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Full Length Research Paper

Implications of GIS Application for the Sustainable Watershed Development in Garhwal Himalaya: A Case study of Takoli Gad Watershed, District Tehri Garhwal, Uttarakhand

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Abstract

Using Geographic Information System (GIS), Takoli Gad Watershed was studied for optimizing the present utilization of natural resource, land use, slope stability, infrastructure distribution and socio-economic status. Remotely sensed data is use to make decision and cross examine the watersheds that have contrastingly different setup, currently undergoing deforestation due to unsustainable human activities. ERDAS IMAGINE 9.1 was used for generating thematic maps and these were superimposed on different combinations for delineating the final output. The thematic maps are used for decision support and planning of the watershed. One of such remedial measure for the target area, were currently soil erosion and consequent slope instability vulnerability exists, soil conserving plants species have been recommended. The high rate of gully erosion and active river network was attributed to local geological conditions that host highly fractured and weak lithology type. The morphometric analysis has also been done to determine the role of external forces on the landform.

Key words: *GIS, Watershed Development*

Introduction

The integrated approach of Geographical Information System (GIS) and Remote Sensing is now being recognized universally as unique, highly effective and extremely versatile technology for evaluation, management and monitoring of natural resource and socio- economic database. It is a computer setup that makes it possible to view and analyze data in the form of digitized maps. GIS technology is increasingly being put in spatial decision support systems and its utilization extends from risk assessment for calamities, natural resources development, and infrastructure development to various geological studies (Saraf, 1997). In this paper GIS, as a tool in the development and measurement of watershed, is discussed with the example of a pilot studies conducted for Takoli Gad watershed.

Watershed basically for this purpose is delimited by the catchment area of the stream. Stream order systems are analyzed with the size and shape of the stream segments. The size and shape of every stream segment varies depending on physiography and anemohydrographic structure (Saxena, 1997). Hence, mostly third to fifth order stream in the watershed are treated as micro level watersheds. The present paper tries to bring out the application of integrated GIS planning and development for the watershed through the case study of Takoli Gad watershed.

The Study Area

Geographically the Takoli Gad watershed lies between 30^0 $14^{'}$ to 30^0 $23^{'}$ N latitude and 78^0 $37^{'}$ to 78^0 $46^{'}$ E longitudes in the Survey of India toposheet No. 53 J/11, 53 J/12 and 53 J/15. The watershed has an area of about 131.43 Km^2 and comes under jurisdiction of district Tehri Garhwal, Uttarakhand. The area falls in inner Garhwal lesser Himalaya and is characterized by gentle and mature topography. The Takoli Gad originates from the Eastern slope of the Chandrabadni Peak (2278 meter) and join the Alaknanda at Juyal Garh (605 meter). Jakhand and Dagar Gad are the two main sub streams / tributaries of the Takoli Gad watershed.

Methodology

The thematic maps of Takoli Gad watershed has been prepared based on Survey of India Topographic maps on the scale of 1:50,000. All the maps like location, drainage, stream order, slope, geology, geomorphology, landuse have been prepared and digitized by the help ERDAS IMAGINE 9.1. The primary data were collected for developing socio-economic database are: Demography, Occupational structure, Landholding/Livestock, Developmental activities, Education,

Natural Resources Data

GEOMORPHOLOGY	GEOLOGY	SOIL	WATER	METEROLOGY	FOREST	LANDUSE	WILDLIFE
• Slope • Elevation • Erosion type • Drainage density • Drainage frequency	• Rock • Charact eristic • Mineral resource • Chemica l comp.	• Soil type • Texture • Colour	• Source • Perinial/ Non perennial • Chemical cont. • pH value	• rain fall • temperature • relative humidity • wind feature	• Forest type • Forest product	• Cultivat ed land • Waste Land • Perman ent pasture • Settlem ent	• Wild species • Habitat • Migrati on • Source of informat ion

