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TOPOGRAPHIC AND GEOMORPHOLOGICAL MAPPING OF RIVER SINDH
A STUDY OF HIMALAYAN RIVER OF JAMMU & KASHMIR

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Abstract

Topographic mapping is characterized by large scale detailed quantitative representation of relief. Topography is one of the most important factors in agriculture, influencing soil characteristics, water flow patterns, sediment and contaminant transport, hydrological behaviour, and irrigation methods. Consequently, topography affects crop yield, soil and water quality, and field mechanization processes. Geomorphology is the study of different landforms, which investigates the relationships between landform development and processes that shape and configure these landforms such as tectonic movement, volcanism, erosion and deposition cycles. The current study was carried out for the river Sindh that holds tremendous importance as it is the main source for drinking water, irrigation and generation of hydropower. The main objective of the present study was to characterize the Sindh catchment on the basis of topography and geomorphology. The data sets used were satellite data IRS LISS111 (2005), ASTER DEM (30m), SRTM DEM (90m), and GPS. Topographic variables like slope and aspect were derived from the ASTER DEM, whereas, Geomorphological features were derived from Arc-View 3.2 based Topographic Positioning Index (TPI). This was followed by an extensive GPS survey of the study area. The results revealed that the river has an average slope of 0-20^0 and the maximum slope in south direction. The Geomorphological studies showed five landform classes including valleys, mountain tops, high ridges, open slopes and plains. The study holds the importance keeping in view the fragile ecology and basic data needed for various others hydrological studies of the study area.

Introduction

Topographic map is a type of map characterized by large-scale detail and quantitative representation of relief, usually using contour lines . A contour line is a combination of two line segments that connect but do not intersect; these represent elevation on a topographic map. Topography is basic to many earth surface processes. It is used in analysis in ecology, hydrology, agriculture, climatology, geology, pedology, geomorphology, and many others, as a means both of explaining processes and of predicting them through modeling. Digital elevation models (DEMs) provide the basic information required to characterize the topographic attributes of terrain. The primary derived topographic parameters associated with DEMs are slope and aspect. Slope and aspect maps are used in a wide variety of applications. Slope and aspect can be used to calculate other significant topographic parameters such as upslope area and topographic index. Many algorithms have been developed to calculate slope, aspect and upslope area from DEMs. The accuracy of these parameters is dependent both on the algorithm and on the errors associated with the DEM itself. Topographic map series became a national resource in modern nations in planning, infrastructure and resource exploitation. Topographic maps have multiple uses in the present day, any type of geographic planning or large-scale architecture, earth sciences and many other geographic disciplines, mining and other earth-based endeavors and recreational uses such as hiking or, in particular, orienteering, which uses highly detailed maps in its standard requirements.

Geomorphological Mapping

Geomorphology is the scientific study of landforms and the processes that shape them. Geomorphology is therefore, the study of landforms, their origin and evolution, the investigation of relationships between landform development and processes that shape and configure these landforms such as tectonic movement, volcanism, erosion and deposition cycles (Hills 1975; Rosengren 1984: Ahnert 1998).

Geomorphology may be defined as the scientific study of the surface features of the earth's surface involving interpretative description of the landforms, their origin and development and nature and mechanism of geomorphologic processes which evolve the landforms with a view that "all landforms can be related to a particular geological process , or set of processes , and that the landforms thus developed may evolve with time through a sequence of forms dependent in part, on the relative time a particular process has been operating" (Easterrook,1969). Maps of geomorphic land units can be rich in attributes including altitude, slope, aspect, soils, climate and vegetation. This information then allows further analysis of landscape processes such as water

movement and erosion. Landforms are surface expressions of rocks, as are various features made by rivers, groundwater, waves and currents, winds, glaciers, and corals. Landforms come in all shapes and sizes. A plateau, delta, volcano
, sinkhole, and beach are all landforms.

Landscapes are shaped by geo morphological and pedagogical processes (Conacher 2002). Importantly, geomorphology provides a 'fundamental template on which landscape processes and human interactions with those processes take place' (Conacher 2002). Collection of information to support land management and land use planning programs has largely been based on Land Systems approaches. Land Systems are derived by integrating environmental features including geology, landform, climate, soils and native vegetation using an ecological approach.

