Dam site selection using remote sensing techniques and geographical information system (GIS): A case study of Kurram Tangi North Waziristan

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Abstract

Pakistan is situated in the subtrophical area of the world, eighty percent of the hundred regions are dry or semi-barren since Pakistan is established. Due to high development in population increasing in water is warming situation world-wide. As a consequence, the requirement for dams has increased dramatically to meet the needs for water supply, fresh hydropower, and irrigation. Suitable dam site selection is considered among the significant tasks for water storages in District North Waziristan Former Federally Administrated Tribal Areas (FATA). This research is aimed at evaluation of potential dam site using advanced Geographic information system (GIS) and remote sensing techniques in the combination with AHP and selection of the relevant criteria and their weights calculation for optimal dam site selection. For this study, data were obtained from the shuttle radar topography mission (SRTM) 30 meter, LANDSAT-8 image, soil data and the geology data. All the layers were analyzed and reclassified giving high weightage to high suitable area and low weightage to low suitable sites. There is no uncertainty that all other variables have been taken into consideration to find the most suitable area. The result of this study illustrate 4 classes such as the highly suitable, moderately suitable, least suitable and not suitable. In last *highly* suitable site for proposed dam in the focused area indicating the pour point of the calculated dam. The sources are also suitable for multipurpose purposes, such as for irrigation, Agrarian use, flood protection, hydroelectricity in the study area.

1. Ntroduction

The growing world population, construction activity, and deforestation have disrupted river basins and manipulated many rivers and river systems. Water loss can be minimized and spared by building dam and used for various irrigation purposes to ensure local livelihoods. Dam building is one of the most effective water use techniques and offers a wide range of services for sustainable agriculture and water scarcity. The choice of the dam location is always crucial, as not only a balance between social, economic, ecological and biological compromises are required (Raza et al., 2018).

Pakistan is an agriculture country and on the other hand industry subsidizes to Pakistan's budget. For agriculture, water is a vital constituent and for industry we need constant electricity. Pakistan's irrigation system depends on delivering rivers with limited storage facilities. River stream are extremely seasonal and annual rivers are established by rain in the monsoon period. We want to build dams for agriculture and inexpensive hydroelectricity. When the manufacture of the Tarbela Dam in 1976, no main water storage schemes was ongoing. It takings an hour to track present irrigation and electricity requirements for the development of a multifunctional dam. Recent research emphases on selecting the dam location using geospatial techniques (Muhammad et al., 2013).

Site selection of dam is a difficult problem subsequently it is exaggerated by, as well as it effects, several diverse aspects including both ecological dynamics and human civilization influences. Temporarily, dams can be constructed for diverse purposes which can also prime to a broader variety of dynamics and effects. Numerous research publications are available on the area of selecting dam locations by diverse aspects as criteria, as well as consuming altered technique to measure the impacts from all criteria (Afifi *et al*., 2015).

A work was conducted of the study area consuming Geographic Information System (GIS) to indicate an appropriate location of dam, applicable in water trapping, holding water in the earth crust, joined along channels. The site selection of dam using “analytical hierarchy process” (AHP), which is one of the best elastic and simplest techniques, but influential at the similar time, for resolving Multi-Criteria Decision Analysis (MCDA) problems (Ibrahim et al., 2013).

The purpose of this study for suitable dam site selection in Kurram tangi North Waziristan district of former federally administrated tribal areas (FATA). Water accessibility is a significant constraint for irrigation and also for drinking purposes. Water insufficiency here also a concerned problem in the research area. Therefore, water usage and storage are obligatory for agrarian activities, particularly in mountain regions. The construction of multifunctional basins is significant not only to raise agricultural production, contain drought, generate electricity, but also to certify the sustainability of the soil and the shelter of livelihoods (Iftikhar et al., 2016). Selection of relevant criteria and their weights calculation for optimal dam site selection. Evaluation of potential dam site using advanced GIS and Remote sensing techniques in combination with Analytical Hierarchy Process. Cross validation and verification of the selected dam site.

2. Materials And Methods

North Waziristan district is the tribal region of the former federal administrated tribal area (FATA) before merging with Khyber Pakhtunkhwa known as North Waziristan Agency. In Former FATA the North Waziristan west boundary attached with Paktia province of Afghanistan and in the south of the North Waziristan lies South Waziristan district and in the north side of the north Waziristan lies the Kurram district and the Hangu district and on the east of the north Waziristan lies Bannu district and karak district. Geographically, North Waziristan lies among the 32.35-degree north to 33.22 degree north latitudes and 69.22 degree east to 70.38 degree east longitudes. North Waziristan total area is the 4707 squares kilometers.

