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Using Multi-Mission Satellite Elevation Data for Delineation of Gilgit Watershed in Pakistan in Geographical Information Technology Environment

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Abstract: The hydro-climatological variations in Gilgit watershed of Upper Indus basin is less scientifically understood due to diverse geography, remoteness of the region and larger variations in climatic conditions. Extraction of catchments at multiple scales is an important task in undertaking the watershed management studies. Satellite remote sensing (SRS) and geographical information technology (GIT) provide a very useful method to study the watersheds. In view of the facts, watershed/ natural resources management in Gilgit river basin, application of geospatial techniques to various elevation datasets is required in order to obtain more accurate results using these elevation datasets. To achieve this goal, the topographic feature extraction has been studied in the catchment of Gilgit river using different Digital Elevation Models (DEMs) viz., SRTM, ASTER GDEM and GTOPO30. Several small watersheds for the Phakor, Karamber, East Gammu, Bhort and Bad-e-Swat glaciers were delineated for the basin definition. The delineated watersheds have been visually analyzed against the optical Landsat 8 OLI imagery for mountainous ridge matching. The results revealed that, SRTM 30m (radar based) exhibited more accuracy among these DEMs because of its precise delineation in the Gilgit sub-basin. However, it is appropriate to say that computed area from all three DEMs generally show close agreement. This study is a good contribution towards better understanding of the watershed management and the hydrological responses in Gilgit watershed of the upper Indus catchment.

Keywords: Gilgit, glacier, sub-basin, watershed, catchment, remote sensing, geoinformatics.

Introduction

The typical profile of any basin drainage, quantitatively, can be investigated by calculations of linear, relief and aerial aspect (Pareta and Pareta, 2011). Drainage morphology of basin as well as sub-basins in various parts of the earth has been assessed via geomorphologic conventional approaches (Rai et al., 2017). Geographical information technology (GIT) / geographical information system (GIS) approaches with different satellite data have allowed the feasible stage for analyzing morphometric factors and topography of a drainage network (Wakode et al., 2013). Morphometric study of drainage network is very useful and feasible in assessment of hydro-climatological variations, flood risk management, watershed management and water resource potential (Ahmad et al., 2018). However, it is difficult to study all drainage networks through ground observation or from survey caused by their range all over uneven terrain in the massive region particularly in rocky areas (Huggel et al., 2002). Recognition of drainage system within basin as well as sub-basins can be accomplished using highly developed methods such as Digital Elevation Models (DEMs) including Shuttle Radar Topography Mission (SRTM) and Advanced Space-born Thermal Topography Mission and Global Elevation Model (ASTER-GDEM). These DEMs have been utilized to analyze drainage system, Gilgit basin area and micro-watershed boundaries delineation (Ali et al., 2017; Pareta and Pareta, 2014).

Study area

Gilgit watershed is an important source which is situated in the northern region of Pakistan. It lies between longitude 72°25'02" E to 74°19'25" E and latitude 35°46'05" N to 36°51'16" N (Fig 1). The geographical watershed area is 13,552 sq.km and elevation varies between 1388 to 6722 m (Ali et al., 2017; 2019). The area altitude distribution and hypsography of the Gilgit watershed is shown in Figure 1. The glaciers are mainly distributed between 3500 to 5500 meters of elevation. The study area contains six major valleys including Gupis, Puniyal, Phandar, Gilgit, Ishkoman and Yasin. Moreover, three small rivers i.e., Phandar, Yasin and Ishkoman merge into Gilgit river (Ali et al., 2019; Mukhopadhyay and Khan, 2015). The hydro-climatological studies of the Gilgit region are sparsely found in the published articles and bibliography. The region is poorly gauged with only 5 meteorological stations in the region which include Gilgit, Gupis and WAPDA met stations at Shandure, Ushkore and Yasin (Adnan et al., 2017; Hasson et al., 2017). This station density is much lower than in technologically advanced countries as in Switzerland. There is one station per 475 square km for temperature and one per 100 square km for precipitation (Gubler et al., 2017). Due to remoteness of the region and larger variations in climatic conditions, northern region is scientifically under-explored. The glacier inventory of Pakistan (2017) developed by SUPARCO mentions that there are 979 small and large glaciers with total glacier area of 1022 square km in Gilgit river basin.