Natural Resources Data

DEMOGRAPHY	OCCUPATIONAL PATTERN	LAND HOLDING & LIVESTOCK	EDUCATION	HEALTH	COMM. & TRANSPORT	ELECT. DRINKING WATER	CROPPING PATTEN
• Population • Literacy • Poverty • Backward class	• Work Force • Wages • Migration	• Individual • Joint • Institutional	• Primary school • Secondary School • High School • Inter College • Higher Edu.	• Hospital • Family welfare Planning • Primary health centre • Veterinar y Dispensar y	• Post Office • Telephon e • Bus Services • Road Condt.	• Type of elect. Supply • Water supply	• Hybrid/lo cal/dry seed • Fertilizer • Pestisides

Health, Communication and Transport, General amenities, Drinking water and Electricity facilities, Social/ Cultural Practices, Land use & cropping pattern. The natural resources and socio-economic data which are used for GIS development in Takoli Gad watershed are given in the Table 1.

The digitized maps, which are available on the database, are given in the Table 2.

Table 2. Digitized thematic maps for Takoli Gad watershed on 1:50,000

Layers	Basemap	Source
• Geology	Toposheet	Lithology by field survey
• Geomorphology	Toposheet	Field observation
• Slope	Toposheet	Countour from toposheet and manual analysis
• Drainage	Toposheet	Toposheet and manual analysis
• Stream Order	Toposheet	Toposheet and manual analysis
• Landuse	Toposheet	Varified during field surveys, and satellite imagery

Application of GIS in watershed Management

A GIS is an information system that is designed to work with the data referenced by Geographic co-ordinates. In other words a GIS is both a database system with specific capabilities for spatially referenced data as well as set of operations for working with data. It is that chain of operations that takes us from planning the observation and collection of data to storage and analysis of data, to the use of the derived information in some decision making process. GIS has played an extremely important role in resource management, environment monitoring, landuse and planning activities. The GIS data include digital description of map features, logical geographical relationship among features and non-graphical data that describe characteristics of the features and phenomena that occur at geographical locations.

The concept of GIS includes land related data in the form of graphical representation , showing spatial relationships graphical data (spatial data) and uses the form of non graphical data of the land itself (attribute data). Each of these types has specific characters and different requirements for efficient data storage, processing and display (Lal et.al. 1998).

Discussion

Watershed management is widely accepted as a holistic approach for sustainable rural development. Minimum data based on agro-ecology, demography, human and animal resources, land and water resources and environment friendly technology are needed to prepare appropriate watershed development plans. In addition, the trends, analysis and the priorities of the beneficiaries, i.e. matrix ranking require to be taken into account for effective implementation of the development plans.

The entire Takoli Gad watershed covered of 67 villages. The total population of watershed is 17765 according to 2011 census. Out of which 8294 are males and 9471 are females and the numbers of household are 3488 (Table 1.3). The population density of the watershed is 135.16 persons per square km. The sex ratio of the watershed is 1141.

Table: 3. Population and literacy pattern in the Takoli Gad Watershed

House Hold	Population			Literacy			
	Male	Female	Total	Male	Female	Total	Per.
3488	8294	9471	17765	6043	4444	10487	59

Land use in the Takoli Gad watershed is determined by a number of geological and geo-morphological factors (Dutt, 1991). Topography plays a dominant role in determining the type, pattern and character of agriculture. The study area owing to its rugged topography, has given rise to almost uneven distributional pattern of land-use. The whole watershed is divided into four land use classes, which are tabulated below

Table 4. Broad Land use in Takoli Gad Watershed

S.No.	Types of Land Use	Area (in ha)
01	Agriculture Land	2825.37
	(i) Irrigated	310.66
	(ii) Non Irrigated	2514.71
02	Waste Land	2700.29
03	Non-Agriculture Land	388.62

	(i) Water Bodies	37.46
	(ii) Settlement	60.59
	(iii) Others	290.57
04	Forest	7228.9

Mostly the drainage is dendritic to sub dendritic thus indicating the profound effect of lithology even in case of young topography. Other common types of drainage patterns are contorted, rectilinear, barbed and radial.