- In North Waziristan five distinguished rivers which are the Kurram River, Kaitu River Tochi River Shaktue and Khaisor. Kurram River flow from koh e sofaid watershed in district Kurram flow through district North Waziristan and connect with Indus River in Isa Khel Khyber Pakhtunkhwa. There are various water streams are the Khoni Aigad, Saidgi Algad, Chashma Aigad, Sagga Aigad, Kanungo Aigad, Tauda China Algad, Tarkhobi Algad, Damoma Algad, Suedar Aigad that are flows in the north Waziristan district.
- The stream order has been obtained from the shuttle radar topography mission (SRTM) 30 meter and downloaded from the US Geological survey (USGS) in two sections to fill the total study area. The Land use data have been produced from LANDSAT – 8 satellites through Google earth imagery. The images downloaded from the US Geological Survey website.
- The secondary data have been gathered from the different department and sources to obtain the aims of the study area (Fata secretariat). The study area stream data was digitized from the scanned “Topo-Sheet” and the digitized stream is assimilated with the data gathered from the former “FATA

Secretariat" KPK, Peshawar. The geology map was acquired of the different rocks formation of the study area from the scanned "Topo-Sheet" obtained from former "FATA Secretariat" KPK, Peshawar.

The soil texture map showing different kinds of the soil of the study area which are obtained from the soil survey of Pakistan.The Land use has been acquired from former "FATA Secretariat" KPK, Peshawar that was helped in the correctness of the last results.

- The study area extracted from the Google Earth imagery is then divided into several classes by supervised classification by sampling. The sample was taken using a training sample in the menu bar. So let's save this training sample which will be used in classification when the data is disturbed. So let's "create signature" for this training sample this signature shows the way to classification. This tool takes a raster image as the input and training sample created on the image is inserted into the sample dataset of the feature. The output location is nominated for the signature file (Shao *at el.*, 2020).
- In ArcGIS hydrological tools were consumed on the Digital Elevation Model (DEM) to locate the drain network. In hydrological assessment tools are used fill sinks; flow direction and flow accumulation was recognized and after that stream was also recognized by using Stahler method (Ahmadullah, 2015).
- The filling tool was run on the pixel surface (DEM) to fill entirely basins. Subsequently there were cells in a digital elevation model, they were sinks. The Digital Elevation Model filling tool was then consumed for these sinks. That tool takings the input as a constant pixel area and returns the output area subsequently the basins must have been filled and as shown in the FIG.
- That tool regulates the stream direction of every cell in the raster. This tool utilizes a pixel area that as the input and output pixel shows the stream direction from each container at its abruptly slope of its adjacent. After that the choice "Force all cells to lose" is nominated. Totally cells on the border at the surface stream external from the raster surface.
- This flow accumulation tool analyses the accumulated stream. The stream direction raster is utilized for that as the input and output pixel indicates the assemble stream in every cell. Subsequently the input weight pixel is voluntary and the defaulting weight one is utilized and put in every cell. "An output data type is utilized as a numeral type". After accumulating the streams, after that categorize the accumulated stream into two categories to fill the higher streams and as shown in the (Fig. 3.4, a).
- This is a result where the stream system employees are assigned a numerical imperative. This technique is utilized to identify and rank flows that have been created based on the "number of branches". The "Stream Order tool" receives input from the direct grid flow system, identify the direction of the input raster stream produced by the "Flow Direction tool" and as a consequence, the output raster develops the inferred stream order. The Focus technique is utilized to sort streaming networks that interconnect the similar flow order. The linking of a primary connection and the consequent imperious leftovers a 2nd-order connection rather of establishing a connection with a 3rd order connection as shown in the (Fig. 3.4, b).
- Geology map was showing different rocks formation and the map was georeferenced and after that the geology map was digitized from the scanned map and then converted into raster data of the study area.
- The soil texture map showing different kinds of the soil and then the soil texture map was georeferenced and after that process the map was digitized and then the soil texture map was converted into raster data of the study area.
- The multi-criteria decision-analysis method is a broadly utilized method for water managing and the "Analytical Hierarchy Process" is one of those suggested by (Saaty, 1980).

3. Results And Discussions

In this study, multi-criteria analysis was used to identify suitable locations for dam site based on Streams order, slope, soil texture, land use/land cover (LULC), and geology. These parameters were assessed by different tools. After that, weights for each criterion were assigned by using AHP and weighted overlay was run to generate the suitability site selection for dam.

