CS (AR)-29/98-99

GEOMORPHOLOGICAL AND LAND USE PLANNING FOR DANDA WATERSHED (TEHRI-GARHWAL DISTRICT, U.P.)

आपो हि ष्ठा मयोभुव

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1 INTRODUCTION

Land is the sole source of the sustenance of the mankind supporting the plants and animals on it, providing the food fibre and shelter. Therefore, proper utilisation and management of land resources for sustenance of human being is needed. Development programmes concerning optimum utilisation of natural resources are now increasingly oriented with watershed as an integral unit. A watershed is a natural entity conforming to the increasing homogeneity of geomorhic sculpturing process. Watershed management implies rational utilisation of land and water resources for optimal and sustained production with the minimum hazard to natural resources and environment. It requires collection and analysis of great deal of information on physical relationship of vegetation-soil-water to land management to ensure economic and social progress of a watershed. The success of planing for developmental activities depends on the quality and quantity of information available on both natural and socio-economic resources. Therefore, accurate and reliable data base generation and management is extremely important for devising ways for optimal planning and management of watersheds.

Remote Sensing (RS) and Geographic Information Systems (GIS) provide an appropriate information base for efficient management of natural resources and environment. The synoptic view provided by the satellite remote sensing and the analysis capability provided by a Geographic Information System (GIS) offers technologically appropriate method for studying land and water resources of a watershed. Remote sensing is generally defined as observing an object from a distance without having direct contact with it. Remote sensing systems are used to observe the earth's surface from different levels of platforms such as satellites and aircraft, and make it possible to collect and analyse information about resources and environment over large areas. The instruments or devices used are called remote sensors. These record electromagnetic energy reflected or emitted from the earth's surface. Different kinds of objects or features such as soils, vegetation and water reflect and emit energy differently. This characteristic makes it possible to measure, map and monitor these objects and features using remote sensing systems.

For many hydrological purposes remote sensing data alone are not sufficient and they need to be supplemented with data from other sources. Hence a multitude of spatially related (i.e. geographic) data concerning rainfall, evaporation, vegetation, geomorphology, soils and rocks have to be considered. Also of interest are social and economic data related to where the demand is for water for urban and industrial supplies, irrigation, etc.

Knowledge of land use and hydro-geomorphology is important for planning and management activities concerned with the surface of the earth. The resource managers and planners for agricultural land use need detailed, timely, accurate and reliable data on the extent, location and quality of land and water resources and climate characteristics. The data on landuse potential and the conservation needs can help in planning for uses that will maintain the quality of land. The application of satellite remote sensing for land use surveys and mapping is gaining importance largely because of its ability to provide rapid and reliable data within a given time framework. Because of its synoptic coverage and repetitivity, the multistage imagery not only enables to map the spatial distribution of land use, but also to monitor its pattern of change over period of time. Such data base on the rate and pattern of change is very essential, environmental impact assessment, for optimum land use planning and proper management etc.

Land use characteristics of a watershed has a significant influence on the quality and quantity of run-off available from it. Various hydrologic processes such as infiltration, evapotranspiration, soil moisture status etc. are influenced by Land use and cover characteristics of watershed. Thus, it may from an important input to hydrologic models. Hydrologic phenomena is highly dynamic in nature and as such Land use and cover information may be required at frequent intervals for making hydrologic inferences.

1.1 Problem Definition

Hilly regions of our country are facing a serious water availability crisis due to various developmental and economic activities in the hills and as a result of reduction in the protective vegetation cover and forests. Due to lack of the protective cover, the infiltration and subsequent recharge to ground water has declined adversely. Viable sources of water like springs, which are plenty in the hills, are drying up because of inadequate recharge of flow domain of the springs. This study attempts to quantify geomorphological characteristics, generation of various thematic data base in GIS format, derivation of land use information using remote sensing digital data, land capability classification and generation of alternate land use plan for the Danda watershed for proper management of natural resources in this mountainous watershed.

2 THE STUDY AREA

Danda watershed is located in Hindolakhal block of Devprayag Tehsil in Tehri Garhwal district of Uttar Pradesh. The Danda watershed lies between latitude 30°13'36"N to 30°14'46"N and longitude 78°37'04"E to 78°38'56"E. The area falls in Survey of India (SOI) Toposheet No. 53 J/12. Details, such as, roads, streams, settlements and spot height, contours etc. are taken from this toposheet. The Danda watershed has an area of 450.44 hectare at the gauging site (under construction) near Dugyar village. The Watershed has a highly undulating topography with steep slopes and scanty vegetation. The elevation within watershed varies from 777m above mean sea level at outlet near Dugyar to 1810m above mean sea level at ridge at watershed boundary. The main source of water is numerous springs and a few perennial streams. **Fig. 1** shows the location of watershed in India. Lithologically, Danda area falls under the Chandpur formation of Jaunsar groups. The rock type of the area is low grade metamorphic rock with slates. These greyish coloured low grade metamorphic rocks are highly fractured and foliated. Important salient features of the study area are given in Table 1 and Table 2 summarises the list of data used in present study

2.1 Present agricultural practice

In the Kharif, the main crops in the area grown are paddy, mandua, kauni, Jhangors, maize, bhat and potato. In the Rabi, wheat, barley, masur, mustard and rapeseed are the chief crops grown in the region.