Takoli Gad has 479 first order stream followed by 98 second order stream, further there are 25 third order, 4 fourth order, 2 fifth order and 1 sixth order stream(Fig……). Therefore, the takoli Gad watershed was considered to fall under the VIth order stream category. The streams of various orders (I^{st} to 6^{th}) were marked on the basis of Strahler's method (1952). However, streams of 3^{rd} order only, were chosen for detailed study.

Relief analysis of any terrain may be done with the help of morphometric techniques. The relief analysis of any physiographic elements can be very accurately quantified by the morphometric techniques like ruggedness number (0.88 to 4), relief ratio (0.18 to 0.70). These technique of morphometric analysis always help in diagnosing the terrain morphology to work out its morpho-units (Lal and Pal, 1990)

Table 5. Relief analysis of Takoli Gad watershed

Stage of Basin	Maximum Height (Meter)	Minimum Height (Meter)	Basin Relief	Relief Ratio	Ruggedness Number
Youth	2301	605	0.34 to 1	0.18 to 0.70	0.88 to 4

Table 6. Morphometric analysis of Takoli Gad watershed

	Drainage Density	Stream Frequency	Total Stream No.	Total length of Stream (Km.)	Bifurcation Ratio	Basin Length (Km.)	Basin Width (Km.)
	2.55 to 5.91	3.65 to 13.13	602	326.68	2 to 9	0.86 to 4.87	0.42 to 2.95
Average	4.23	8.39	-	-	5.5	2.86	1.68

The morphometric analysis of the basin (watershed) has a particular relevance to geomorphology of the area. Fluvially eroded landscapes are composed of intra basin. The morphology of the landscape is governed by the drainage of the river and its tributaries. Without studying the nature and intensity of the drainage the morphology of the landscape may not be explained. Morphology of a landscape is a function of drainage, climate and structure of the basin (Strahlar, 1964). Rock is the base, drainage is the fast agents and climate makes the suitable conditions for the drainage to make needful morphology of the rock. But the analysis of the drainage is very essential to work out its patterns, evaluation and genesis, which predict rational development of the landscape. Therefore the drainage of the whole basin has been made with the parameters like drainage density (2.55 to 5.91), stream frequency (3.65 to 13.13), stream numbers (602), stream length (326.68), stream order , bifurcation ration (2 to 9), basin area, which shows that relationship between stream frequencies with the area, it is generally observed that with the increase in area, the stream frequency also increases (Table 5). Similar results occur while setting the pair wise relationship with the total length and area of the watershed. It is observed that with increase in the area the length of stream also increases. The low degraded terrains indicate the maximum length of the watershed under youth stage, but pair-wise relationship between sinuosity and area of the basin indicates increase in the area when sinuosity index decreases. Comparing with drainage density and stream frequency it is recorded that with the increase of drainage density the stream frequency also increases.

The distribution of slopes in the Takoli Gad watershed reflects the control of geology and the cycle of erosion (Raize & Henary, 1937). The slopes have been categorized into five major slope groups i.e very gentle (less than 15^0), gentle slope (15^0-25^0), moderate slope (25^0-35^0), steep slope (35^0-45^0) and very steep slope (above 45^0). The map shows the uneven distribution of slopes throughout the entire area. The highest slope (more than 45^0) occupy very small area about 4.12 sq km. (3.04 %). This slope is confined to the higher ridges which are the remnants of old cirque head walls. The steep slope (36^0-45^0) again occupy very small area about 6.40 sq Km. (4.87 %). This type of slope present near the barsoli, Gawana, Manjuli village etc. Some cultivated land is also found on such slopes. The moderate slopes (26-35) covers an area of 31.22 sq Km. (23.75 %).These slopes are considered as most aggradational slopes. Such slopes appeared to have developed over the large accumulated colluvial material, as these slopes are in the process of continuous modification. Frequent debris flow, soil creep etc. on the valley sides are the indication of its recent origin. The gentle slopes (15^0-25^0) occupy very large area about 60.63 km^2 (46.13 %).