3.1 Hydrological Network

In a Geographic Information System environment, a reservoir modeling approach was applied where SRTM DEM was used to delimit the Kurram River basin in the study area. Strahlers law describes the flow sequence and we draw out the drainage network of the Kurram river basin. Similarly, the slop map created from Digital Elevation Model in the ArcGIS and the slope was classified from higher to lower degree value. The Digital Elevation Model himself is deliberated an elevation layer divided into five classes. The satellite image is prepared and categorized by consuming a supervised image classification method. The land use and land cover map is created in five classes, containing agriculture, built up, water bodies, barren land, and mountain. Geological map is digitizing and after keep as raster layers and the geological map is classified into five classes. In addition, the "Euclidean distance" tool in "ArcGIS" creates distance zones away from flows and the level is used later in place of the order of the flow itself and the distance from stream is classified in to five classes. Euclidean distance layer is called the reciprocal variable of the flow order. The classification of each criterion is based on expert opinion, GIS experts, literature, geographers and geologists.

3.2 Digital Elevation Model (DEM)

In the Geographic Information system GIS environment the watershed modelling techniques was applied by consuming the SRTM Digital elevation model to define the Kurram River basin in the Kurram Tangi, North Waziristan district. The Strahlers law explain the stream order and we have extracted the drainage system of the basin of the Kurram River in the study area. The elevation of the DEM is categorized into the five classes as shown in the (Fig. 3) in the Digital elevation model map. Give the suitability rank such as highly suitable, moderately suitable, less suitable, and least suitable and not suitable.

3.3 Stream Order

This is a result where the stream system is assigned a numerical imperative. This technique is used to identify and rank flows that have been created based on the number of branches. The Stream Direction tool admits input from the linear stream raster system, identify the direction of the input raster stream created by the Stream Direction tool, and consequently the output raster makes the consequent stream order. The stream order is categorized into five orders as shown in the (Fig. 4) of stream order map. Giving suitability rank to the stream order such as 1st order not suitable, 2nd order least suitable, 3rd order less suitable, 4th order moderately suitable and 5th order high suitable.

3.4 Distance from Stream

In ArcGIS the Euclidean distance tool is consumed to make distance zones from streams. Euclidean distance layers are known as the common parameter of the stream order. The distance from stream is categorized into five classes and the unit of the categorized classes in meter (m) as shown in the (Fig. 5) in the distance from stream map. Giving suitability rank to the classes such as highly suitable, moderately suitable, less suitable, least suitable and not suitable.

3.5 Slope

In ArcGIS the slope map was made from the Digital elevation model. The slope degree was categorized from high to low values, and the values from high to low are ranked as the degree unit as shown in the slope map of the study area in the (Fig. 6).

3.6 Land Use and Land Cover

The Land Use and Land Cover map was develop and categorized into five classes and the five classes contain the agriculture, barren land, water bodies, built up land and mountain of the study area as shown in the (Fig. 7) in the land use and land cover map. Giving Suitability ranks to the barren land highly suitable, water bodies moderately suitable, mountains less suitable, built up least suitable and agriculture not suitable.

3.7 Soil Texture

The soil texture map contains the different types of soil of the study area. The soil texture map categorized into six classes such as the loamy and clayey, part (no calcareous soils ustrochrepts, hoplustalfs, and ustorthents with some ustifluvents/ ustipsamments) of alluvial or loes plains/ terraces and the second is loamy and clayey, part saline soil (comborthids and torrifluvents with some solarthids/ haplatorrerts) of piedmont plains and the third is the mountains: rock outcrops and loamy very shallow soils (xerorthents and xerochrepts) velley, mainly loamy soils (xerochrepts and xerothents/ xerofluvents) and the fourth is the loamy shallow soils (ustorthents ustochrepts and haplustolls) and rock out crops valley, mainly loamy soil ustorchrepts and ustifluvents, and the fifth one is the mountains, rock outcrops and loamy very shallow soils (ustorthents and ustochrepts with little haplustoils) valley, mainly loamy soils (ustochrepts and ustorthents/ ustifluvents) and the last one is the mountains, rock outcrops with very patchy cover of heterogeneous soils materials, valley; mainly loamy, part gravelly soils (combarthids, calcierthids and torriorthents) are shown in the (Fig. 8).

3.8 Geology

The geological map was containing the different types of rocks in the study area. The rocks are the piedmont and related deposit, Eocene and Palaeocene sedimentary rocks, cretaceous intrusive rocks, cretaceous and Jurassic sedimentary rocks, alluvium and the alluvium and extrusive mud as shown in the geology map in the (Fig. 9).