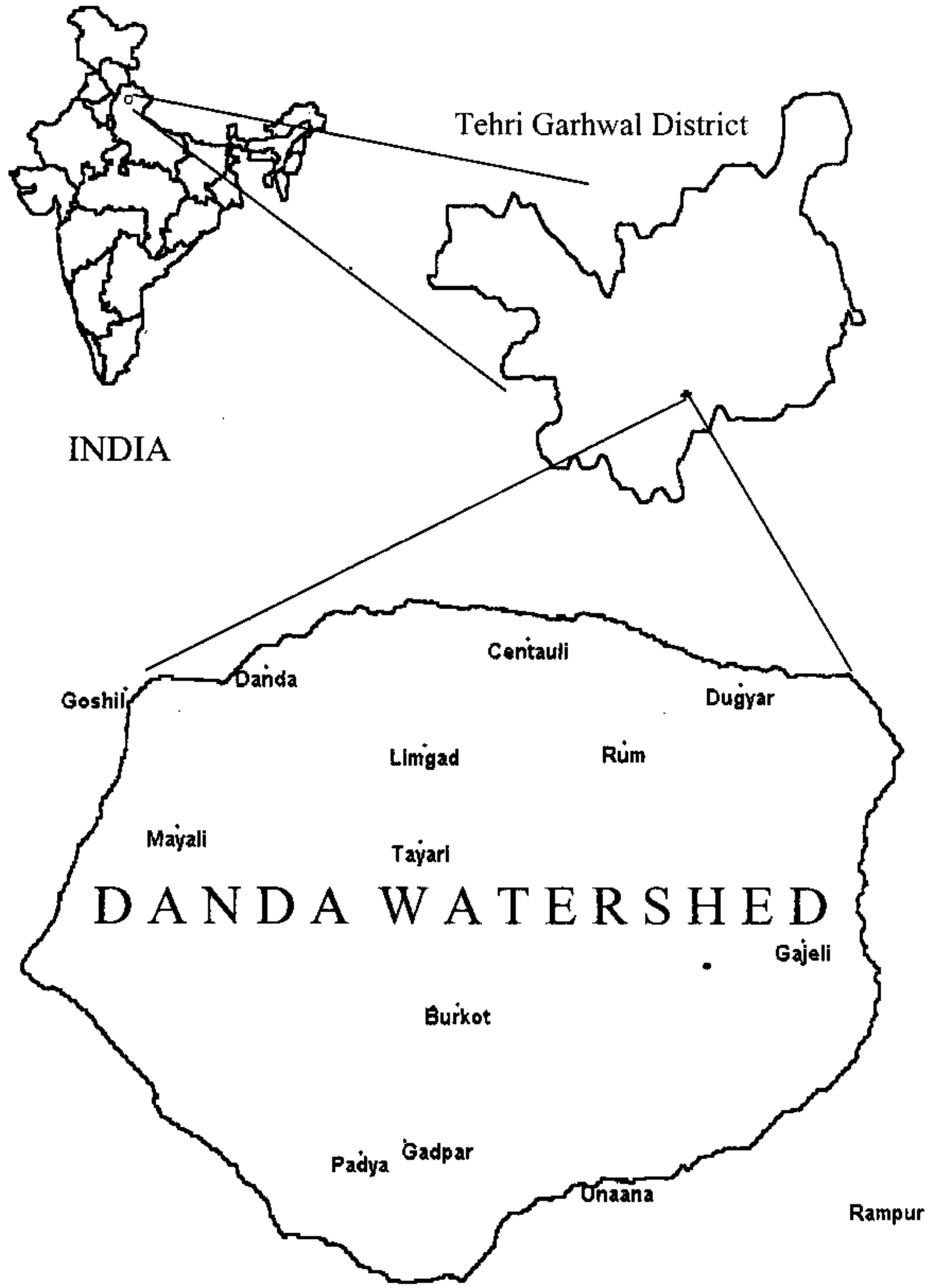


Fig. 1 Location map of Danda watershed

From October-November to April to the middle of May, other cash crops grown in the region are ugal (buckwheat), turmeric, pepper, ginger, and chillies and vegetables like potatoes, cabbages, cauliflowers, yams, brinjals, pumpkins asparagus, rhubarb, mint and watercress. The major forest produce is timber and fuel wood. The minor forest products include bamboo, grass, leaves, leaf manure, oil tanning material, dyes, gums, resin, medical herbs, edible fruits, honey and wax. Beside animal products like hides, skins, bone horns, musk-pods and manual feathers.

2.2 Climatological overview

The watershed falls under Subtropical (cool temperate) climate zone in Himalayan mountain ranges of India. The watershed under study falls in rain shadow zone of mountains with moderate rainfall with annual average of 900mm. The rainfall occurs in almost all the months of the year except in October and November which, receives scanty rainfall. The bulk of rainfall received in the area is in the months of July, August and September. The values of maximum and minimum daily temperatures were available at Devprayag, Nagchaud, Tehri and Ranichauri. It is seen that the highest value of maximum temperature 38.5^0 C is recorded at Devprayag in the month of May and June and the next highest value of maximum temperature is recorded at Tehri in the month of June. The Corresponding values recorded at Nagchaud and Mukhim are 36^0 C and 26.1^0 C in the month of June. The minimum temperatures recorded in these stations ranges between 2.8^0 and 4.2^0 C in the month of January/ December. Evaporation data is available at Devprayag and Ranichauri. The average daily evaporation at Ranichauri varies between 1.5 mm/day in the month of January and 4.6

mm/day in the month of May. Similarly the average daily evaporation at Devprayag varies between 1.39 mm/day in the month of January and 6.3 mm/day in the month of May. Annual average rate of evaporation is 3.47 mm/day at Devprayag and 2.75 mm/day at Ranichauri.

Table 1. Important salient features of the Danda watershed

Geographic Location	Latitude: 30°13′36″N to 30°14′46″N Longitude: 78°37′04″E to 78°38′56″E Hindolakhal Block of Tehri District
Geographical Area	4.50 km^2
Climate	Subtropical(cool temperate) Moderate rainfall with annual average of 900mm
Physiography	High relief, deeply dissected topography Elevation varies between 777-1810m
Lithology	Mainly Phyllites of Chandpur Formation
Economic Activity	Agriculture, Horticulture and Animal Husbandry

Table 2. Spatial and attribute data sets used in present study

Type of Data	Details of Data	Source of Data
Survey of India Toposheet	53J/12 (scale 1:50,000)	Survey of India, Dehradun
Remote sensing digital data	LISS-III :Date 12.11.97 (Path / Row:97/50) PAN : Date 12.11.96 (Path / Row: 97/50))	NRSA, Hyderabad

