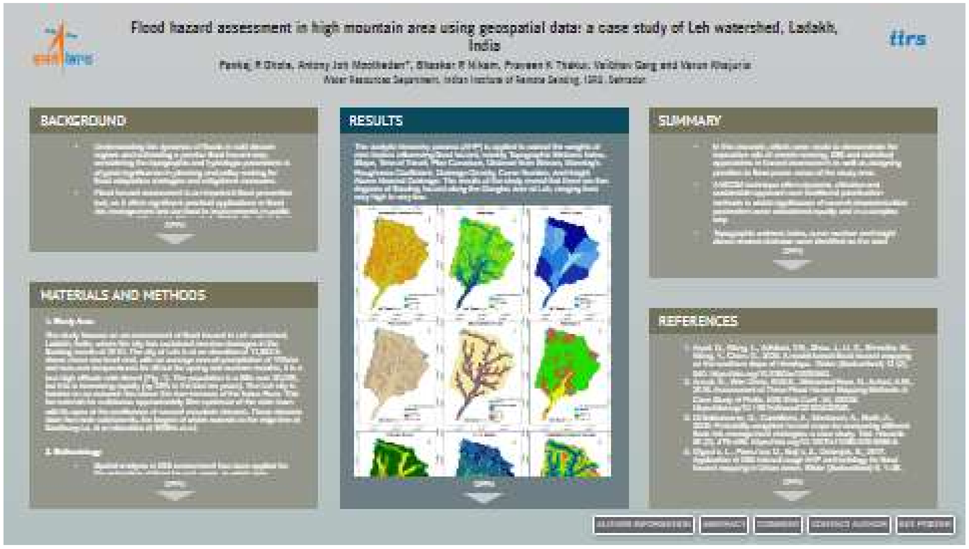
Flood hazard assessment in high mountain area using geospatial data: a case study of Leh watershed, Ladakh, India



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PRESENTED AT:

BACKGROUND

- Understanding the dynamics of floods in cold dessert regions and estimating a precise flood hazard map considering the topographic and hydrologic parameters is of great significance in planning and policy making for flood adaptation strategies and mitigations measures.

- Flood hazard assessment is an important flood prevention tool, as it offers significant practical applications in flood risk management and can lead to improvements in public awareness of flood risk (Yang et al., 2018). The flash flood disaster system is complex, and includes disaster causing factors, disaster-pregnant environments, and disaster-bearing bodies. It has the characteristics of high nonlinearity, spatial-temporal dynamics, and uncertainty, and coupling of various challenges in the system may produce extremely complex phenomena (Wei et al., 2001).

- The classical method for analysing flood-prone areas with different risk levels is based on the application of hydrological-hydraulic modelling. However, model simulation methods require much more high-quality data, as the relevant calculations are very complex. Also, the process is largely time consuming and expensive.

- Multi Criteria Decision Analysis (MCDA) method is a modelling and methodological tool for dealing with complex problems. The analytic hierarchy process (AHP) has a demonstrated ability to assess and map flood risk with good accuracy (Danumah et al., 2016). However, one of the limitations of AHP is its high subjectivity in choosing the weights for each factor since it is significantly affected by the expert's experience and knowledge

MATERIALS AND METHODS

1. Study Area

The study focuses on an assessment of flood hazard in Leh watershed, Ladakh, India, where the city has sustained massive damages in the flooding events of 2010. The city of Leh is at an elevation of 11,562 ft. above mean sea level and, with an average annual precipitation of 100mm and sub-zero temperatures for all but the spring and summer months, it is a true high altitude cold desert (Fig .1). The population is a little over 30,000, but this is increasing rapidly (by 25% in the last ten years). The Leh city is located on an outwash fan above the river terraces of the Indus River. This fan extends for a distance approximately 5km upstream of the main town with its apex at the confluence of several mountain streams. These streams drain five main catchments, the largest of which extends to the ridge line at Kardhung La, at an elevation of 5359m m.s.l.

2. Methodology

- Spatial analysis in GIS environment has been applied for the estimation of flood hazard zones, in which nine relevant physical factors have been selected namely, curve number, slope, time of travel, height above nearest drainage, topographic wetness index, plan curvature, drainage density, distance from stream and manning's roughness coefficient.
- In order to achieve the objective, multicriteria decision analysis is used to build a flood hazard map of the study area. The analytic hierarchy process (AHP) is applied to extract the weights of nine factors influencing flood hazard.