3.9 Analytical Hierarchy Process (AHP)

It is describing as a comprehensive tool this participates applied and individual ideas of professionals to accomplished the “decision-making process” by evaluating multiple factors. This technique ranks each assigned factor on a scale of equivalent importance by evaluating every component beside a pairwise assessment. That study calculates the significance of the variables that was affects the potential of the water. The arranged strata are allocated weights consequent from this method and have undergone a weighted overlap analysis. On the pairwise assessment grid, the chain keeps the corresponding value of every variables and its meaning along the 2nd variable. The general pairwise assessment grid is created by stabilizing the pairwise assessment array. Next, the weights are assessed from the “arithmetic mean”. The “consistency index” is evaluated consuming the “corresponding expressions” according to the "Saaty 1980" and the "Analytical hierarchy process” (AHP) table is given below in (table.3.1).

Table 3.1
Weightage Table Analytical Hierarchy Process (AHP)

	Stream order	Slope	Dem	Land use	Geology	Soil Texture		Nth	Vector
Stream order	1.00	3.00	2.00	3.00	4.00	1.00	72.00	2.35	0.383319664
Slope	0.33	1.00	2.00	3.00	5.00	1.00	10.00	1.58	0.258282273
Dem	0.50	0.50	1.00	2.00	3.00	0.33	0.50	0.87	0.141869357
Land Use	0.33	0.33	0.50	1.00	2.00	0.50	0.06	0.56	0,091419765
Geology	0.25	0.20	0.33	0.50	1.00	0.33	0.01	0.38	0.06255447
Soil Texture	0.25	0.20	0.33	0.50	1.00	1.00	0.01	0.38	0.06
								6.14	1
Sum	2.67	5.23	6.17	10.00	16.00	4.17	82.57		
Sum*pv	1.022185772	1.35167723	0.874861036	0.914197647	1.000871525	0.260643626	5.424436835		
Lambda max	5.687167844								
Consistency Index CI		0.106109209							
RI	1.12								
CR = CI/RI	0.094740365								

3.10 Suitability map for Proposed Dam Site

The outcomes showed suitability maps for dam locations known as "overall suitability". In the suitability map there are four classes such as "highly suitable, moderately suitable, least suitable and not suitable". The map was acquired by counting in the analysis the Euclidean distance layer as the reciprocal of the current order layer. In the reclassified “Euclidean distance layer”, the distance to streams was divided into four classes, and all variables including slope, elevation, stream order, distance from stream, soil texture, geology and land use, and land cover on the map. The resulting map showed a high suitable area at the bottom of the study area where the flow orders was very low. There is no uncertainty that all other variables have been taken into consideration to find the most suitable area, the lower section with the most appropriate slope. The sources are also suitable for multipurpose purposes, such as for irrigation, Agrarian use, flood protection, hydroelectricity in the study area. The classes show such as the highly suitable, moderately suitable, least suitable and not suitable in the (Fig. 4.10) in the suitability map of the study area. In last obtained suitable site selection for proposed dam in the focused area and indicate the pour point of the calculated dam in the focused area is ground validated from the Google earth images and there is in the focused area the action delay dam is present and with the all aspect and variables choose the multi-purpose dam in the focused area which are shown in the suitability map.

4. Conclusions

The consequence created suitability map for dam site selection in Kurram Tangi North Waziristan district in former FATA and the suitability map for suitable dam site are categorized into four classes highly suitable, moderately suitable, least suitable and not suitable in the study area.

The results of the study can help in the development strategies and policies for proposed suitable dam site in the North Waziristan district and address the water storage issue by the Government of Pakistan, Pakhtunkhwa energy development organization and non-governmental organization.

The current study proposes a new dam suitability model, built on the integration of Geographic Information System, remote sensing and Analytical Hierarchy Process and multi criteria decision analysis, to find a possible location for the construction of the suitable dam in the Kurram river Basin in North Waziristan district former FATA. The selection of the suitable site for dam consists on the different parameters such as digital elevation model, stream order, slope, land use and land cover, soil texture and geology of the study area. Dam Suitability Stream Model Usages Analytical Hierarchy Process to give weights to every parameter, with the highest weight assigned to the most important variable of the Dam Suitability Stream model. The weighted overlay analysis aggregates total important variables in the form of raster map with their respective calculated weights, which led to the suitability map. The consequences indicated the "Overall suitability" map based on order of flows and distance from stream. The finding of the suitability map is categorized into four classes of suitability such as highly suitable, moderately suitable, least suitable and not suitable in the study area.