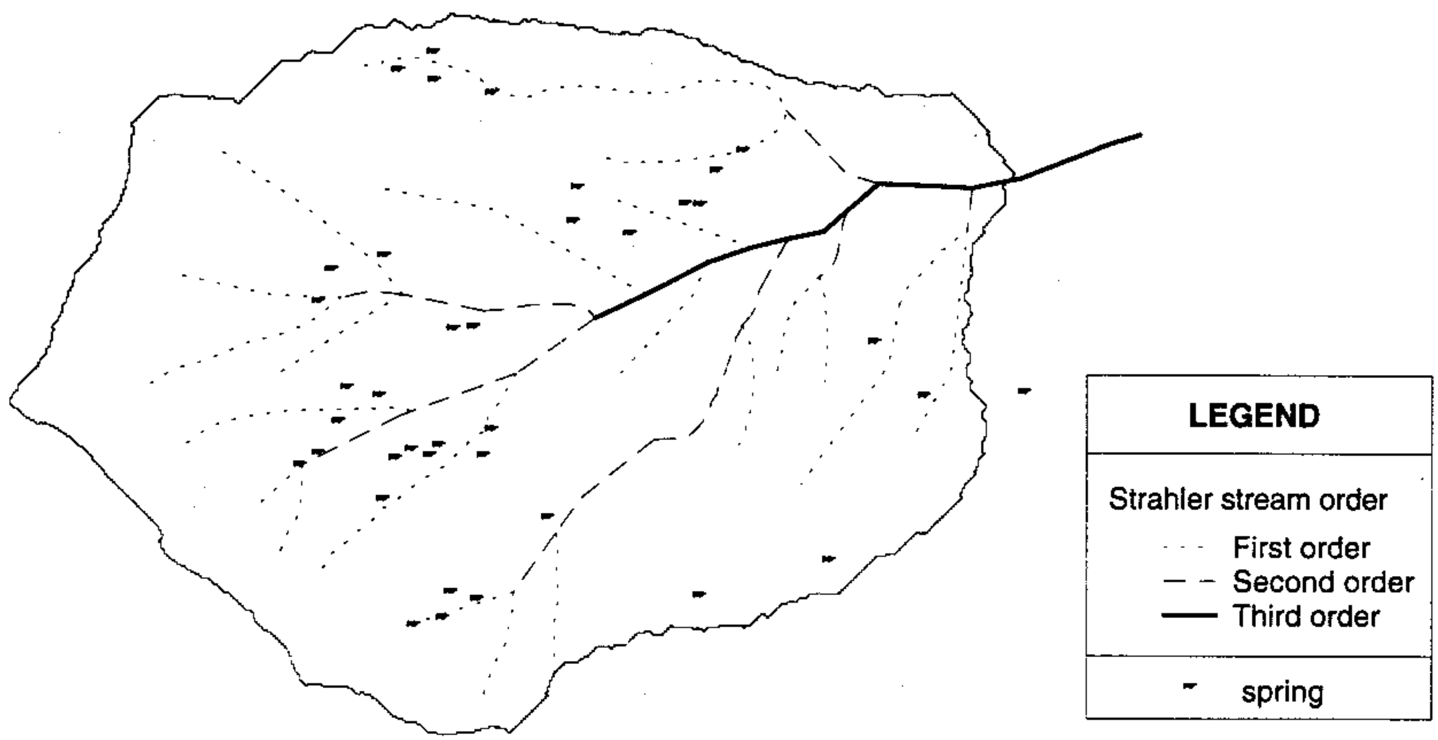
3 GENERATION OF THEMATIC MAPS

3.1 Hydro-geomorphology Map

Streams: Drainage information for this map has been derived from SOI toposheet and IRS-1C PAN data. The drainage pattern present in SOI topographic sheet was digitised and drainage lines were superimposed on IRS-1C PAN digital data. Digitised drainage pattern was compared with satellite observed drainage pattern and a corrected drainage map was finally prepared. In this watershed, various streams forming a dendritic pattern are present. The streams are seasonal in nature and remain dry in non-rainy seasons. Small amount of water is available only in the downstream portion of the main stream. This map is useful for site location for harvesting of surface water and for prioritising the watershed development. Fig. 2 shows the final drainage map generated through overlay of digitised drainage pattern and satellite observed drainage pattern. Watershed boundaries have been drawn based on water divide derived from analysis of digital elevation model and morphology of terrain observed on the topographic maps and by physical check up in the area.

Springs: There are a number of springs present in the Danda watershed. A survey for locating springs was carried out and a total of 35 spring of varying discharge were identified. Location of these springs is shown in Fig 2.

DANDA WATERSHED



HYDRO-GEOMORPHOLOGY

Fig. 2

Tanks: A few tanks have been constructed by U.P. Jal Nigam to provide drinking water to some villages located in the watershed. Small tanks have also been constructed by the villagers near the springs to meet the drinking water needs. There is no reservoir in the area.

3.2 Contour Map

Contour map has been prepared from the SOI toposheet on the scale of 1:50,000. The contours shown in this toposheet at an interval of 20 metre were digitised along with some spot heights. This map shows the contour height and location of villages and streams present in the area. The digitised contour map is used to generate Digital Elevation Model (DEM) of the watershed.

3.3 Digital Elevation Map

The contour map and spot height map of the area were merged together and a composite map having information about contours as well as spot height was formed. This combined map was further interpolated at 6-metre pixel resolution using map interpolation function available in Integrated Land and Water Information System (ILWIS) to generate a DEM of the area. This DEM was further checked for flats and pits present in it. Since the area lies in steep mountainous terrain, only few flats and pits were observed in the DEM. These flats and pits were then removed using iterative map calculation functions of ILWIS and final DEM was generated. Removal of flats and pits in a DEM is necessary to maintain continuity of water to the catchment outlet from any point inside the catchment. This DEM is then used to delineate watershed boundary using eight direction pour point algorithm. Fig. 3 shows the DEM of the watershed along with derived catchment boundaries. As can be seen from this figure that the elevation varies from 777 to 1810 m above mean sea level in this watershed. The study area shows the continuous increase of elevation from east to west. A 3-dimensional image drape is also generated using this DEM and satellite data to have a perspective view of the watershed. Fig. 4 shows the 3-dimensional image drape of Danda watershed.

3.4 Slope Map

The DEM derived above was further analysed to generate slope map of the watershed. The slope map is helpful in prioritising areas for development measures like engineering, land suitability etc. The slope map of the area was prepared using map calculation function of ILWIS. Fig. 5 shows the slope map of the area. As can be seen from Fig. 5 that most of the watershed area falls under slope categories from 25-100%.