Geomorphology has two general goals: 1) to explain how landforms vary from place to place; and 2) to develop theories about the origin and development of landforms. In order to achieve these goals, geomorphologists examine the nature of surface rocks and geologic processes, such as soil formation, weathering and erosion, mass movements, and transportation and deposition of sediments. They use a wide range of techniques for data collection, including field, laboratory, and numerical techniques. Geomorphologic research aids in understanding the role that landform development plays in complex ecosystems. The findings also help prepare for and lessen impacts of, Hazardous geological events, such as landslides, floods, beach erosion, and slope erosion.

Objectives of the present study were

- Topographic mapping of River Sindh using Global Positioning System (GPS).
- DEM based Geo-morphological mapping of River Sindh.

Study Area

Location

Sindh Catchment is falling in Ganderbal district. Ganderbal district has been recently carved out from Srinagar district in the state of J&K. Ganderbal is located at 34.23° N and 74.78° E. It has an average elevation of 1619 M (5312 feet). The Sind with a course of about 100Km and a basin area exceeding 1,559sq km is perhaps the most developed side valley of Jhelum. Its upper most feeders rise below the lofty peaks near Zoji-La (3256m) as a number of other head streams join from the Amaranth(5003m), Kola hoi (5425m) and Panjtarni snow fields. The main origin of river Sindh is from Panjtarni glacier Thajwas glacier is situated at an altitude of 3000m above mean sea level. The glacier is covered with the snow all the year around. It adds large amount of water to the river Sindh. Other lakes in the region that adds the water to the river Sindh includes Gadsar, Krishnasar and the famous Gangabal Lake. The study area is shown in Figure 1.

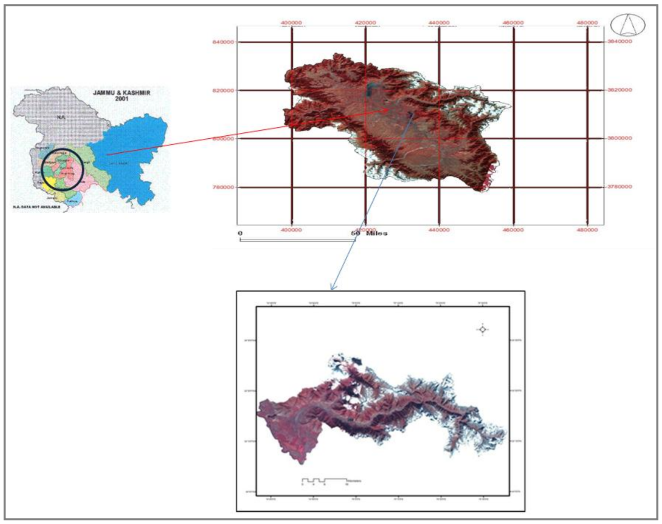

Figure 1, Study Area

Materials and Methods

Data sets used

An IRS-LISS- III of October 2005 was used to map the whole Sindh watershed, and also to digitize the spatial extent of river Sindh, which was mapped from it. Also srtm DEM of 90m resolution was also used as an input to Arcview based TPI (topographic position index). This data was used with image processing softwares viz ERADAS arcview and arcgis software.

Data Analysis

In order to achieve the objectives of study an integrated approach involving remote sensing, GIS and field surveys were employed. For the Digital image processing, Earth Resources Data Analysis System (ERDAS IMAGINE 9.1) software's were employed in order to process the LISS-III satellite images. For carrying out the GIS analysis and database generation Arc View 3.2 and Arc map 9.3 were used.

Geomorphological analysis

From the ASTER DEM (30m), the slope was generated by using model builder extension of Arc view 3.2. Aspect map was also generated using the same extension. From the ASTER DEM (30m), the drainage map was also generated using the Hydrology Extension of ArcGis9.3.the Slope map was given input to the topographic positioning index(TPI),which is an extension of Arc view 3.2 and the resulting geo-morphological map was generated. This extension calculates Topographic Position Index (TPI) grids from elevation grids, and provides a simple and repeatable method to classify the landscape into slope position and landform category using the TPI values. The TPI is the basis of the classification system and is simply the difference between a cell elevation value and ftethe average elevation of the neighborhood around that cell. Positive values mean the cell is higher than its surroundings while negative values mean it is lower. The degree to which it is higher or lower, plus the slope of the cell, can be used to classify the cell into slope position. If it is significantly higher than the surrounding neighborhood, then it is likely to be at or near the top of a hill or ridge. Significantly low values suggest the cell is at or near the bottom of a valley. TPI values near zero could mean either a flat area or a mid-slope area, so the cell slope can be used to distinguish the two. Classifying by Slope Position: TPI values can easily be classified into slope position classes based on how extreme they are and by the slope at each point A somewhat more sophisticated method, illustrated by Weiss in his poster, is to define threshold TPI values in terms of standard deviations from the elevation, which therefore take into account the variability of elevation values within that neighborhood. This means that grid cells with identical TPI value may be classified differently in different areas, depending on the variability in their respective neighborhoods. This method may or may not be useful in your analysis. You would use this method if you felt that cells with high neighborhood elevation variability should have to meet a higher TPI threshold in order to be classified into some category. As with TPI values in general, neighborhood size is also a critical component of the Slope Position classification process. Small neighborhoods capture small and local hills and valleys while large neighborhoods capture larger-scale feature.