Declarations

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Figures

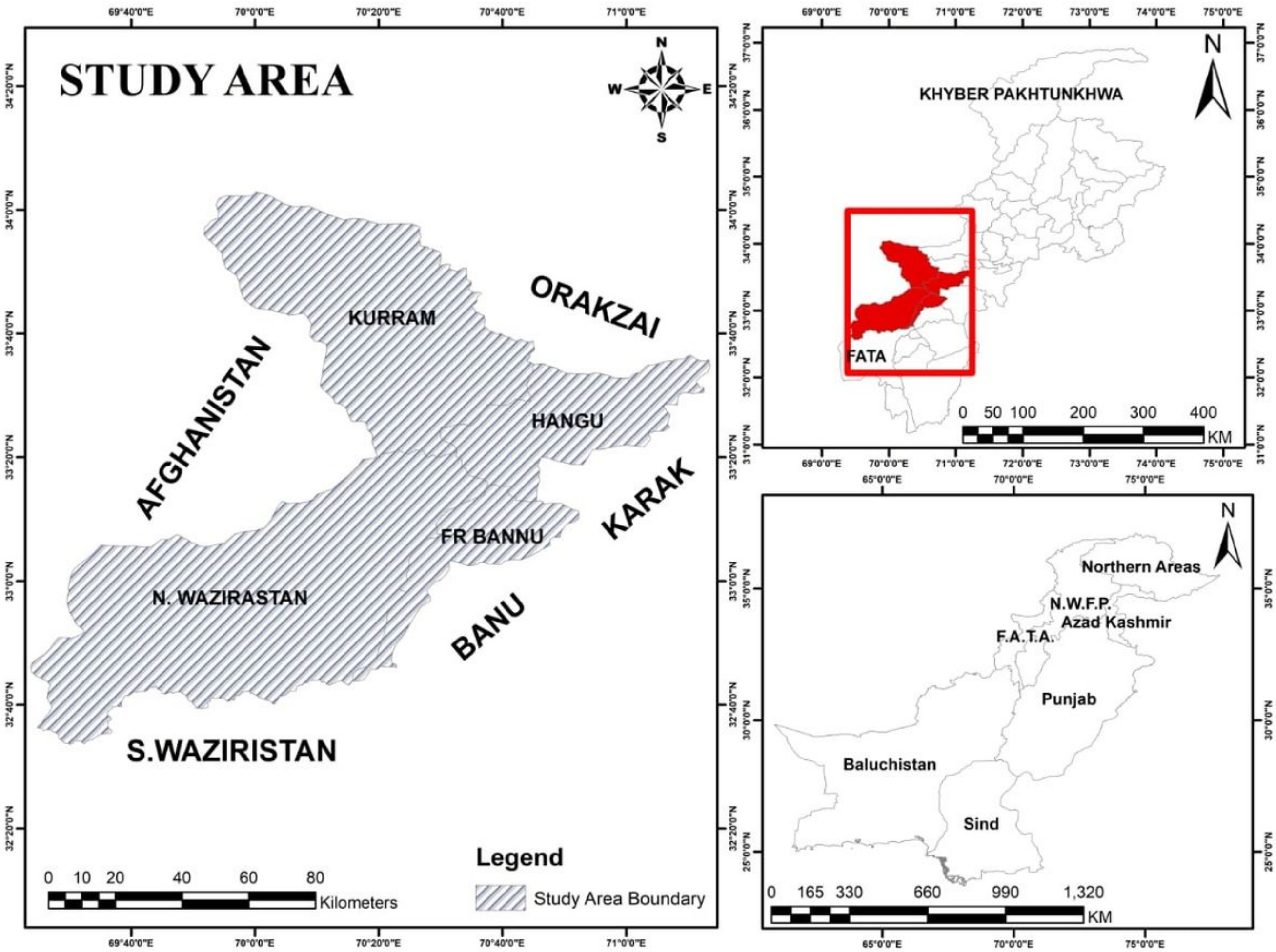

Figure 1

Study Area Map

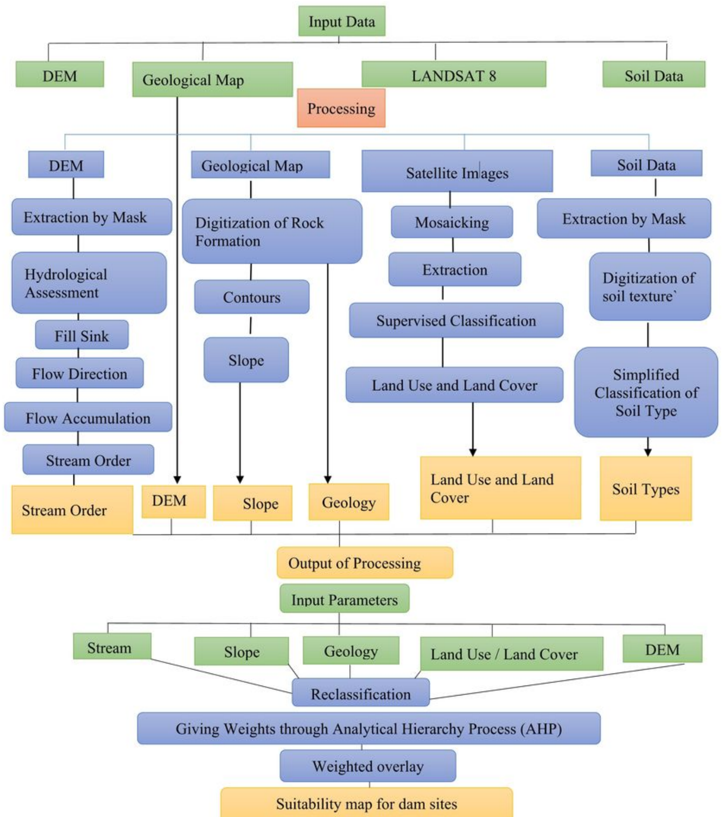

Figure 2