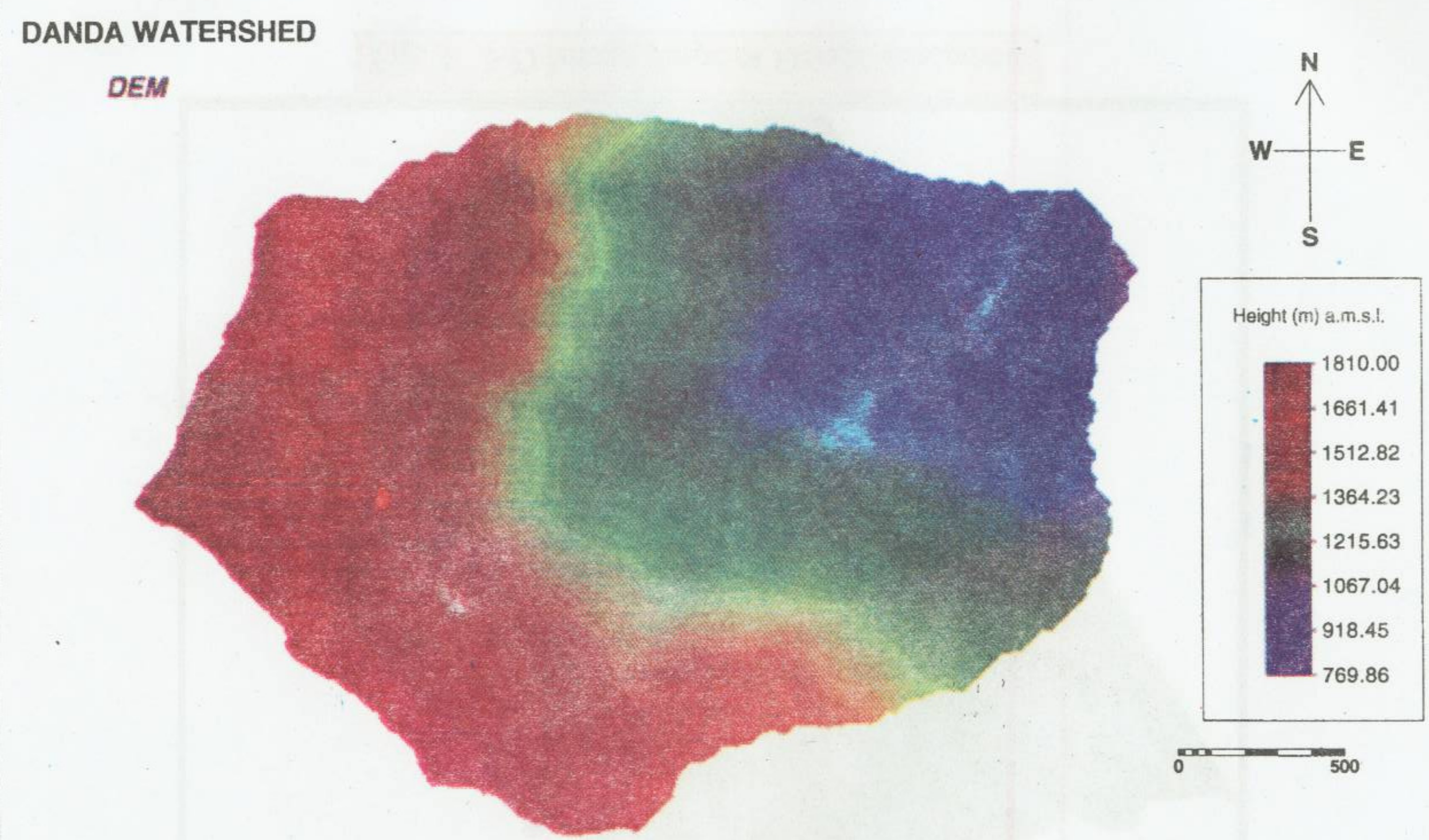

DANDA WATERSHED
DEM
N
W
E
S
Height (m) a.m.s.l.
1810.00
1661.41
1512.82
1364.23
1215.63
1067.04
918.45
769.86
0
500

Fig. 3

Fig. 4. 3-D Image drape of Danda watershed

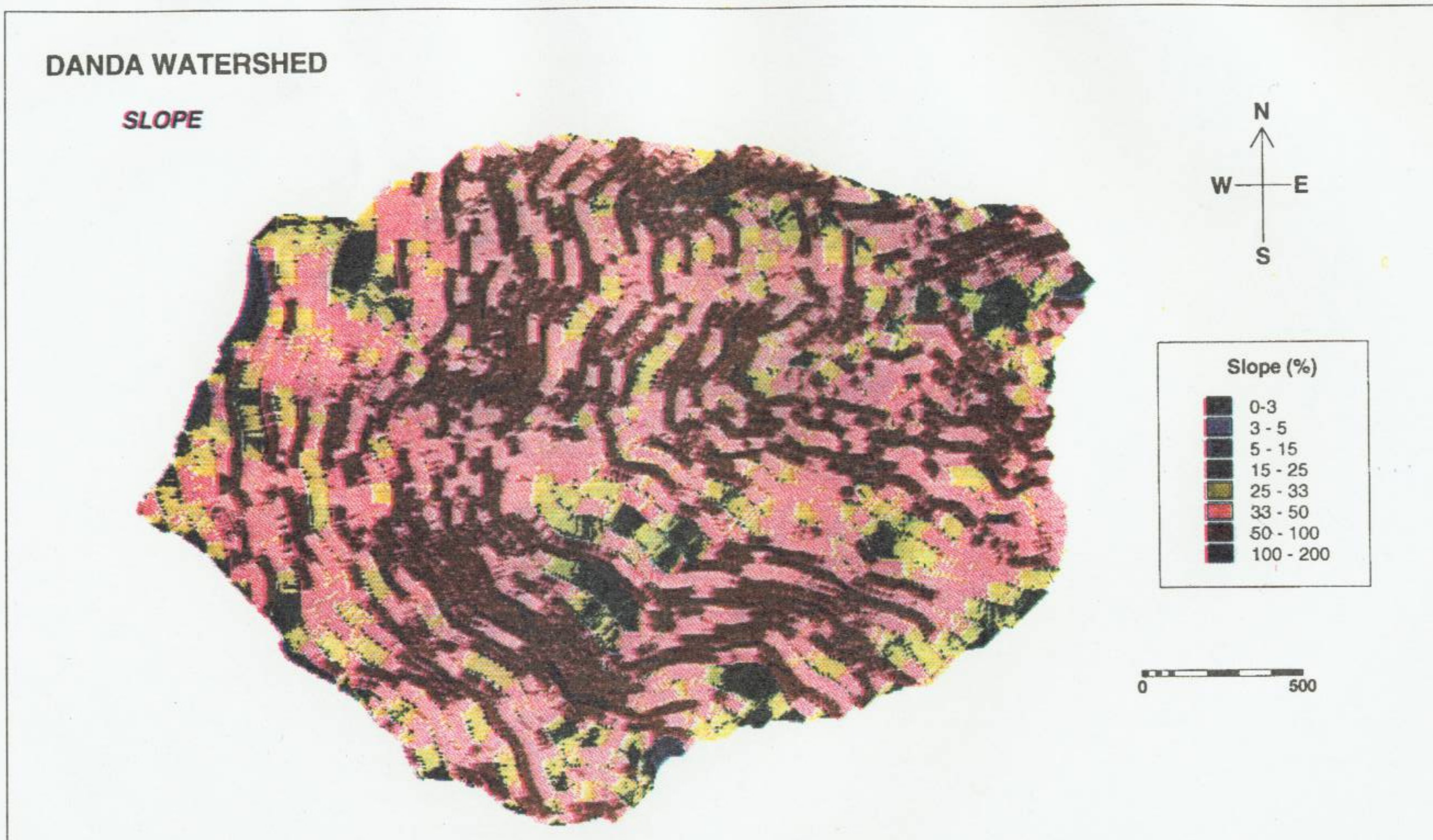

DANDA WATERSHED
SLOPE
N
W
E
S
Slope (%)
0-3
3 - 5
5 - 15
15 - 25
25 - 33
33 - 50
50 - 100
100 - 200
0
500

Fig. 5

3.5 Landuse Mapping

Knowledge of land use and land cover is important for planning and management activities concerned with the surface of the earth. The resource managers and planners for agricultural land use need detailed, timely, accurate and reliable data on the extent, location and quality of land and water resources and climate characteristics. The data on land use potential and the conservation needs can help in planning for uses that will maintain the quality of land. The application of satellite remote sensing for land use surveys and mapping is gaining importance largely because of its ability to provide rapid and reliable data within a given time framework. Because of its synoptic coverage and repetitive, the multistage imagery not only enables to map the spatial distribution of land use, but also to monitor its pattern of change over period of time. Such data base on the rate and pattern of change is very essential, environmental impact assessment, for optimum land use planning and proper management etc.

Land use characteristics of a watershed has a significant influence on the quality and quantity of run-off available from it. Various hydrologic processes such as infiltration, evapotranspiration, soil moisture status etc. are influenced by land use and cover characteristics of watershed. Thus, it may from an important input to hydrologic models. Hydrologic phenomena is highly dynamic in nature and as such Land use and cover information may be required at frequent intervals for making hydrologic inferences.