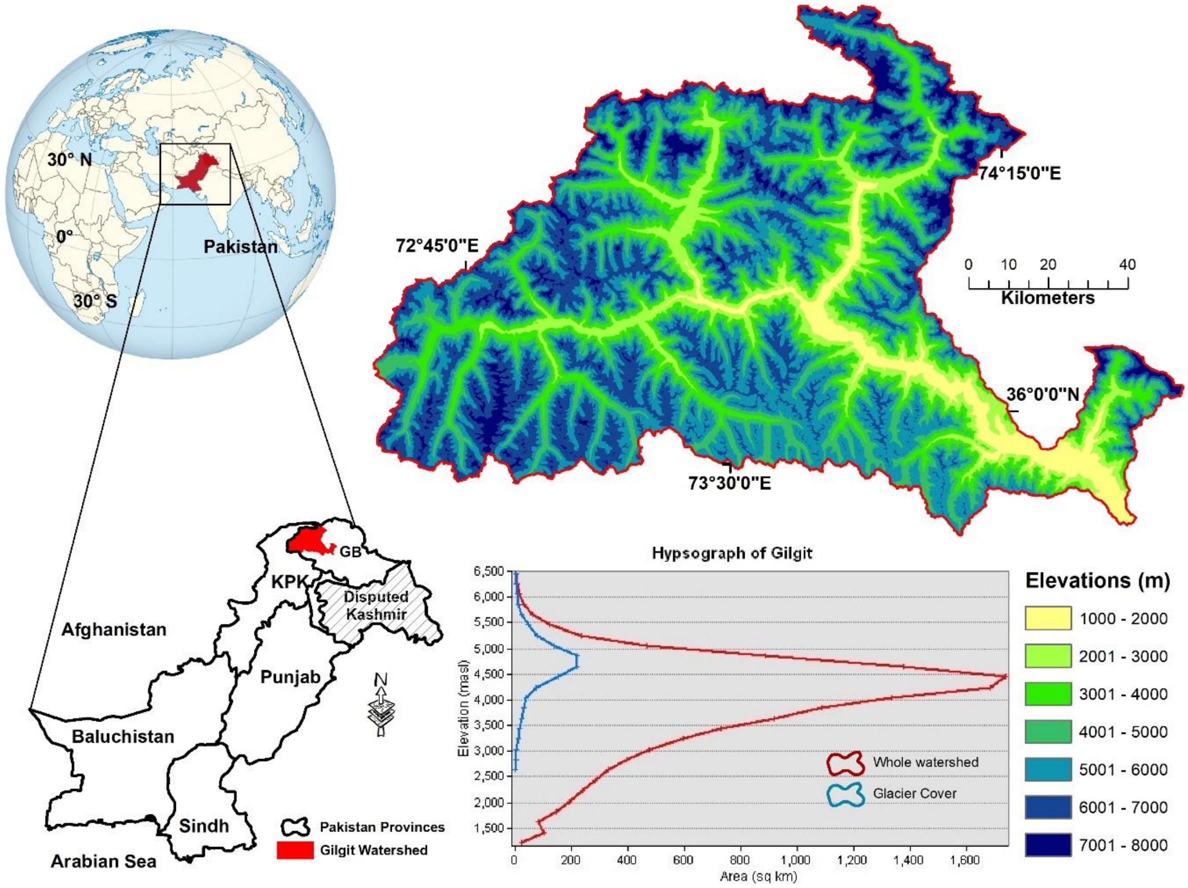

Fig. 1 Study area.

Notably large glaciers in the Gilgit river basin are Phakor, Karamber, East Gammu, Bhort and Bad-e-Swat.

Moreover, most areas in northern Pakistan are vulnerable to flash floods, supraglacial lakes, glacier lake outburst floods and landslide (Kanwal et al., 2017; Qaisar et al., 2019; Rahim et al., 2018). The present study aims to compare watershed delineation via different DEMs data by using numerous utilities from the Spatial Analyst toolbox in ArcGIS and to determine the delineation of watersheds by number of upstream points and flow direction in GIT/GIS environment for each grid point in a DEM. This delineation is executed by reconditioning of DEMs in different phases including watershed delineation, creation of shape file of pour point and snapping of pour points.