Flow Chart of the Study area

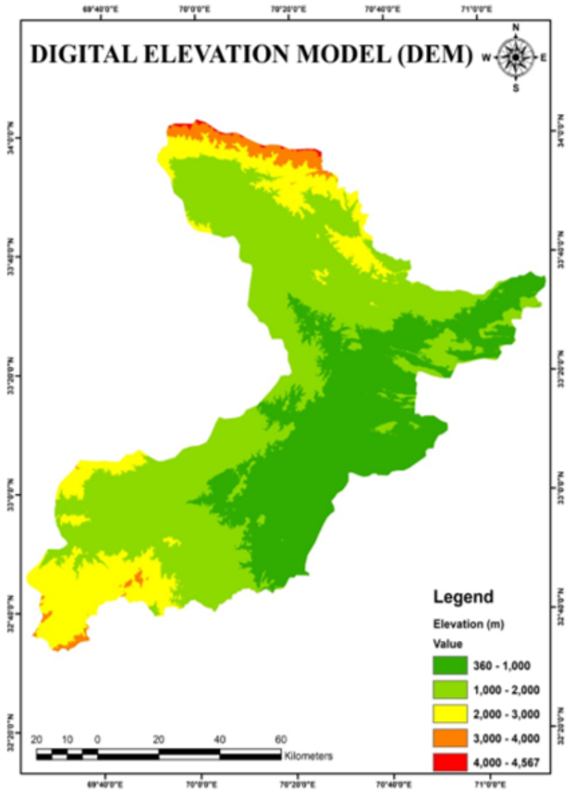

Figure 3

Digital Elevation Model

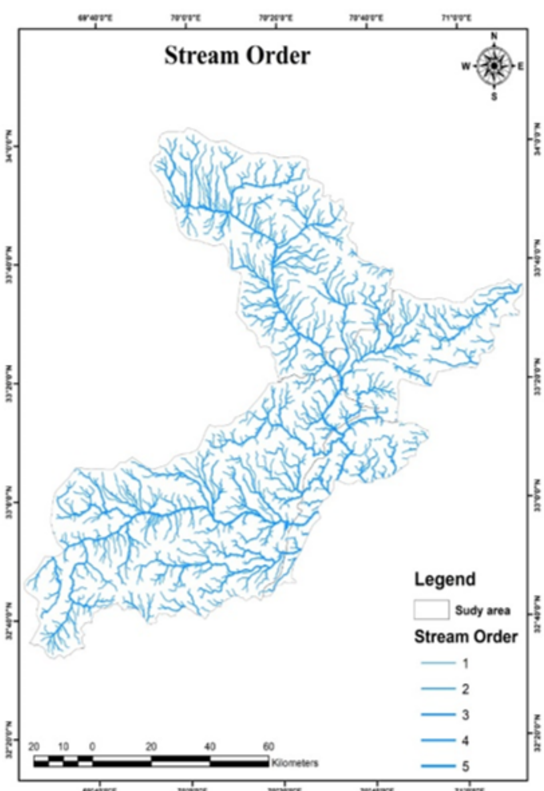

Figure 4

Stream Order

