosion status in the basin is useful to determine the extent of soil conservation measures required in the basin. In the erosion classification, the basin can be divided into five classes of erosion from e_1 ***to*** e_5 as presented in Table 3.

Table 3: Soil erosion phases for land capability classification

S.N	Symbol	Erosion Phase	Characteristics
1.	e_1	Not apparent or slight (sheet)	0 to 5% topsoil or original plough layer with a horizon removed.
2.	e_2	Moderate (sheet and rill)	25 to 75% topsoil removed.
3.	e_3	Severe (sheet, rill and small gullies)	76 to 100% topsoil and up to 25% sub soil removed
4.	e_4	Very severe (shallow gullies)	Gullied land
5.	e_5	Very very severe (gullies)	Very severely gullied land or sand dunes.

3.3.4 Land permeability

A permeability map can be generated based on the rate of flow through the soil at different places in the basin as suggested in Table 4.

Table 4: Permeability classes of soil for land capability classification

Symbol	Name of class	Rate of flow (cm/hr)	Symbol	Name of class	Rate of flow (cm/hr)
1.	Very Slow	< 0.13	5.	Moderately Rapid	5.0 to 13.0
2.	Slow	0.13 to 0.50	6.	Rapid	13.0 to 25.0
3.	Moderately Slow	0.50 to 2.0	7.	Very Rapid	> 25.0
4.	Moderate	2.0 to 5.0			

3.4 Determination of capability of land

For determination of capability, limitation and proposed measures of conservation of each unit of land in a basin, all the above maps are overlaid over each other and a final land capability map of the basin can be generated, in which each unit of land has a particular slope class, soil depth class, permeability class, erosion phase and other climatic limitation. For example, a unit: $\dfrac{LS - d_4}{B - e_1}$, represents a unit having loamy sand, soil depth in the range of 45 to 90 cm, slope in the range of 1 to 3% and no apparent or slight (sheet) erosion. On the basis of above configuration the above land unit can be classified as II_e and on similar lines, all land units of basin can be classified.

4.0 ANALYSIS AND RESULTS

For determination of land capability classes detailed surveys for soil depth, erosion classes, soil types, slope classes and permeability have been conducted in the basin and all relevant maps prepared. These maps have been generated in ILWIS 3.0- a GIS software. All maps have been crossed and suitable capability class assigned according to standard rating tables and suggested guidelines.

4.1 Soil Type Distribution

The soils in the study area are mainly clayey-loam, loamy-sand and sandy-gravel type. The clayey-loam soil is found in the river beds, which is suitable for agriculture purposes, while the sandy-gravel soil is predominantly found in barren areas where possibilities of pasture development and agro-forestry exist. The area under each soil type has been presented in Table 5 and the map depicting the distribution of soil types is given in Fig. 2.

Table 5: Distribution of soils in the study area

S.N.	Soil type	Area (ha)	Percentage
1.	Clayey loam	349.61	14.62
2.	Loamy sand	1097.40	45.89
3.	Gravely sand	944.27	39.49

4.2 Soil Depth Classification

For determination of spatial variation of soil depth in the basin, the soil depth has been determined at 20 sampling sites in the basin. The sites have been selected in such a way so that all the land uses have been covered and sites are well distributed uniformly in the basin. A raster map showing the value of soil depth for each of the pixel of the basin has been generated by ordinary Krigging operation. The soil type map is presented in Fig. 3 and the area under each soil depth class is given in Table 6.