Materials and Methods

In this study several DEMs have been used including high resolution SRTM, ASTER GDEM and coarse resolution GTOPO30. There are several methods for delineated of watersheds which have been studied. The most appropriate is hand delineation, which is based on information of contour, demonstrated on topographic maps (Al-qaysi, 2016). Literature survey shows that, there are many advance approaches in GIT (or GIS technology) but this method is still used for creating a digital watershed dataset (Gregory et al., 2003). The pre-processing of terrain has been undertaken for watershed basin processing and delineation of the study area.

The methodological framework in sequential manner includes a). DEM processing for whole Gilgit region,

Table 1 Satellite data used in this study.

Sr	Imagery ID	Sensor	Date of Acquisition :: Publication reference	Coordinates/ Row/Path	Resolution
1	SRTM1N35E074V3	SRTM	23-SEP-14 :: JPL-NASA (2014); Farr et al., (2007)	35, 74	1 arc second ~30 m
2	ASTGTMV003_ N35E074	ASTER GDEM	2000-03-01 to 2013-11-30 :: Tachikawa et al., (2011)	35, 74	30 m
3	GT30E060N40	GTOPO30	1-12-1996 :: Denker (2005); USGS-EROS (1996)	15, 80	30 arc second ~1000 m

b). extraction of DEM for Gilgit study area, c). filling voids / DEM gaps, d). extraction of flow directions, e). extraction of flow accumulations, f). catchment grid delineation, g). catchment polygon conversion, h). neighboring catchment processing and i). computing watershed area. This is the methodological framework in a sequential order. In late 2008, ASTER GDEM was released and claimed to be the best available elevation dataset for the scientific community, especially for climate applications (Hayakawa et al., 2008; Shafiq et al., 2011; Tachikawa et al., 2011). The satellite data used in this study for delineating watersheds in the Gilgit river basin are shown in Table 1.

The function basin and watershed function is used to evaluate the flow direction by DEM for watershed delineated. The conventional approach usually comprises to estimate aspect, slope and shaded relief by using neighborhood tool in numerous raster process systems and points of inflection. However, aspect, slope and inflection information are closely related to overland flow and watersheds, finding direction of flow in large flat region non-neighborhood limitations are occurred (Jenson and Domingue, 1988; Jenson, 1991; Taylor, 2016).

The topographic evaluation is necessary to delineate watershed or basin. This topographic information acquired from DEMs which are useful to get terrain information in a group of applications including landslides, surface analysis for hazards, glacier change analysis, creation of relief maps, glacier monitoring and mapping, avalanches, damage and risks evaluation and many other studies.

The first reconditioned DEM of Gilgit river basin was done by filling the depressions in DEM including to generate a depression less DEM. The 2nd stage is to calculate the flow direction of every cell in depression less DEM. The flow direction indicated the path where water runs from a cell by using D-8 method.

The 3rd reconditioning stage of DEMs is to calculate flow accumulation of every cell. Moreover, evaluation has been done in which the flow accumulation of DEM in each down slope cell has been estimated. This suggested that, the quantity of upstream cells that flow in them. The cell occupied area of concentrated flow has been used to identify the stream channels. Zero value of flow accumulation of cells shows that, no other cell flow with the related cell which characterized the pattern ridges.

Results and Discussion

The extracted Gilgit watershed based on ASTER GDEM 30 m is shown in Fig 2 (a). It covers a total area of about 12757.446 km^2 with elevation allocation ranges from 1388 m to 7104 m. This watershed has an average of peaks at an elevation of 4051.94 m. Furthermore, Fig 2 (b-f) displays the delineated watersheds (in red polygons) of Bad-e-Swat, Bhort, East Gammu, Karamber and Phakor glaciers having areas 49.410 km^2, 54.698 km^2, 42.730 km^2, 223.916 km^2 and 20.356 km^2 respectively.