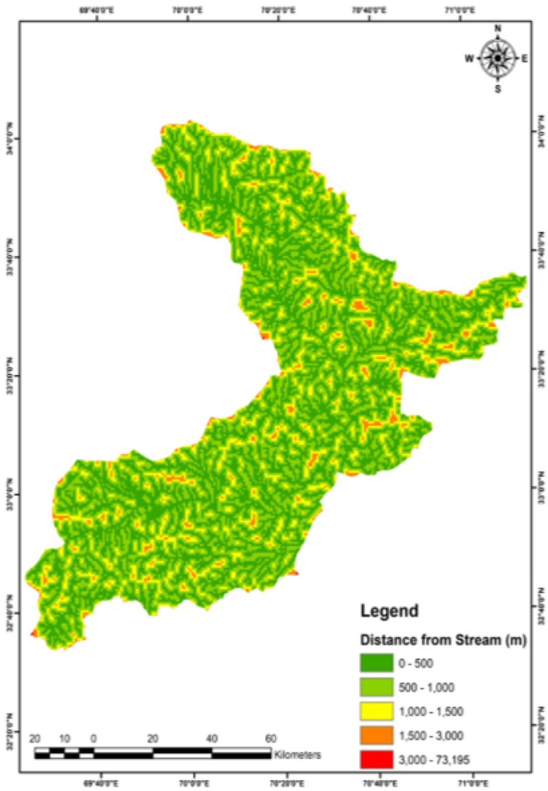

Figure 5

Distance from Stream

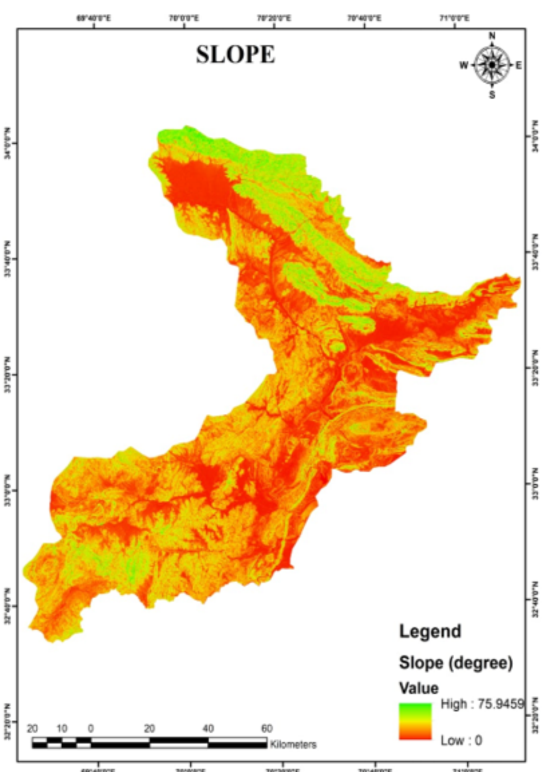

Figure 6

Slope

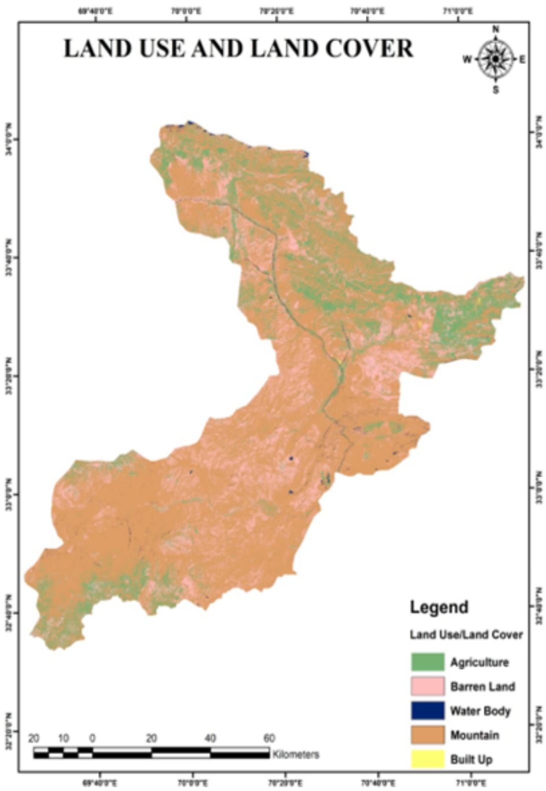

Figure 7

Land Use and Land Cover