Agriculture practices are mostly confined on these slopes. The very gentle slope (less than 15^0) covers an area 29.06 km^2 (22.21 %) and are observed along the main valley course where the channel gradient is less and the wide valleys covered by the deposition of alluvial terraces occur, such as at Jakhand, Dugadda, Dangchaura along the main course of the Takoli Gad watershed (Table 6).

Table: 6. Slope Distributions in Takoli Gad Watershed

Slope in degree	Area in Km^2	Area in %	Cumulative %	Remarks
<15	29.06	22.21	22.21	Very Gentle
15-25	60.63	46.13	68.34	Gentle
25-35	31.22	23.75	92.09	Moderate
35-45	6.40	4.87	96.96	Steep
>45	4.12	3.04	100	Very Steep

Fig 1. Longitudinal profile of Takoli Gad Watershed

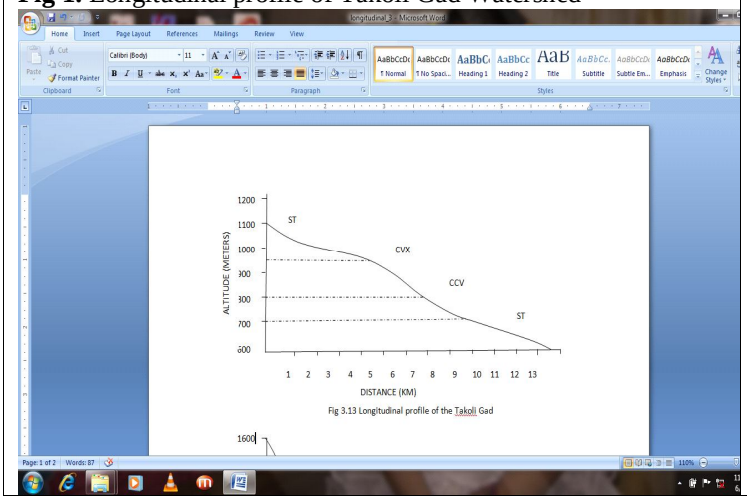
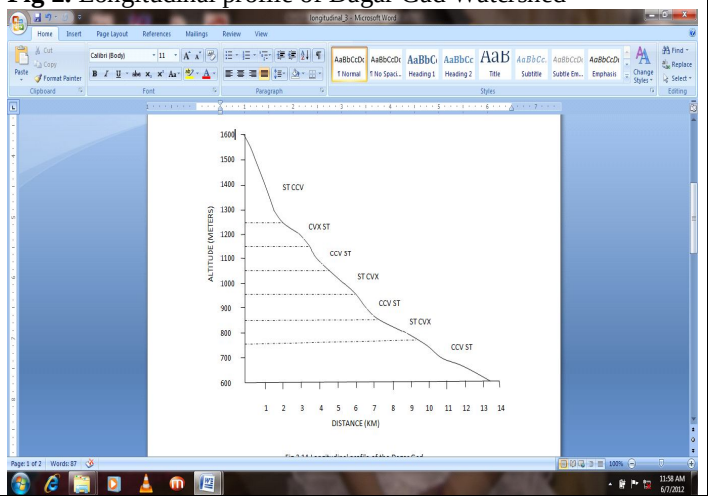


Fig 2. Longitudinal profile of Dagar Gad Watershed



The area is constituted by variety of rocks such as various types of phyllites, quartzites, basic and carbonate. The rocks of Garhwal group exposed in the study area are regionally correlated with the Damtha group (Valdiya, 1980). The phyllite rocks exposed in the middle part of the study area are correlated with Chandpur formation of Tejam group (Kumar et. al., 1974). The Khirsu quartzite is supposed to be equivalent to Nagthat formation (Auden, 1934 and 1935, and Kumar et. al., 1974).