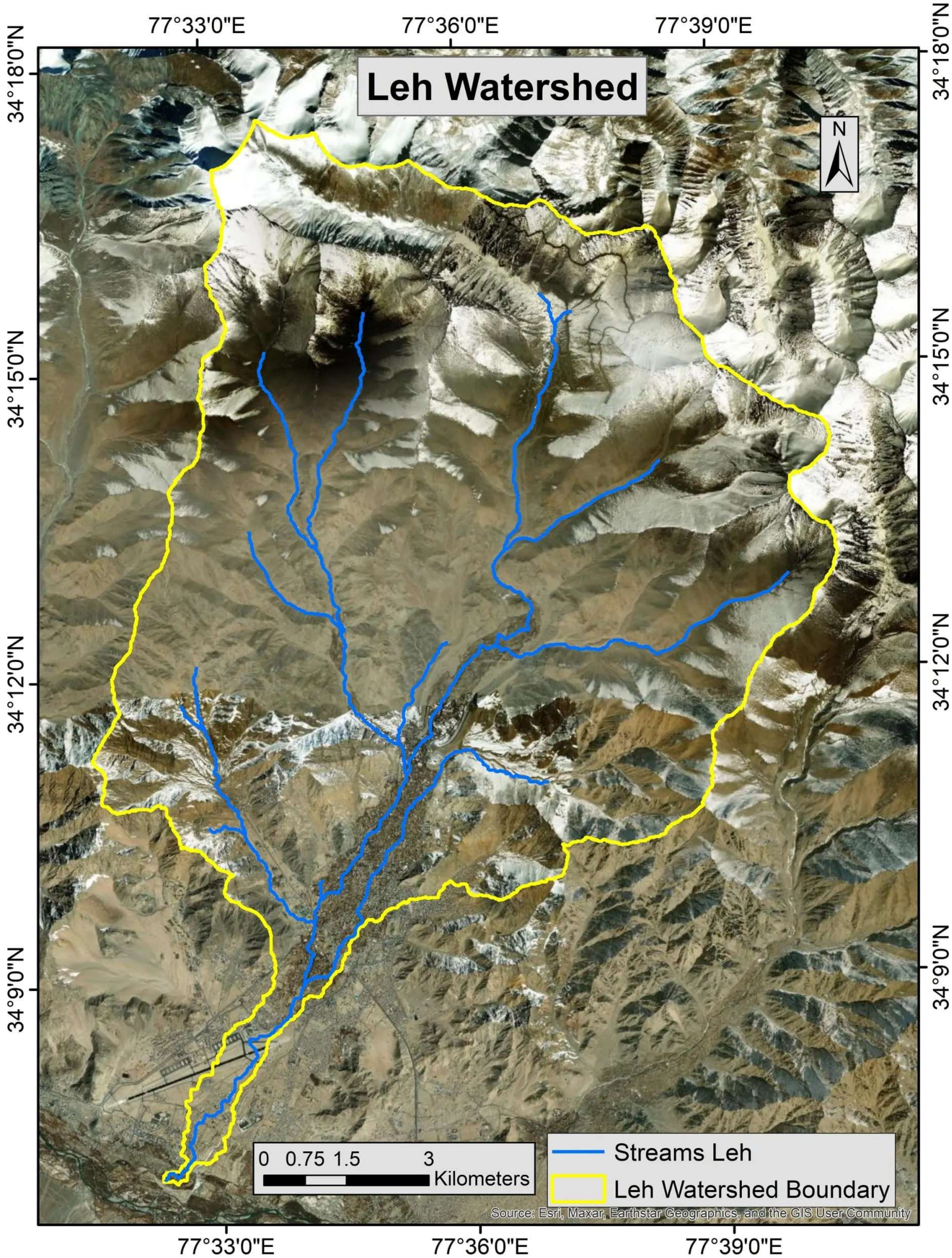

Fig. 1: Description of study area extend and the streams inside the watershed

RESULTS

The analytic hierarchy process (AHP) is applied to extract the weights of nine factors influencing flood hazard, namely Topographic Wetness Index, Slope, Time of Travel, Plan Curvature, Distance from Stream, Manning's Roughness Coefficient, Drainage Density, Curve Number, and Height Above Nearest Drainage. The results of the study reveal that there are five degrees of flooding hazard along the Ganglas river at Leh, ranging from very high to very low.