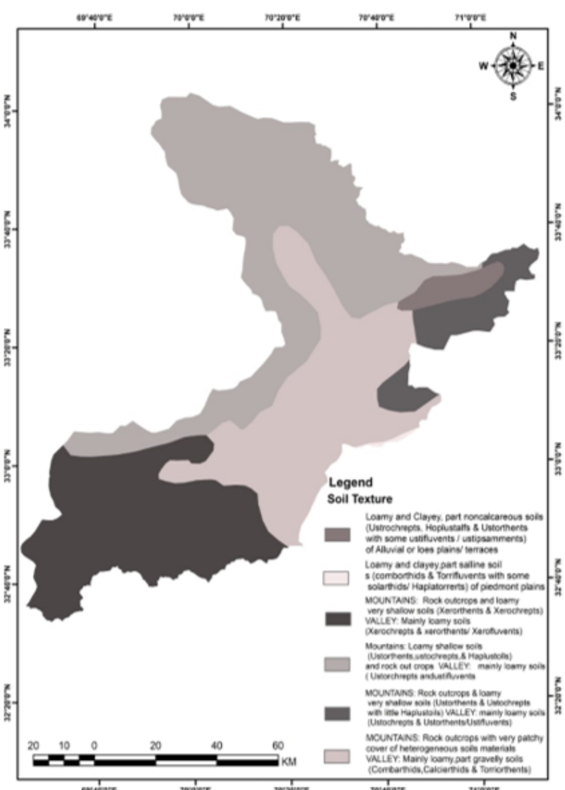

Figure 8

Soil Texture

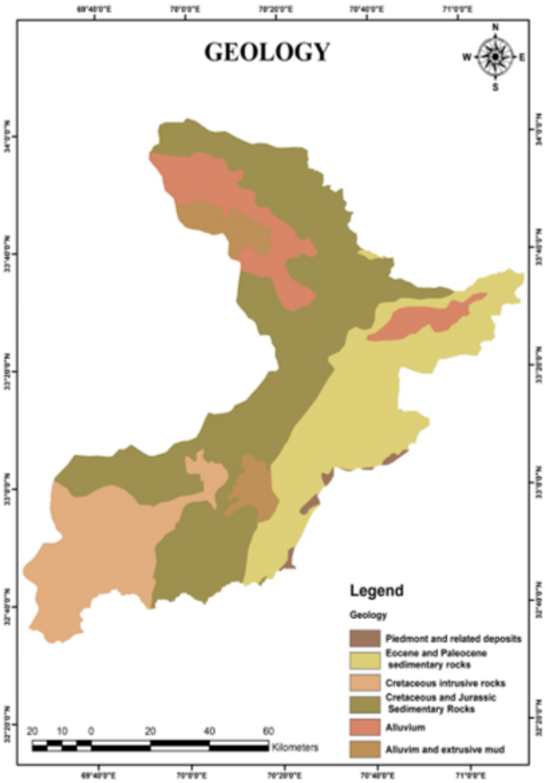

Figure 9

Geology

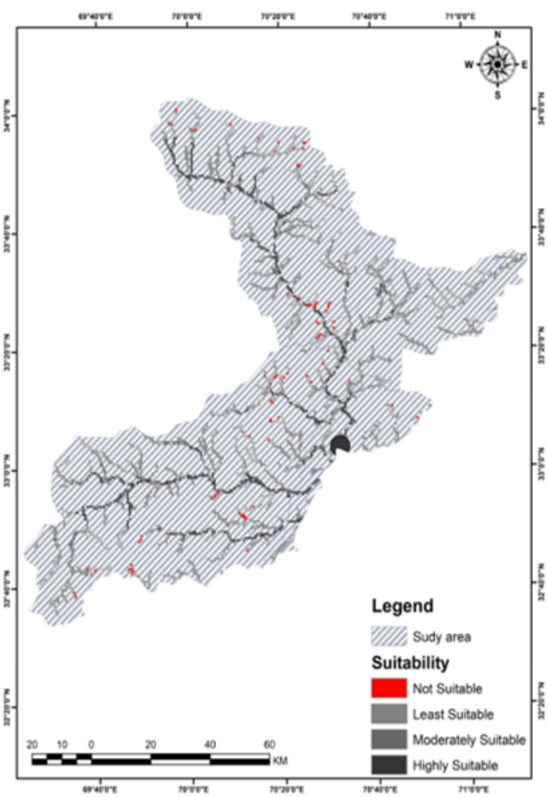

Figure 10

Suitability Map