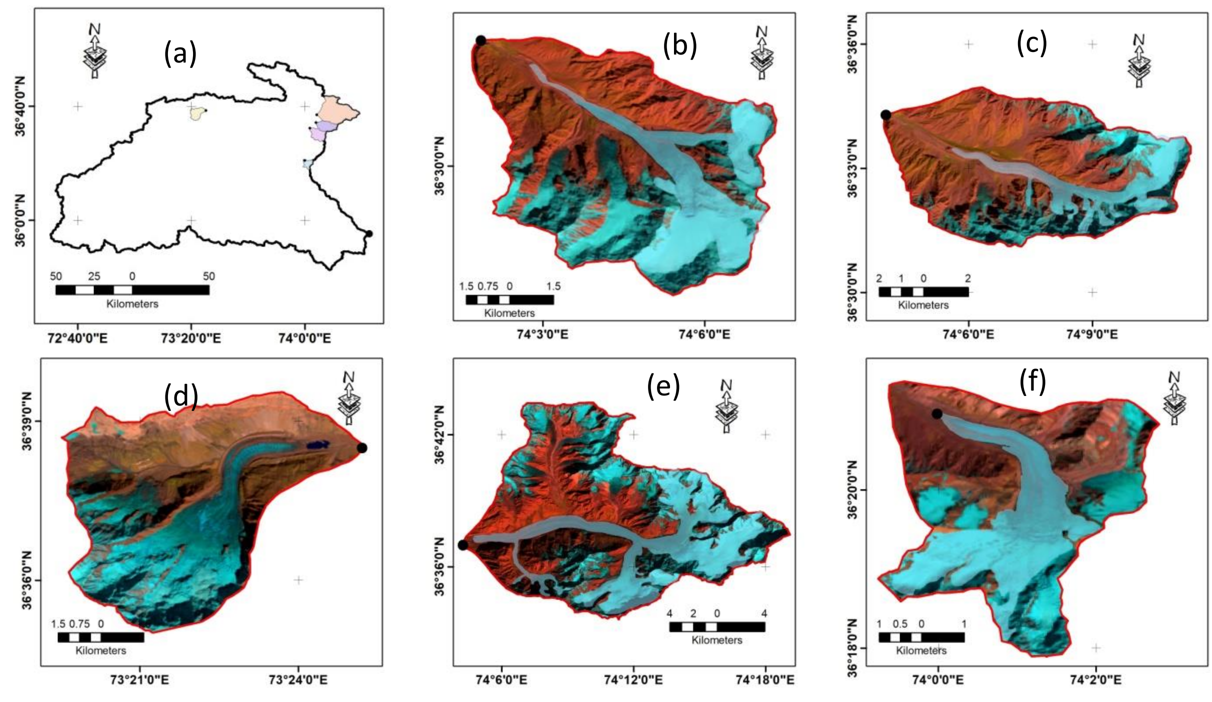

Fig. 2 Delineated watersheds based on ASTER GDEM 30 m (a) Gilgit basin, (b) Bad-e-Swat glacier, (c) Bhort glacier, (d) East Gammu glacier, (e) Karamber glacier, (f) Phakor glacier.