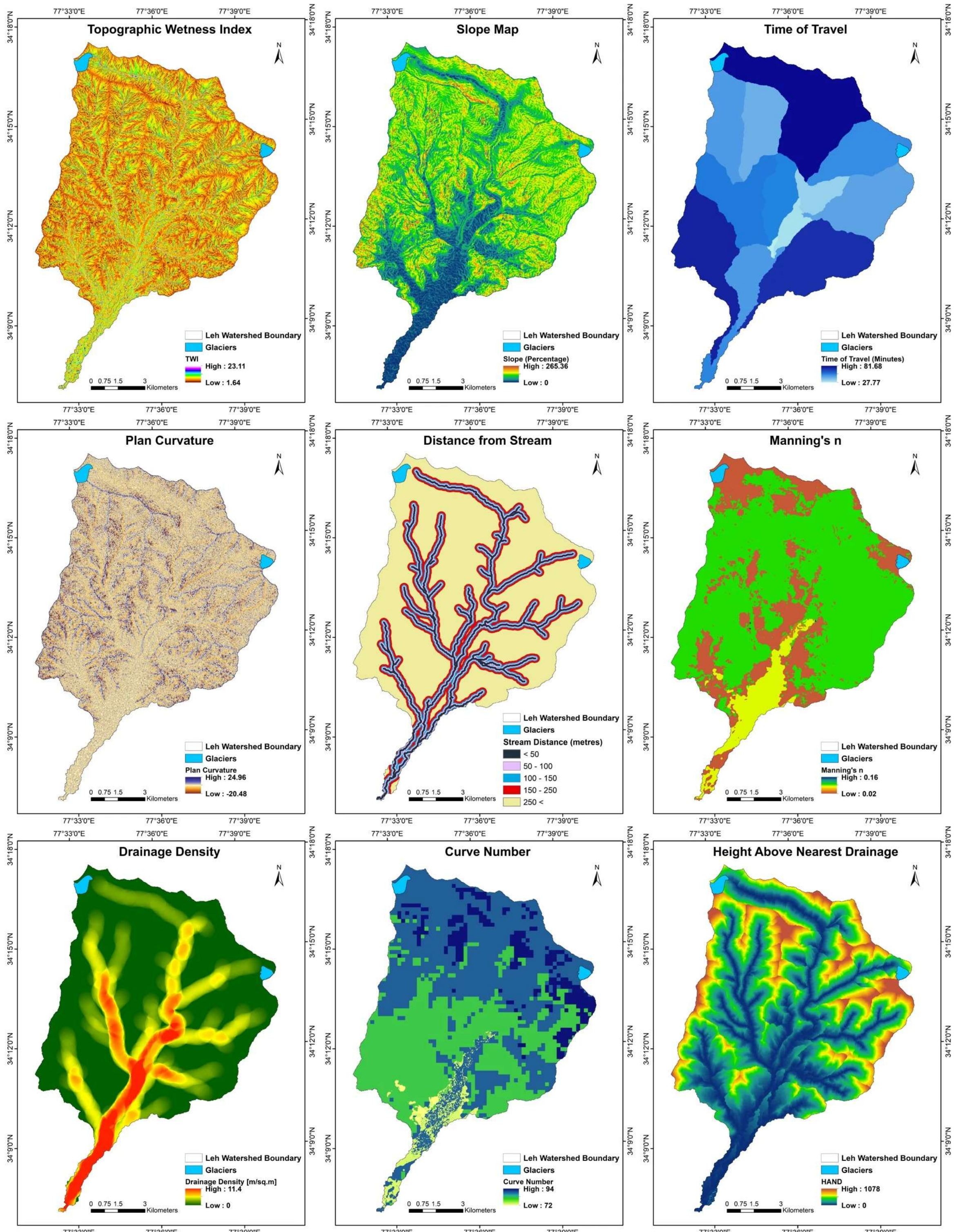

Fig. 2: The different layers computed for MCDM analysis: Topographic Wetness Index, Slope, Time of Travel, Plan Curvature, Distance from Stream, Manning's Roughness Coefficient, Drainage Density, Curve Number, Height Above Nearest Drainage