Since land use is dynamic features over space and time, it is difficult to get real time information through conventional means. Also, these methods are time consuming, laborious and costly. Spatial variations of Land use and soil generate uncertainties about the point data collected by conventional methods. As such spatial repetitive and synoptic data from satellites collected over a wide range of electromagnetic spectrum suit the requirements of Land use and soil monitoring. Data collected by various sensors over various regions of electromagnetic spectrum help in differentiating one feature from the other. So Land use features can be identified, mapped, and studied on the basis of their spectral characteristics and also the factors which influence these characteristics.

Healthy green vegetation have considerably different characteristics in visible and near infrared regions of the spectrum whereas, dry bare soil has a relatively stable reflectance in both the regions. Water shows very low reflectance in visible part of the spectrum and almost no reflection in infrared part of the spectrum. Thus by using multispectral data suitably, different ground features could be; differentiated from each other and thematic map depicting land use could be prepared with satellite data.

For the watershed under study, a landuse map has been prepared from digital analysis of satellite data using Earth Resources Data Analysis System (ERDAS) Imagine 8.3.1.

For generation of landuse map of the area, IRS-1C LISS-III data and PAN data of scene 96/50 for November 1997 was used. Since the area of watershed is small, the LISS-III scene was merged with PAN scene after carrying out geometric corrections on both of the scenes. The merged scene was re-sampled at 6-metre pixel resolution to get multi-spectral information at 6-metre resolution. Six classes of landuse i.e. agriculture, fallow, dense forest, degraded forest, grass with shrubs and wasteland (with shrubs, cactus) have been identified in the watershed. The map also indicates that the area is dominated by cultivated land without any irrigation facility. Fig. 6 shows derived landuse map of the area. Landuse statistics of the watershed is given in Table 3.

Table 3. Present landuse statistics of Danda watershed

Sl. No.	Landuse	Area (Ha)	Area (%)
1.	Agriculture	95.83	21.27
2.	Fallow	11.73	2.60
3.	Forest	103.94	23.08
4.	Agriculture (irrigated)	26.04	5.78
5.	Shrubs	25.61	5.68
6.	Waste land	94.43	20.97
7.	Open scrub	92.43	20.52

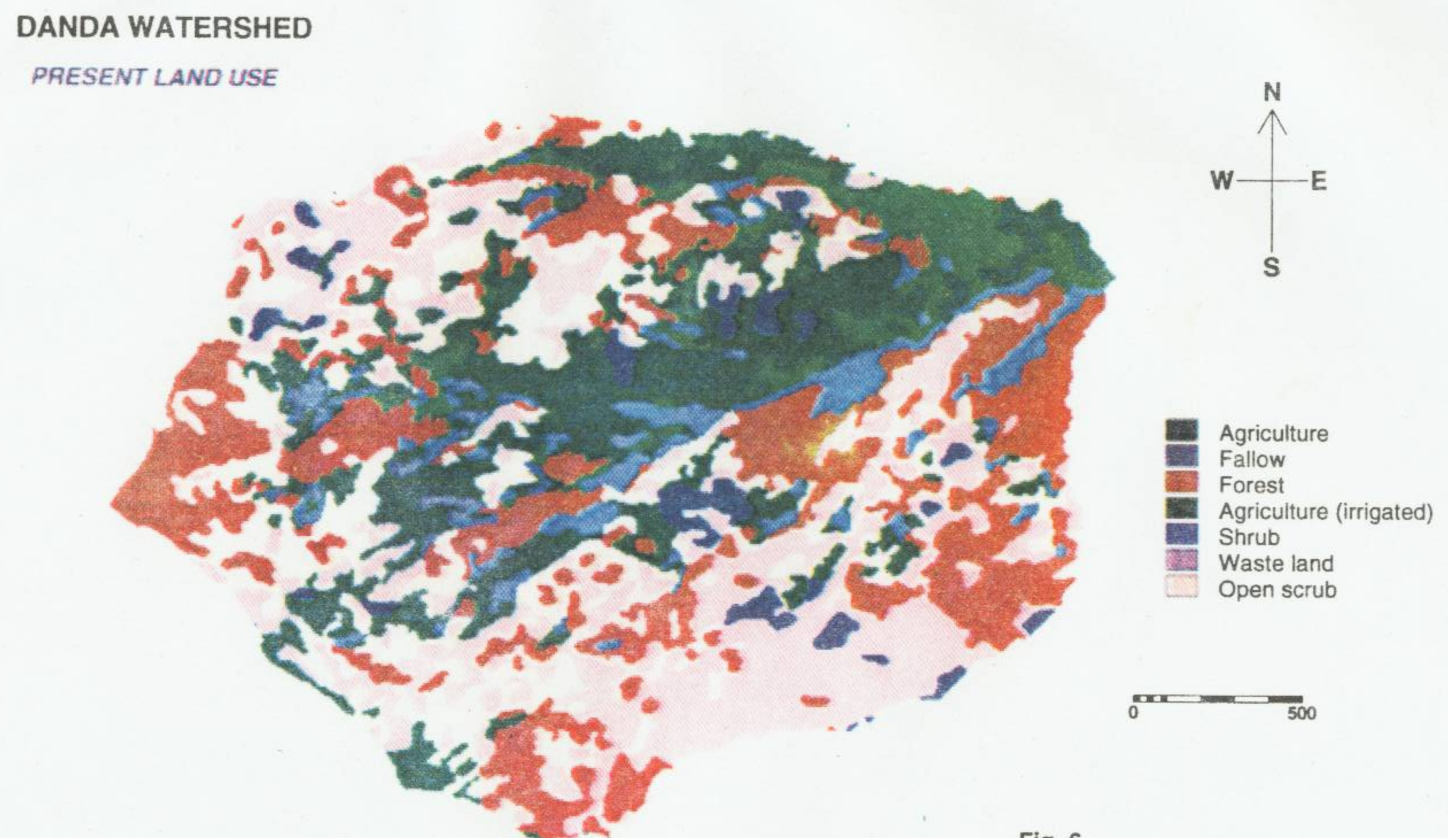

DANDA WATERSHED
PRESENT LAND USE
N
W
E
S
Agriculture
Fallow
Forest
Agriculture (irrigated)
Shrub
Waste land
Open scrub
0
500

Fig. 6

3.6 Soil Mapping

In Garhwal area, the majority of soils are diluvial in nature. Most of the agricultural soils usually lose the top horizon either due to construction of terraces or erosion. In the terraced hillside, the downslope drift of mineral matter is sharply reduced and the soil is stabilised. On steep slopes, soils are generally shallow and usually have a thin surface horizon and medium to coarse texture. Sub-soils are deep and heavily textured. Top surface horizon with a high content of organic matter is a characteristic feature of the area. These soils are highly leached and acidic in nature. Valley soils are developed from the colluvium brought down from the upslopes. Soils of the valley bottom on river terraces comprise of alluvium, brought and deposited by rivers in the process of aggradation.

Soil map of the area is derived from supervised classification of the satellite data in conjunction with limited field data collected from field visits and general information collected from the villagers, and the block office. Fig. 7 shows the soil map derived from satellite data.