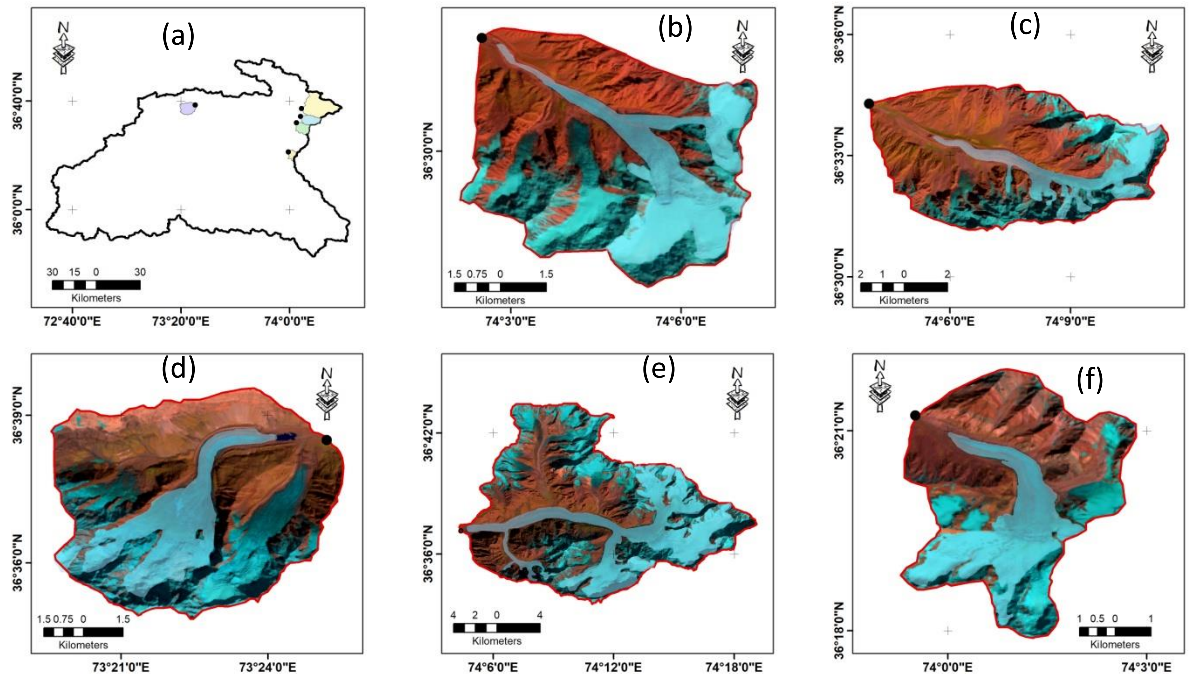

Fig. 3 Delineated watersheds based on SRTM 30 m a) Gilgit basin, (b) Bad-e-Swat glacier, (c) Bhort glacier, (d) East Gammu glacier, (e) Karamber glacier, (f) Phakor glacier.

The locations of the watersheds of individual glaciers (Fig. 2b-f) are included in the Gilgit watershed (Fig. 2 a). The extracted Gilgit watershed based on SRTM 30 m is shown in Figure 3a which covers a total area of about 12760.996 km^2 with elevation ranges from 1405 m to 7114 m. This watershed has an average of peaks at an elevation of 4046.626 m. Furthermore, Figure 3 (b-f) display the delineated watersheds (in red polygons) of Bad-e-Swat, Bhort, East Gammu, Karamber and Phakor glaciers having areas 45.914 km^2, 57.781 km^2, 57.781 km^2, 223.807 km^2 and 24.077 km^2 respectively. The comparison of computed area from different DEM datasets is shown in Table 2.

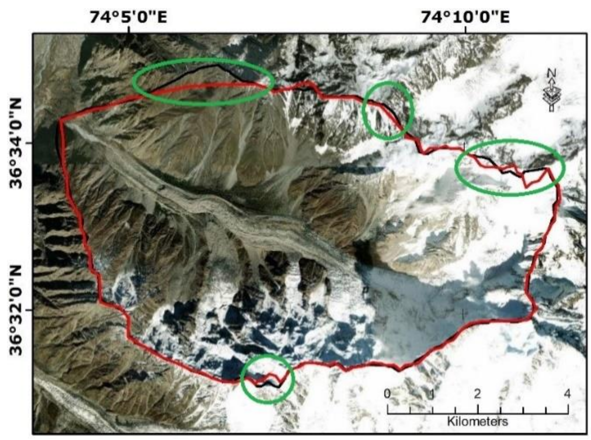

Fig. 4 Bhort glacier – Polygons from Fig 2-c and Fig 3-c are combined to highlight mismatches) for the comparison of watersheds derived from SRTM (Red) and ASTER-GDEM (Black)

The differences of the watersheds from different DEMS are shown in Figure 4. The red polygon represents watershed from SRTM (1 arc sec) and black polygon represents watershed from ASTER-GDEM. There are many mismatches highlighted in circles along the watershed of Bhort glacier. Both watersheds have been visually analyzed against the optical Landsat 8 OLI imagery for mountainous ridges matching. The results revealed that, SRTM 30m (radar based) exhibited more accuracy among these DEMs because of its more precise delineation.

The Gilgit watershed has also been extracted from a special DEM named GTOPO30 which is a 30-arc second DEM equivalent to 1000 m spatial resolution. GTOPO30 has been used in several studies for performing the corrections and calibrations with SPOT derived DEMs and the SRTM (e.g., Endreny et al., 2000; Denker 2005). The delineation of the Gilgit sub-basin results a covered total area of 12760.996 km^2 with elevation distribution ranging from 1405 to 7114 meters above sea level.

Table 2 Comparison analysis of DEMs (all areas are in km^2).