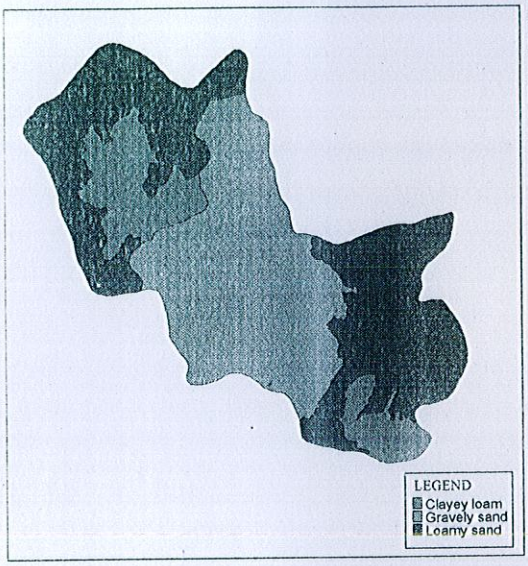

Fig. 2: Soil type distribution map

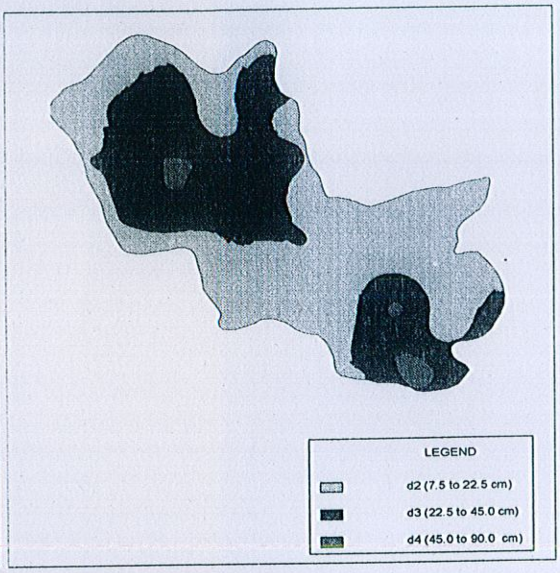

Fig. 3: Soil depth variation map

4.3 Slope Classification

For preparation of slope classification of map, the digital elevation map (DEM) of the basin has been used and slicing operation performed to determine the distribution of different slope classes in the basin. The slope in the study area varies from 0% to33% with slope classes varying between A and G. The distribution of different slope classes is given in Table 7. The slope classification map of the basin has been presented in the Fig. 4. From the analysis of slope classes, it can be seen that the topography of the basin is highly undulating and nearly 84% area of basin falls in slope group C to F.

Table 6: Distribution of soil depth classes

S.N.	Symbol	Class name	Depth Range (cm)	Area (ha)
1.	d_2	Shallow	7.5 to 22.5	1306.30
2.	d_3	Moderately deep	22.5 to 45.0	1035.00
3.	d_4	Deep	45.0 to 90.0	51.98

Table 7: Distribution of slope classes in the study area

S. N.	Symbol	Name	% Slope	Area (hectare)
1.	A	Nearly level	0 to 1	6.64
2.	B	Gently sloping	1 to 3	321.03
3.	C	Moderately sloping	3 to 5	539.64
4.	D	Strongly sloping	5 to 10	757.35
5.	E	Moderately steep	10 to 15	331.33
6.	F	Steep	15 to 25	392.09
7.	G	Very steep	25 to 33	43.19

4.4 Erosion class map

A detailed survey of the study area has been carried out to ascertain the erosion status. The area is a degraded and the erosion from forested area is moderate, while the cropping land is affected by severe erosion. The erosion is more from agriculture area because most of agricultural in the basin is being taken up in the river bed or near the river tributaries without any soil conservation measures. The basin has abundant barren areas, where most of the top soils have been removed and rocky outcrops are visible. The map of the distribution of erosion classes in the basin is given in Fig. 5. and the area under various erosion classes is given in Table 8.