Khirsu quartzite is hard, medium to coarse grained and grey to white in colour. The phyllites are fine grained and light green to khaki in colour. Quartzite of Garhwal group is intricately folded, ferruginous and is characterized by yellowish brown colour. It is fine to medium grained.

The carbonate rock is represented by dolomitic limestone. The rock is blue to bluish white in colour. The wide variation in lithology, structure, processes of denudation and climatic fluctuations have developed an undulating and rugged terrain containing mountain ridges and intervening deep gorges and valleys along with variety of slopes.

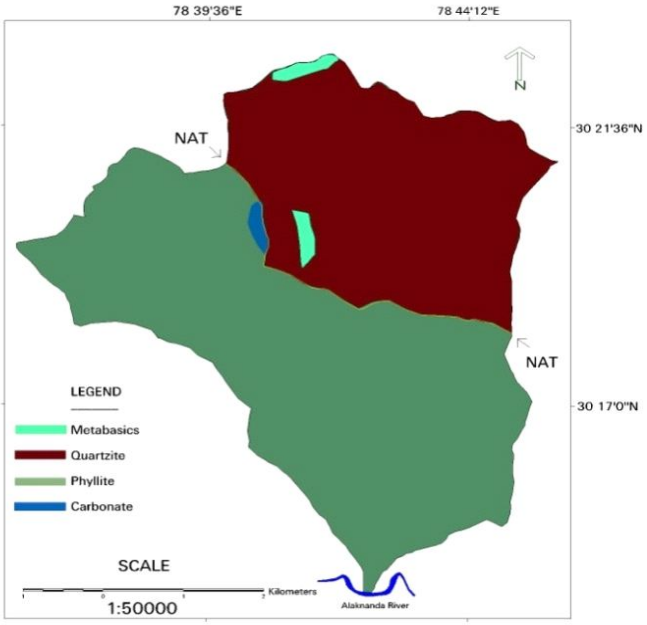
The area is characterized by various type of landforms representing the complex processes of erosion and deposition under the influence of fluvial and neotectonic activity during Quaternary period. Different phases of landform development and climatic changes have left their imprints on the terrain.

The relation of slope with landuse shows that most intensive agriculture usage is found on slopes of lower gradient. Somewhat random distribution of land not available for cultivation over moderate slopes is linked to their relatively recent appearance as a result of the conversion of forest land to more intensive usage for farming and fodder collection. Altitude and landuse study shows that patches of thick forests are confined to high altitude regions, which constitute the recharge area.

Land capability classification showed that the most of the area of watershed fall in class V to Class VIII, i.e 77.85 % which are not suitable for cultivation but very well suited to forestry, grassland and wildlife. Per capita agricultural land area of the watershed is 0.22 ha in low altitude zone, 0.14 ha in middle altitude zone and 0.12 ha in high altitudinal zone. Similar results were obtained for Mamly watershed in Sikkim as reported by Sharma et al. (1992).