DEM dataset	Gilgit basin	Bad-e-Swat	Bhort	East Gammu	Karamber	Phakor
SRTM	12760.996	45.914	53.857	57.781	223.807	24.077
ASTER GDEM	12757.446	49.410	54.698	42.730	223.916	20.356
GTOPO30	12711.14	-	-	-	-	-

The comparison analysis between SRTM and ASTER GDEM has been done by matching the extracted area of watershed for Gilgit basin and different glaciers. The results revealed that, SRTM 30m exhibited more accuracy among these DEMs because of its precise delineation in the Gilgit sub-basin as analyzed in combination with optical remote sensing imagery. However, it is appropriate to say that attributes and features for both DEMs generally show close agreement to each other.

Conclusion

A catchment, watershed or drainage system is the hydrological unit together by drainage lying upslope from a pour point or specific outlet. The watershed extracting characteristics are important for water resource management and hydrological analysis in GIT/ GIS including catchment delineation and stream network.

Focusing on the problems of ridges mismatch in watershed delineation in the mountainous regions. This paper has introduced DEM-based delineation's comparison with multi-sensor, multi-mission DEM datasets at multi-resolution viz., SRTM, ASTER GDEM and GTOPO30 using the pre-defined method to complete watershed delineation. The comparative analysis was employed for the delineation of drainage and watershed at the basin level and further at the sub-catchments of 5 large glaciers viz, Phakor, Karamber, East Gammu, Bhort and Bad-e-Swat. The delineated watersheds were visually analyzed against the optical Landsat 8 OLI imagery for mountainous ridge matching. It is concluded that SRTM 30m (radar based) is more accurate for this region.

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References

Adnan, M., Nabi, G., Poomee, M. S., Ashraf, A. (2017). Snowmelt runoff prediction under changing climate in the Himalayan cryosphere: A case of Gilgit River basin. *Geoscience Frontiers*, **8** (5), 941-949.

Ahmad, S., Israr, M., Liu, S., Hayat, H., Gul, J., Wajid, S. (2018). Spatio-temporal trends in snow extent and their linkage to hydro-climatological and topographical factors in the Chitral river Basin (Hindukush, Pakistan). *Geocarto International*, 1-24.

Al-qaysi, N. H. H. (2016). Delineation of the Watersheds Basin in the Konya City and Modelling by Geographical Information System. *Journal of International Environmental Application and Science*, **11** (3), 303-311.

Ali, K., Bajracharya, R. M., Sitaula, B. K., Raut, N., and Koirala, H. L. (2017). Morphometric Analysis of Gilgit River Basin in Mountainous Region of Gilgit-Baltistan Province, Northern Pakistan. *Journal of Geoscience and Environment Protection*, **5** (07), 70-88.

Ali, K., Bajracharya, R. M., Chapagain, N. R., Raut, N., Sitaula, B. K., Begum, F., et al. (2019). Analyzing Land Cover Change Using Remote Sensing and GIS: A Case Study of Gilgit River Basin, North Pakistan. *International Journal of Economic and Environmental Geology*, **10** (1), 100-105.

Denker, H. (2005). Evaluation of SRTM3 and GTOPO30 terrain data in Germany. *Gravity, Geoid and Space Missions* (pp. 218-223). Springer, Berlin, Heidelberg.

Endreny, T. A., Wood, E. F., Hsu, A. (2000). Correction of errors in SPOT-Derived DEM's using GTOPO30 data. *IEEE Transactions on Geoscience and Remote Sensing*, **38** (3), 1234-1241.

Farr, T.G., Rosen, P.A., Caro, E., Crippen, R., Duren, R., Hensley, S., Kobrick, M., Paller, M., Rodriguez, E., Roth, L. and Seal, D., (2007). The shuttle radar topography mission. *Reviews of Geophysics*, **45** (2) 1-13.

Gregory, I. N., Arts, and Service, H. D. S. H. D. (2003). *A place in history: A guide to using GIS in historical research*: Oxbow Oxford.

Gubler, S., Hunziker, S., Begert, M., Croci-Maspoli, M., Konzelmann, T., Brönnimann, S., Schwierz, C., Oria, C. and Rosas, G., (2017). The influence of station density on climate data homogenization. *International Journal of Climatology*, **37** (13), 4670-4683.