DANDA WATERSHED

SOIL

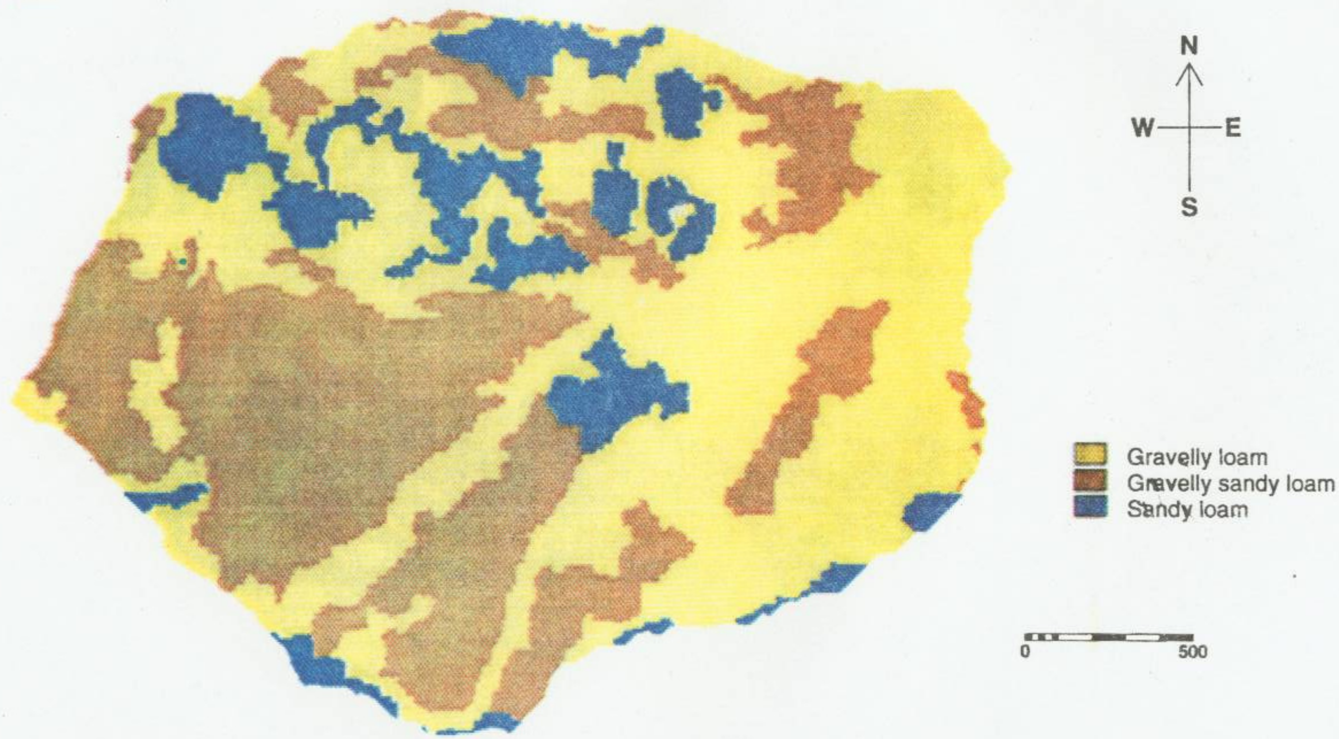


Fig. 7

4 ANALYSIS

4.1 Quantitative analysis of drainage networks

The linking of the geomorphological parameters with the hydrological characteristics of the basin provides a simple way to understand the hydrologic behaviour of the different basins particularly of the ungauged basins. Before taking up the studies related with hydrologic simulations using the geomorphologic characteristics, the important geomorphological properties have to be quantified from the available topographical map of the basin. The geomorphological properties which are important from the hydrological studies point of view include the linear, aerial and relief aspect of the watersheds. Detailed definitions and description of various geomorphological parameters can be found in Chow (1964) and Singh (1992).

In many hydrological studies such as design flood estimation, water availability studies and runoff estimation, geomorphological characteristics have been frequently used, particularly in the regional studies, in order to make the required estimates for ungauged catchments. Some of the hydrological studies, wherein the different aspects of the geomorphological characteristics are utilised include: Regional unit hydrograph studies using geomorphological and physical characteristics of catchment, regional flood frequency analysis using geomorphological characteristics, development of geomorphological Instantaneous Unit Hydrograph (GIUH) application of geomorphological parameters and physiographic characteristics in model studies.

The quantitative analysis of channel networks began with Horton's (1945) method of classifying streams by order. He developed a system for ordering stream networks and derived laws relating the number and length of streams of different order. Strahler (1957) slightly revised Horton's classification scheme in which ordering procedure is based on the following rules:

1. Channels that originate at a source are defined to be first- order streams;
2. When two streams of order u join, a stream of order (u+1) is created.
3. When two streams of different orders join, the channel segment immediately downstream has the higher of the order of the two continuing streams.
4. The order of the basin is the highest stream order, u.

The mapping of drainage pattern can be carried out using satellite data. Computation of the parameters required for morphometric analysis using manual methods like area measurement using dot grid method or using planimeter and length measurement using curvimeter are very tedious and time consuming. It is more difficult if the map is on higher scale like 1:50,000 and 1:25,000. The ordering, lengths, area and perimeter etc. can be easily estimated using Geographic Information System (GIS) technique. Use of GIS can not only make this task relatively easy but accurate as well. For quantification of various geomorphological parameters of Danda watershed, the digitised drainage and interpolated contours maps were used. Important parameters thus derived by GIS analysis are listed in Table 4.

Table 4. Geomorphological parameters of Danda watershed

Sl. No.	Parameter	Symbol	Value	Unit
1.	No. of stream of order 1	N_1	21	
2.	No. of stream of order 2	N_2	6	
3.	No. of stream of order 3	N_3	1	
4.	Mean length of order 1	$\overline{L_1}$	563.56	Meter
5.	Mean length of order 2	$\overline{L_2}$	646.22	Meter
6.	Mean length of order 3	$\overline{L_3}$	1359.75	Meter
7.	Mean area of order 1	$\overline{A_1}$	16.70	Hectare
8.	Mean area of order 2	$\overline{A_2}$	14.69	Hectare
9.	Mean area of order 3	$\overline{A_3}$	29.72	Hectare
10.	Total watershed area	A	450.44	Hectare
11.	Watershed perimeter	P	11.74	Km
12.	Total length of streams of all order	L_w	17.07	Km
13.	Drainage density	D	3.637	Km/km^2
14.	Stream frequency	F	5.97	$1/km^2$
15.	Form factor	R_f	0.0161	Dimensionless
16.	Circularity ratio	R_c	0.856	Dimensionless
17.	Elongation ration	R_E	0.887	Dimensionless
18.	Bifurcation ratio	R_B	4.581	Dimensionless
19.	Relief ratio	R_h	0.337	Dimensionless
20.	Relative relief	R_p	0.088	Dimensionless
21.	Ruggedness number	R_n	3.753	Dimensionless

4.2 Land-capability classification

Land-capability classification is a systematic classification of land where each unit of land is classified according to what it is capable of producing and also according to the risk or damage that would result if they are mismanaged. This classification is made primarily for agricultural purposes and it enables the farmer to use the land according to its capabilities and to treat it according to its needs. Land is arranged in various capability classes after considering a number of soil characteristics and associated land features and climate. The main soil characteristics to be taken in to account are texture, depth, permeability, salinity and alkalinity of top soil and sub-soil. The important associated soil features are slope, effect of past erosion, natural soil drainage, frequency of over flow etc.