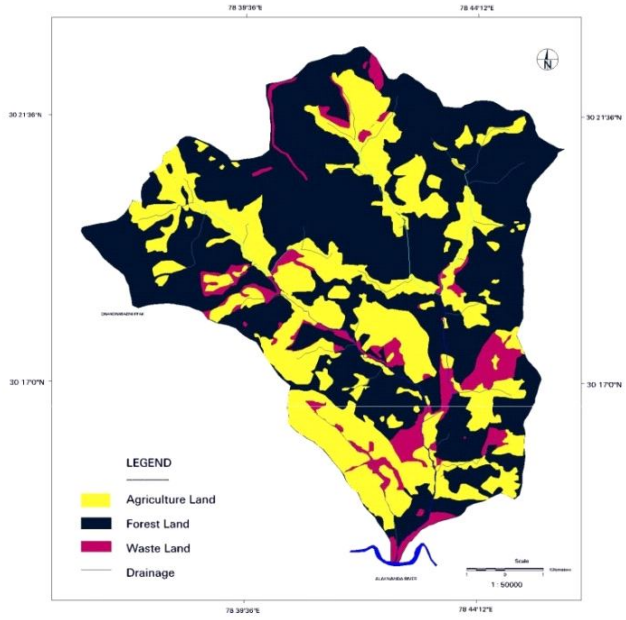
Conclusion

As discussed above that integrated approach of GIS and Remote Sensing data can play very important role in the field of planning and development of watershed. With the development and availability of fast and efficient computer and software, GIS and Remote Sensing tools are going to have more vital role to play in the natural resource development to support planning and decision-making process. Besides this, it has also been demonstrated that GIS is a good tool for watershed management to prepare the thematic maps like location, stream order, drainage, geology, geomorphology and landuse etc. The different theme layers were separately digitized for data inputs to vectorize all layers for both watersheds using the GIS technology. By superimposing the layers, the land capability classification has been made and thus data is appropriately analyzed and used for proposing some remedial measures for the degraded part of the watershed. The measures and the planning aspects would help the watershed area to develop towards more sustainable manner.



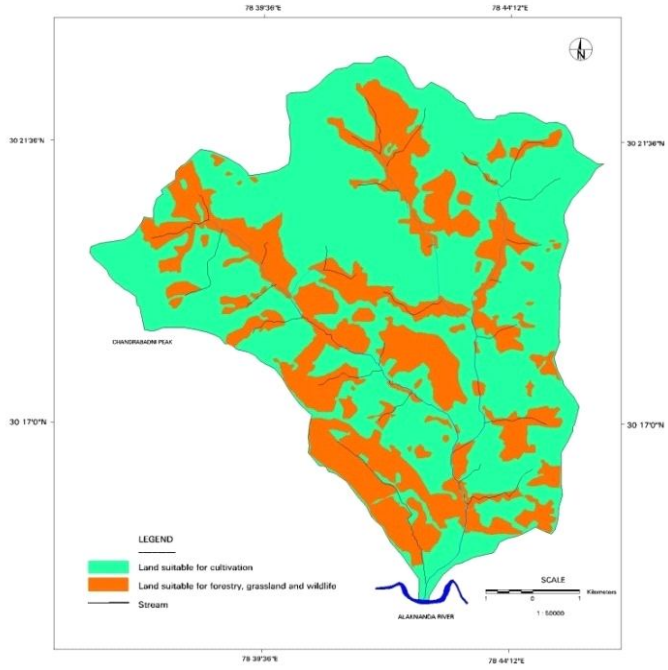
MAP 2: Geological Map of Takoli Gad Watershed

Map 1: Geological Map of Takoli Gad Watershed



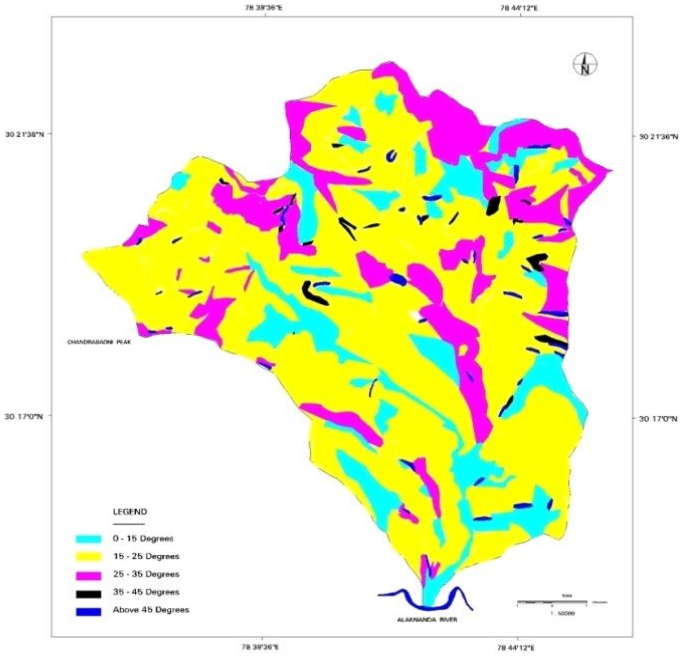
Map 9: LAND USE MAP OF TAKOLI GAD WATERSHED