GPS Based Topographic Mapping

GPS is a productive tool for acquiring digital terrain data where the necessary control is available and the sky is visible. It also provides useful means by which the accuracy of existing digital terrain data may be evaluated. data. From the GPS data, topographic mapping was done. More than 5000 points were taken at a distance of 10-15m away from each other. The elevation data obtained from the GPS was then compared with the ASTER and SRTM DEM's. Since the accuracy of DEMs usually is not uniform because they use various data sources in their construction. A reasonable indication about the accuracy of digital elevation models (DEM) can be obtained by the comparison with the GPS data. This was done by the determination of the Mean Deviation between the DEM's and GPS heights. The various errors in the DEM production may be approximated by different kinds of functions in order to fit the DEMs to a set of GPS points through an integrated least squares (LS) adjustment the methodology adopted in this study is shown in figure 1.1 below.

Results

Generation of Slope Map of Catchment

In the current study Aster DEM (30m) was used to generate the slope. On the basis of slope the study area has been divided into 10 classes i.e.0^o-5^o,5^o-10^o, 10^o-15^o, 15^o–20^o, 20^o-25^o, 25^o-30^o,30^o–35^o, 35^o-40^o, 40^o– 45^o and 45^o–90^o.Slope map is important for knowing the general topography of the study area.(Fig 1.2)The slope map of the study area reveal that most of the area is under the slope range of 45^o-90^o having an area of 230.3 km^2 caparisoning 13% of the total area of the catchment. This explains why there are high percentages of land under canyons and gorges found in the area. Also due to high slope river flow velocity is always very high. The least area is under the slope range of 10^o-15^o having an area of 112.41 km^2 consists of 6% of the total area of the catchment. The river Sindh falls in the slope range between 0^o-20^o.The slopes is used to compute the direction and volume of flow. In the study area, high elevated region are highly mountainous and rugged and low elevated regions are steeper.

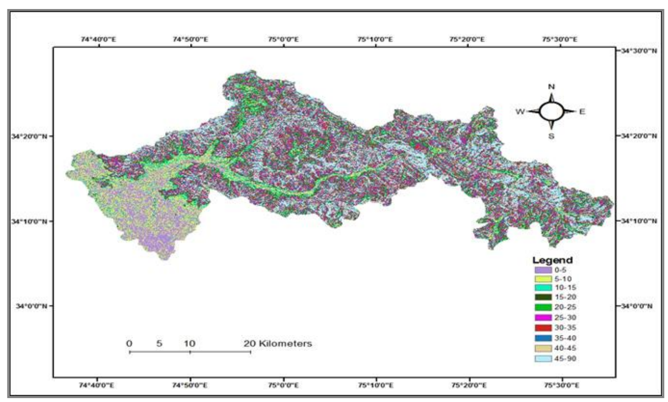

Figure 2, Slope Map of Study Area

Table 1, Statistics showing the class wise area of each slope type

CLASS	AREA(Sq. Km.)	AREA(%)
0-5	155.21	9.332
5-10	159.77	9.606
10-15	112.41	6.759
15-20	129.37	7.778
20-25	132.91	7.991
25-30	173.13	10.410
30-35	190.07	11.428
35-40	189.13	11.372
40-45	190.78	11.471
45-90	230.30	13.847

Generation of Aspect Map

After slope map aspect was derived using Aster DEM, Aspect is considered as a slope direction, it is the direction in which a unit terrain faces. The aspect map was derived to reveal the general trend of the slope in mountainous topography. On the basis of Aspect, The study area was divided into nine classes i.e. South, East, North, East North, West North, South West, South, Flat and South East. (Fig 3) shows the aspect map of the study area. The maximum aspect is in south direction having an area of 295.98km^2 and comprising 17.793% of the total catchment area. The least aspect is in Flat direction having an area of 0.59 km^2 comprising 0.035% of the total catchment area. Table 6.2 shows the statistics of aspect map.