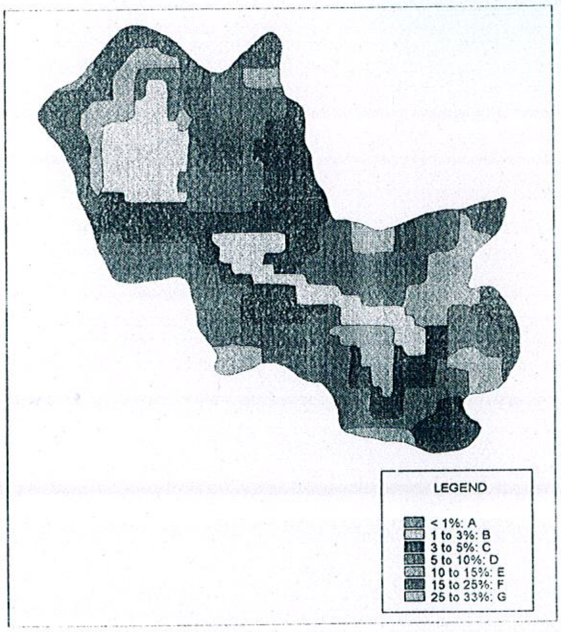

Fig. 4: Slope class map

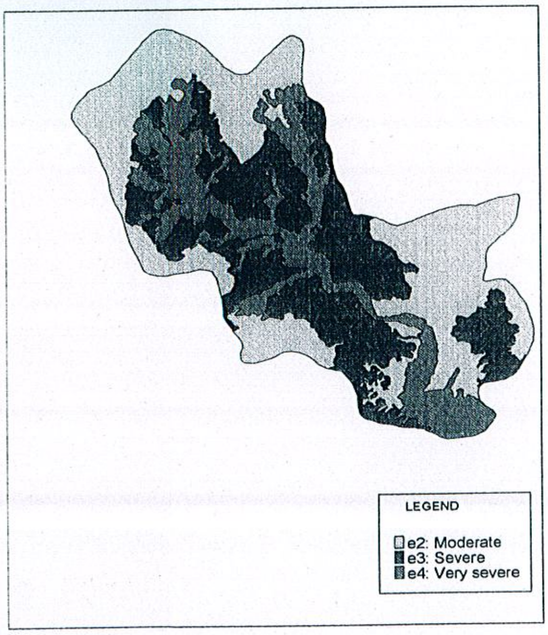

Fig. 5: Erosion class map

Table 8: Distribution of erosion classes in the study area

S. N.	Symbol	Erosion Phase	Area (hectare)	Percentage
1.	e_2	Moderate (sheet and rill)	993.33	41.54
2.	e_3	Severe (sheet, rill and small gullies)	847.47	35.43
3.	e_4	Very severe (shallow gullies)	550.48	23.02

4.5 Permeability class map

In order to obtain the permeability class map of the basin, infiltration tests using double-ring infiltrometer have been conducted on 14 sites. Krigging and slicing operation have been performed in ILWIS 3.0 to obtain distribution of different classes of permeability. From the analysis, it has been observed that the permeability classes including slow, moderately slow, moderate and moderately rapid classes exist in the basin. The area under each permeability class is given in Table 9. The permeability distribution map of the basin is given in Fig. 6. It has been observed that more than 50% basin area falls in the category of moderate permeability rate.

Table 9: Distribution of permeability classes

S.N	Symbol	Name	Rate of Flow (cm/hr)	Area (hectare)
1.	2	Slow	0.13 to 0.50	5.42
2.	3	Moderately Slow	0.50 to 2.0	954.00
3.	4	Moderate	2.0 to 5.0	1269.85
4.	5	Moderately Rapid	5.0 to 13.0	162.01

4.6 Land capability classification

For determination of land capability classification for the basin, all maps including soil type, soil depth, slope class, erosion class and permeability maps have been crossed in GIS and using standard check lists and guidelines, a land capability has been assigned to each combination. Class II to VII has been found in the basin. The area covered under each sub-class with the proposed land use is given in Table 10. The land capability class map for the study area has been presented in Fig 7.