Map 2: Landuse Map of Takoli Gad Watershed



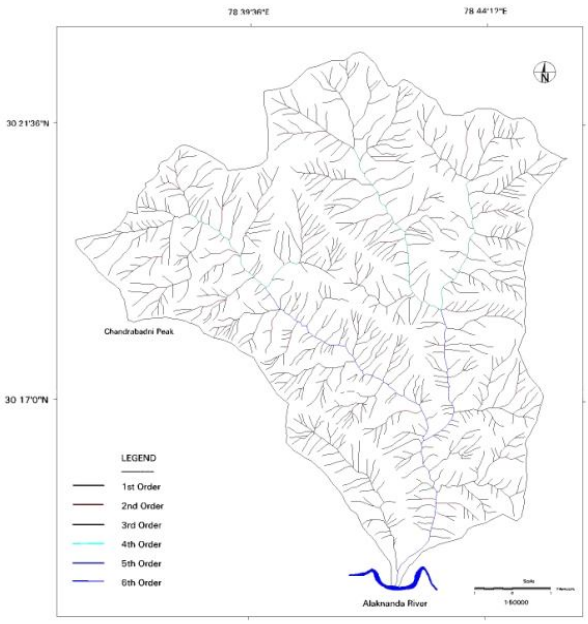
Map 10: LAND CAPABILITY MAP OF TAKOLI GAD WATERSHED

Map 3: Land Capability Map of Takoli Gad Watershed



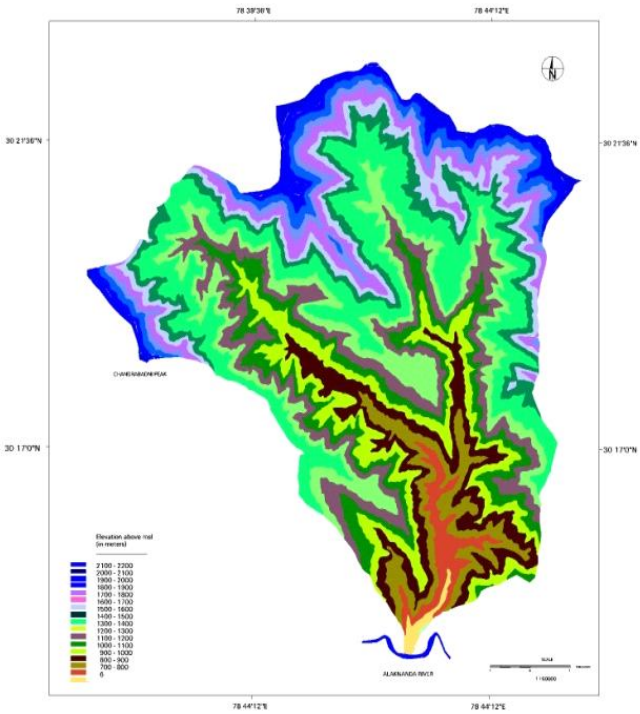
Map 6: SLOPE MAP OF TAKOLI GAD WATERSHED

Map 4: Slope Map of Takoli Gad Watershed



Map 7: DRAINAGE MAP OF TAKOLI GAD WATERSHED

Map 6: Drainage Map of Takoli Gad Watershed



Map 8: DIGITAL ELEVATION MODEL (DEM) OF TAKOLI GAD WATERSHED

Map 5: Digital Elevation Model of Takoli Gad Watershed

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