The concept of land-capability classification has been developed in USA for soil conservation on farm lands (Klingbiel and Montogomery, 1961). This concept has been adopted in India by the All-India Soil and Land-Use Survey Organisation for similar purposes. According to this classification scheme, the land is divided into 8 capability classes from I to VIII. These 8 classes are grouped in two land-use suitability groups, viz. (i) land suited for cultivation and other uses (class I to IV) and (ii) land not suited for cultivation but suited for other uses (class V to VIII).

A review of land classification methods used in different countries indicate that the land capability classification system is most universally applicable with little modification (Chaudhary *et al.*, 1962). Land capability for Indian conditions have been suggested by Tejwani (1976). For Himalayan region, the texture is very much influenced by the coarse fraction larger than 2mm diameter. The soil is invariably found admixtured with gravel and stone, which considerably affect the crop yields. Khybri (1979) suggested that for developing land capability classes for steeper slopes, soil depth and land slope are to be considered in combination, particularly for construction of bench terraces on such slopes.

Soil surveys were carried out to determine the soil types in the study area. The survey included determining soil depth, slope, texture and erosion condition. General information was collected from the villagers, fields and the block office. From the details of various soil profiles. landscape features, the land capability classification was done as per Khybri (1979). Fig. 8 shows the developed land-capability map for the watershed. As can be seen from Fig. 8 that the land in the watershed can be grouped in three land capability classes viz. Class IV, class VI and class VII lands. The details of each land-capability class is given below:

Class IV This category comprises of 93.01 hectares (20.65 %) of watershed area. This land is fairly good and suitable for occasional or limited cultivation. The area is characterized by moderately steep slope with moderate erosion, slope percentage is less than 33%. The soil contains 10-50% gravel.

Class VI 44.13 % of the study area (198.77 hectares) fall under this category. This land is suitable for grazing and agro-forestry. Some of the characteristics of such land are susceptible to severe erosion by water and with steep slopes and shallow soil. Slope percentage is greater than 33%.

Class VII This category comprises of 158.67 hectares (35.22 %) of the study area. This class has land with steep slopes, rough stone or very severely eroded soil. Slope percentage is greater than 50%. The soil is loam with 20-50% gravel or stones and occurs on very steep slopes.

4.3 Generation of alternate land use plan

Various thematic maps generated above were overlaid to arrive at an action plan (a set of suggested landuse activities) for sustainable development of the area using Geographic Information System (GIS). A database, chiefly derived from remote sensing, on natural resources such as present landuse, land capability, slope, soils, hydrogeomorphology etc were organised in different layers using Integrated Land and Water Information System (ILWIS) software. An integrated layer of Composite Land Development Units (CLDU) was created by intersecting the resources layers. A set of decision rules were applied on CLUDs to generate action plan map, showing location specific recommendations in the watershed. The comparison between the existing landuse and proposed action plan gives considerable amount of growth in vegetative cover. As can be seen from developed alternate landuse plan that there is ample scope for development of this watershed and a total of 69.94 hectare waste land can be brought under different uses. Other location specific recommendations are depicted in Fig. 9. It is to emphasise here that to achieve proposed growth in vegetation in thie watershed, additional water conservation structures such as moisture conservation pits, check dams and spring water storage tanks are required to be constructed at suitable sites. It is recommended that 50 to 100 moisture conservation pits per hectare be constructed in upper reaches of the watershed to augment spring discharge and conserve monsoon rain water. In addition to this check dams are required to be constructed at every 25 hectare upslope catchment area to store rain water for augmenting irrigation facilities and to check gully advancement. Suggested action plan landuse statistics is given in Table 5.

Table 5. Suggested landuse statistics for Danda watershed

Sl. No.	Landuse category	Area	
		Hectare	%
1.	Forest plantation	75.20	16.65 %
2.	Existing forest	103.94	23.07 %
3.	Existing agriculture land	95.83	21.27 %
4.	Agriculture (additional)	6.53	1.45 %
5.	Existing agriculture (irrigated)	26.04	5.78 %
6.	Fuel-fodder/fiber plantation	33.90	7.53 %
7.	Shrubs (existing)	25.61	5.68 %
8.	Grazing land	54.90	12.19 %
9.	Waste land	28.50	6.33 %