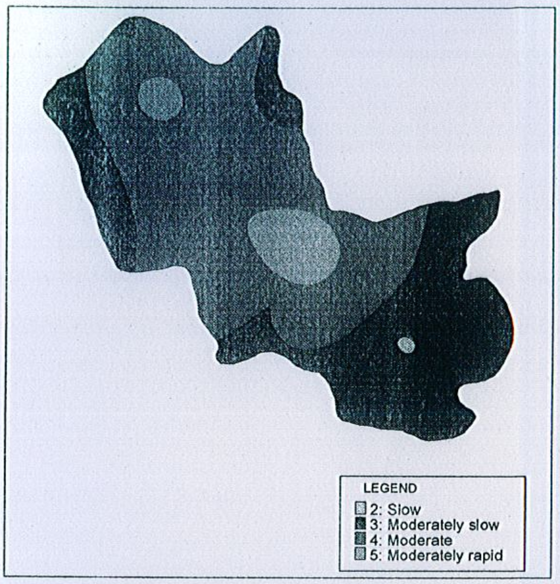

Fig. 6: Permeability class map

Table 10: Land capability classes in the study area

S.No	Land capability	Area(ha)	Proposed Land use
1.	IIe	178.93	Agriculture (Irrigated)
2.	IIes	153.50	Agriculture (Irrigated)
3.	IIIe	218.96	Agriculture (Irrigated)
4.	IIIes	452.87	Agriculture (Irrigated)
5.	IVe	187.73	Agriculture (Irrigated)
6.	IVes	762.21	Agriculture, Pasture & Agro forestry
7.	Ve	45.39	Pasture & Agro forestry
8.	VIe	271.00	Forest
9.	VIes	77.52	Forest
10.	VIIe	16.82	Forest
11.	VIIes	26.07	Forest