Hasson, S., Böhner, J., Lucarin, V. (2017). Prevailing climatic trends and runoff response from Hindukush–Karakoram–Himalaya, upper Indus Basin. *Earth Syst. Dyn.*, **8**, 337–355.

Hayakawa, Y. S., Oguchi, T., and Lin, Z. (2008). Comparison of new and existing global digital elevation models: ASTER G-DEM and SRTM-3. *Geophysical Research Letters*, **35** (17) L17404.

Huggel, C., Kääb, A., Haeberli, W., Teysseire, P., and Paul, F. (2002). Remote sensing based assessment of hazards from glacier lake outbursts: a case study in the Swiss Alps. *Canadian Geotechnical Journal*, **39** (2), 316-330.

Jenson, S. K. (1991). Applications of hydrologic information automatically extracted from digital elevation models. *Hydrological Processes*, **5** (1), 31-44.

Jenson, S. K., Domingue, J. O. (1988). Extracting topographic structure from digital elevation data for geographic information system analysis. *Photogrammetric Engineering and Remote Sensing,* **54** (11), 1593-1600.

Kanwal, S., Atif, S., Shafiq, M. (2017). GIS based landslide susceptibility mapping of northern areas of Pakistan, a case study of Shigar and Shyok Basins. *Geomatics, Natural Hazards and Risk,* **8** (2), 348-366.

Mukhopadhyay, B., Khan, A. (2015). A reevaluation of the snowmelt and glacial melt in river flows within Upper Indus Basin and its significance in a changing climate. *Journal of Hydrology,* **527** (8), 119-132.

Pareta, K., Pareta, U. (2011). Quantitative morphometric analysis of a watershed of Yamuna basin, India using ASTER (DEM) data and GIS. *International Journal of Geomatics and Geosciences,* **2** (1), 248-269.

Pareta, K., Pareta, U. (2014). New watershed codification system for Indian river basins. *Journal of Hydrology and Environment Research*, **2** (1), 31-40.

Qaisar, M., Shafiq, M., Ghauri, B. M. K., Younes, I., Abuzar, M. K. (2019). Comparative analysis of different remote sensing techniques for mapping of supraglacial lakes on Hispar glacier. *International Journal of Economic and Environmental Geology*, **9** (2), 66-74.

Rahim, I., Ali, S. M., Aslam, M. (2018). GIS based landslide susceptibility mapping with application of analytical hierarchy process in district Ghizer, Gilgit Baltistan Pakistan. *Journal of Geoscience and Environment Protection*, **6** (2), 34-49.

Rai, P. K., Mohan, K., Mishra, S., Ahmad, A., Mishra, V. N. (2017). A GIS-based approach in drainage morphometric analysis of Kanhar River Basin, India. *Applied Water Science,* **7** (1), 217-232.

Shafiq, M., Santos, B., Alexandra Perez, A., Blank, C. (2011). Enhancing global climate data exchange to better monitor climate change and empower policy makers, scientists and the community. *Paper presented at the 62nd International Astronautical Congress*, Cape Town.

SUPARCO, and ITP-CAS. (2017). Glacier Inventory of Pakistan: Pakistan Space and Upper Atmosphere Research Commission, SUPARCO Road, P.O. Box No. 8402, Karachi-75270, First edition, volume 1.

Tachikawa, T., Hato, M., Kaku, M., Iwasaki, A. (2011). Characteristics of ASTER GDEM version 2. In 2011 *IEEE International Geoscience and Remote Sensing Symposium,* 3657-3660.

Taylor, R. G. (2016). A comparison of mixed integer programming and a heuristic approach for harvest blocking in Australia: Mississippi State University.

JPL-NASA (2014). U.S. releases enhanced shuttle land elevation data". JPL-shuttle radar topography mission. Retrieved 11 January 2020.

USGS EROS (1996) Digital elevation - Global 30 Arc-Second Elevation (GTOPO30), DOI number: 10.5066/F7DF6PQS Retrieved 11 January 2020.

Wakode, H. B., Dutta, D., Desai, V., Baier, K., Azzam, R. (2013). Morphometric analysis of the upper catchment of Kosi River using GIS techniques. *Arabian Journal of Geosciences,* **6** (2), 395-408.