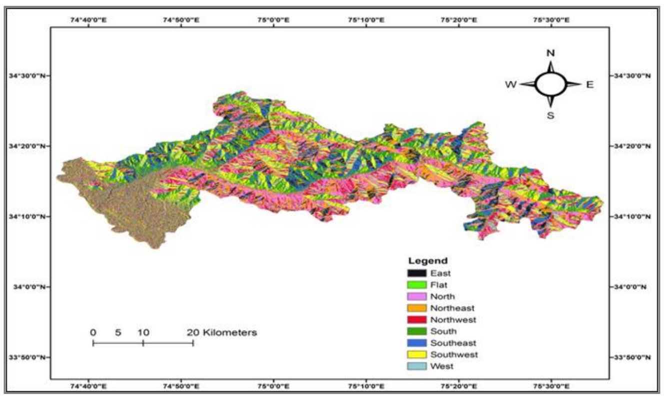

Figure 3, Aspect Map as derived from Aster DEM

Table 2, Statistics showing class-wise area of each aspect type

ASPECT	AREA(km^2)	Area (%)
FLAT	0.59	0.035
EAST	130.72	7.858
WEST	163.36	9.820
NORTH EAST	180.76	10.866
SOUTH EAST	203.75	0.122
NORTH WEST	222.64	0.133
NORTH	227.33	13.666
SOUTH WEST	238.33	14.327
SOUTH	295.98	17.793

Generation of Drainage map of Catchment

Drainage map of the study area was generated from the ASTER DEM. The map was used to plot GPS points in order to find their accuracy. The drainage of this Sindh catchment was found to be of dendritic type. It is characterized by a tree or fern-like patterns with branches that intersect primarily at acute angles. Dendritic drainage patterns are developed by random head ward erosion of streams. 4 shows the drainage of the study area, GPS points collected during the field survey to the area were overlayed over drainage map, in order to check whether the area that was mapped for drainage really exists there or not.. A drainage basin is an ideal unit for understanding the geomorphological and hydrological processes and for evaluating the runoff pattern of the streams. The drainage is important for morphometry analysis that provides the useful parameter for the assessment of the groundwater potential, surface and groundwater resource management, runoff and geographic characteristics of the drainage system.

Mathematics

Math typesetting can be done by Equation Editor, or by any other system that produces clear math types. Symbols and shorter expressions can be placed within the text, e.g., $\lambda_i \rightarrow 0$ and $P_s \leq P_r$. More complex expressions should be placed in a new line in display style:

$$P(k) = \binom{m}{k} P_1^k \left(1 - P_1\right)^{m-k} \quad (1)$$

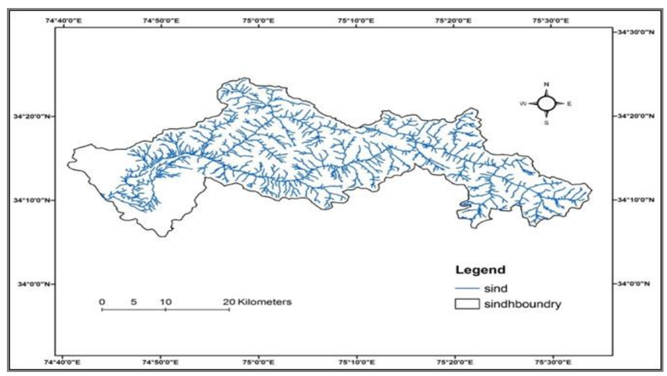

Figure 4, Drainage Map of the study area

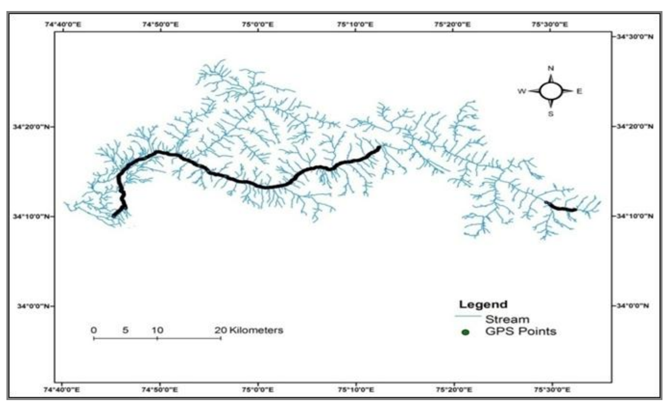

Figure 5, GPS points of field survey overlayed on drainage map

Generation of Geomorphological Map of study area Using TPI (Topographic position index)