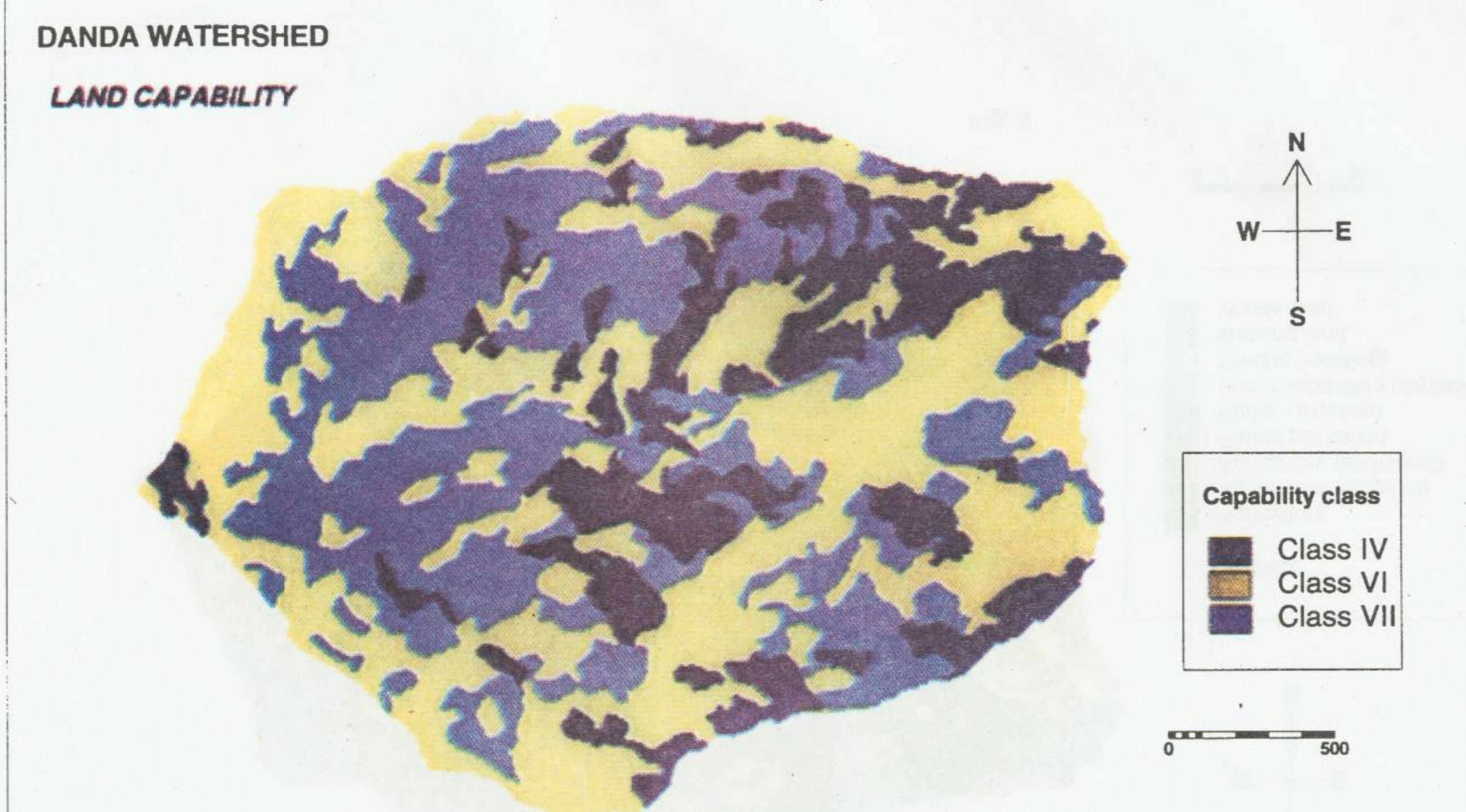

DANDA WATERSHED
LAND CAPABILITY
N
W
E
S
Capability class
Class IV
Class VI
Class VII
0
500

Fig. 8

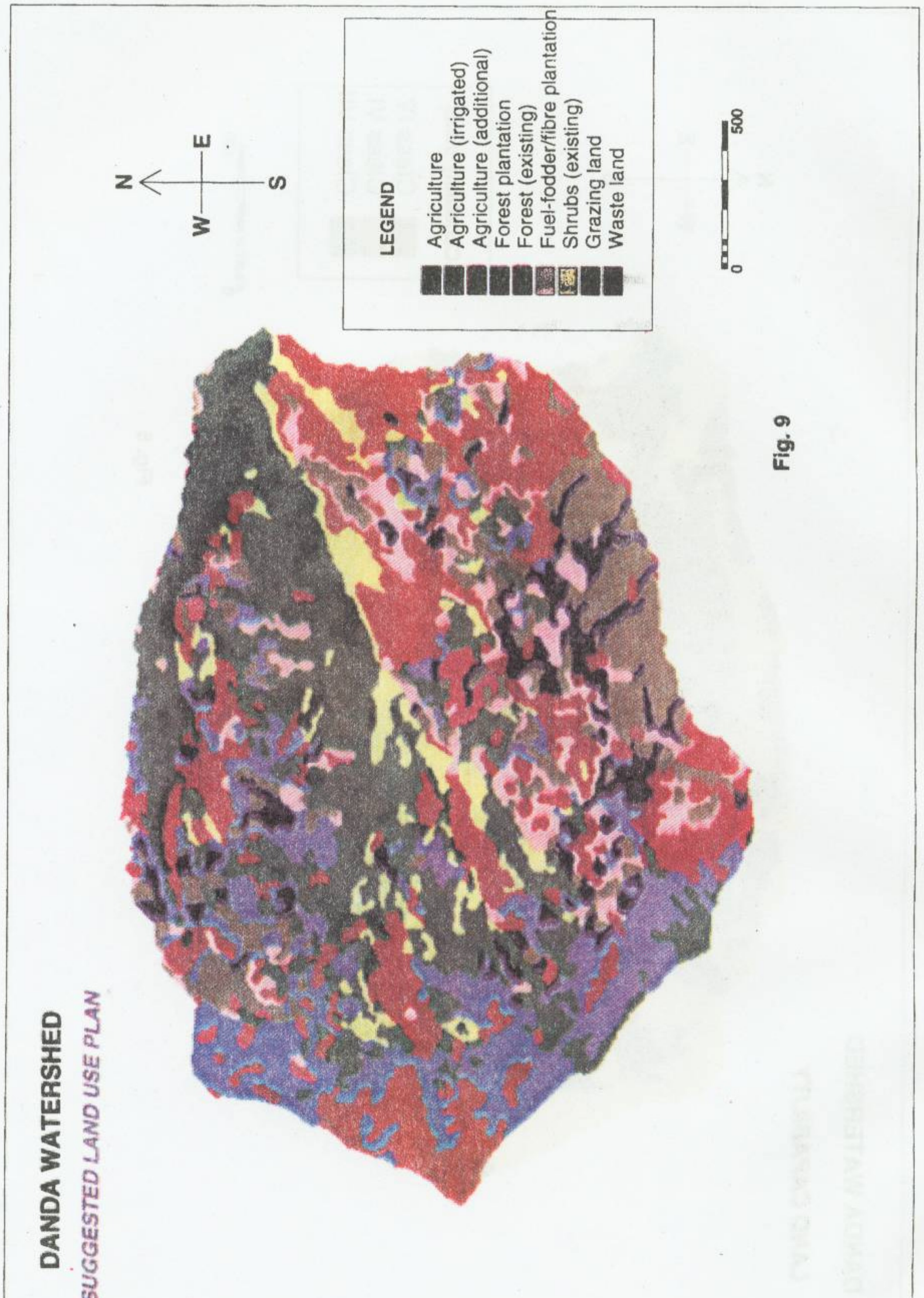

DANDA WATERSHED
SUGGESTED LAND USE PLAN
N
W
E
S
LEGEND
Agriculture
Agriculture (irrigated)
Agriculture (additional)
Forest plantation
Forest (existing)
Fuel-fodder/fibre plantation
Shrubs (existing)
Grazing land
Waste land
0
500

Fig. 9

5 CONCLUSIONS

An integrated approach where remote sensing and GIS techniques have been utilised for evaluation of catchment characteristics such as geomorphology, landuse, soil, slope etc. Quantitative analysis of geomorphological parameters of this watershed was carried out and various geomorphological parameters which are important from the hydrological studies point of view have been evaluated. The linking of the geomorphological parameters with the hydrological characteristics of the basin provides a simple way to understand the hydrologic behaviour of the different basins.

Various thematic maps generated above were overlaid to arrive at an action plan (a set of suggested landuse activities) for sustainable development of the area using Geographic Information System (GIS). A database, chiefly derived from remote sensing, on natural resources such as present landuse, land capability, slope, soils, hydrogeomorphology etc were organised in different layers using Integrated Land and Water Information System (ILWIS) software. An integrated layer of Composite Land Development Units (CLDU) was created by intersecting the resources layers. A set of decision rules were applied on CLUDs to generate action plan map, showing location specific recommendations in the watershed. The comparison between the existing landuse and proposed action plan gives considerable amount of growth in vegetative cover.

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