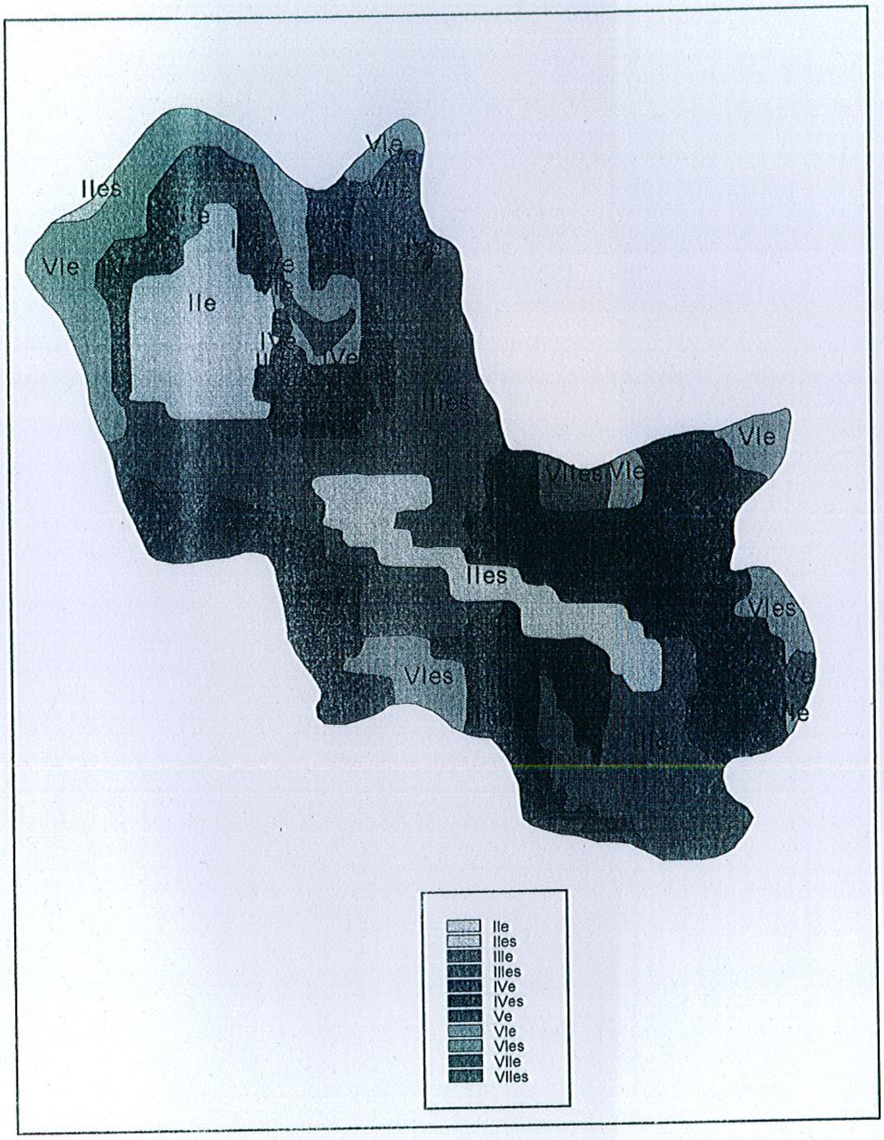

Fig. 7: Land capability classification map

5.0 CONCLUSONS

The objective of sustainable development can only be achieved when management goals are ecologically viable and economically feasible. The underlying concept of sustainability is that of productivity and quality of the environment, and the natural resources which can be achieved through policies aimed at maintaining balance between the exploitation and regeneration of the natural resources. As demonstrated in the study, the land capability classification can be carried out based on the soil survey integrated into a GIS framework. The land capability classification of the study area suggests that about 1191 ha is suitable for irrigated agriculture whereas the area not suited for agriculture can be used for agro-forestry, pastures and forests. The development of the basin based on these lines will prevent the study area from further degradation and help in restoring the fragile ecosystem as the land resources will be exploited on a sustainable basis based on its capacity and limitations. The soil conservation measures can also be planned based on the land capability classification. The present approach of the sustainable development planning can be replicated for similar basin development programs elsewhere.

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Dr. H. S. Gour Central University, Sagar 470 003

DEPARTMENT OF APPLIED GEOLOGY

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Aug./Sep 2010

Ref. *EAT/AG/Nat. Semi-1*

To,

Subject: ***Invitation for National Seminar & Alumni meet***

Sir/Madam,

It is our great pleasure to inform you that the Department of Applied Geology is organizing a **National Seminar on Applications of Geoinformatics for National Development** on **29th & 30th Nov. 2010**, at Sagar. The seminar is designed to disseminate and propagate geoinformation technology to assist society and government for enhancing their capabilities and facilitate knowledge transfer to increase the productivities of end users.

This seminar will provide a platform where academicians, students, researchers, engineers, builders and stakeholders from diverse fields will realize, recognize and reveal applications, development and usage of geoinformation sciences to resolve various important issues for sustainable national development.

Seminar will host key note address, guest lectures, special lectures, technical sessions, poster sessions and lastly panel discussion. A special highlight of the seminar is interactivity which will provide the delegates and speakers an opportunity to participate in the discussion. An exhibition area of about 2000 sq m will be available to showcase the latest innovation. Likely sponsors and advertisers are requested to book their space for exhibition stalls and publication in Souvenir-cum-abstract volume before **14th Nov. 2010**

The Department of Applied Geology is well known center of excellence in geosciences education and has produced several top executives in the field of geoinformatics. Therefore, it is also planned to organize an alumni's meet. All alumni's are requested to participate in the seminar.

We would like to request you to participate/recommend/nominate delegates & benefit from this wonderful gathering of national geoinformatics leaders. A broad outline of the seminar is enclosed for your ready reference.

Looking forward to see you in this grand seminar.

Thanking you,

With best regards,

(R.K. Rawat)

Dr. R. K. Rawat
Director & Organising Secretary
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Dr. H. S. GOUR CENTRAL UNIVERSITY
SAGAR 470003 (M.P.)

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