Geo-morphology is concerned with the study of landforms which include Plateaus, Mountains, Valleys, Plains and Hills. The land-form map represents the highest level of the hierarchy Land-scape/Relief/Landform. It groups the major physiographic land elements. It involves an appreciation for processes that constantly erode or deposit materials on the earth's surface, In order to know the geomorphology of the study area, i.e. Sindh watershed, TPI (Topographic position index) was used. The TPI is used to calculate Topographic position index grids from elevation grids and generates the general geomorphology of the study area by classifying the elevation grids into various geo-morphological units viz plains, canyons, mountain tops and open slopes. This position index provides a simple and repeatable way for classifying landscape into slope position and landform category using TPI values. The most dominant class in the study area is open slopes having an area of 532.39km^{2}comparisioning of 32.009% 0f the total catchment area and least dominant class is Canyons, deeply incised streams having an area of 279.7km^2 camparisoning 16.816% of the total area. Fig 6 shows the Geo morphological Map of Sindh Catchment. Table 3 Statistics of the Geomorphological Map.

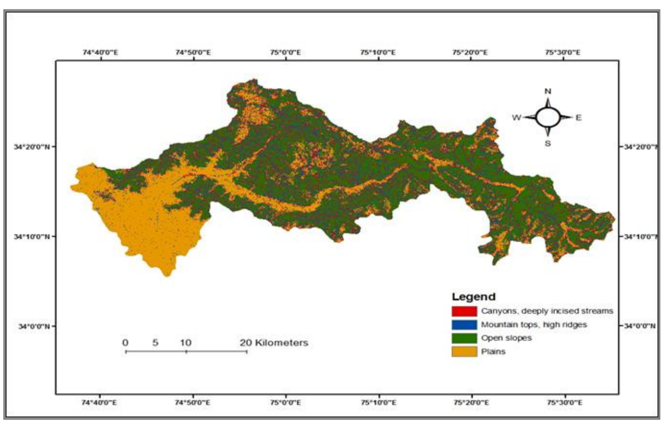

Figure 6, Geomorphological Map of Sindh Catchment

Table 3, statistics of the Geomorphological Map shows Area occupied by each class of geomorphic unit.

CLASS	AREA(km^2)	AREA (%)
Canyons, deeply, incised streams	279.7	16.816
Plains	447.97	26.933
Open slopes	532.39	32.009
Mountain tops, high ridges	403.17	24.240

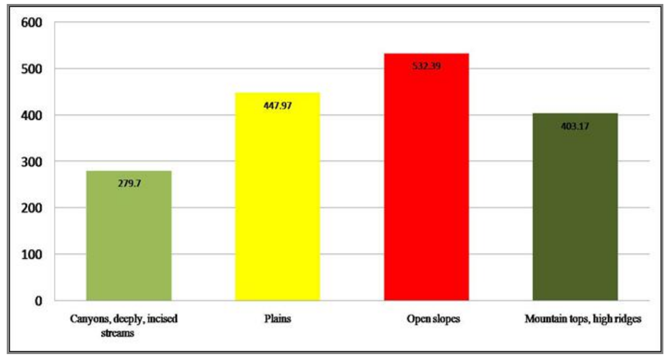

Figure 7, Bar chart of Geomorphological Map

Conclusions and Recommendations

In this study geomorphic landforms of the Sindh River were investigated with a view to understand the geomorphological processes operating in study area. The study area is one of the main tributaries of river Jhelum. Geomorphologically, the study area consists of mountain tops, plains, Canyons (Deeply incised streams) and Open slopes. The study area has a very complex and rugged topography with very high relief and steep slopes the results of, slope, aspect provide a better understanding of the geomorphic processes prevailing in the study area. Relief influences steepness, which controls the energy available for driving forces (runoff). To carry out the present study a combination field work, map study and remote sensing and GIS techniques were used. The use of GIS in geomorphological research and mapping brings an important qualitative shift. It reinforces objectivity, makes a wider verification/falsification frame. And it also gives the new possibility of more exact analysis and synthesis. Moreover GIS technology makes possible a more effective utilization of result geomorphological research in geoecology, geology and environmental applications. It is a definite world trend, which should be developed and supported systematically, it is hoped that through this study basic data necessary for hydrological modeling has been generated, which will help in forumulating a compherhesive policy for management of GLOF'S and other mountains hazards in this area.

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