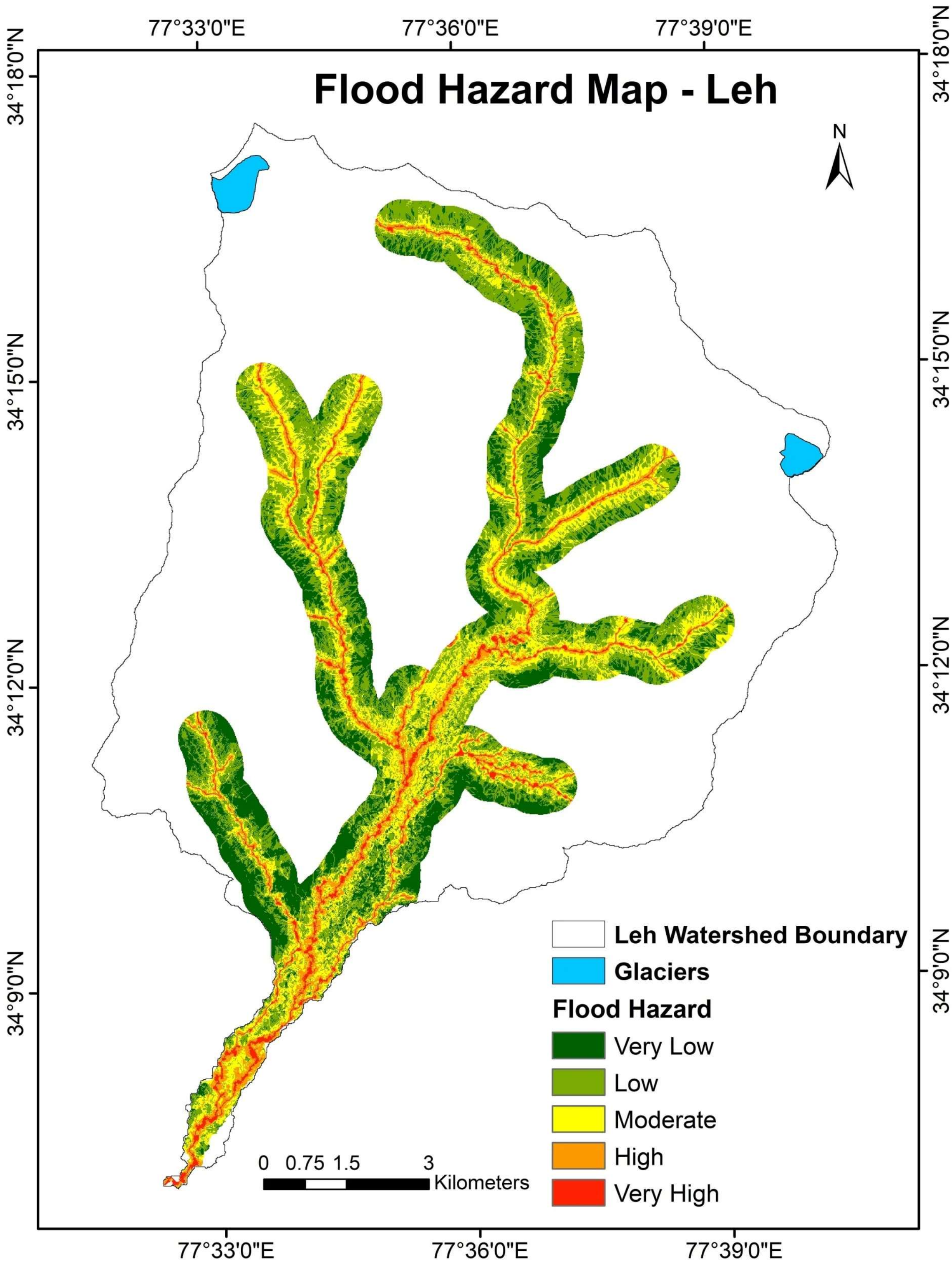

Fig. 3: The Final flood hazard map for the Leh watersged

SUMMARY

- In this research, efforts were made to demonstrate the imperative role of remote sensing, GIS and statistical approaches in hazard assessment as well as assigning priorities to flood prone zones of the study area.

- A MCDM technique offers dynamic, effective and sustainable approach over traditional prioritization methods in which significance of several characterization parameters were considered equally and in a complex way.

- Topographic wetness index, curve number and height above nearest drainage were identified as the most influential criteria in preparing the flood hazard map with weightages of 25.4, 20.2 and 18.2, respectively. Plan curvature had the least impact on final hazard map.

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ABSTRACT

Understanding the dynamics of floods in cold dessert regions and estimating a precise flood hazard map considering the topographic and hydrologic parameters is of great significance in planning and policy making for flood adaptation strategies and mitigations measures. The present study focuses on an assessment of flood hazard in Leh watershed, Ladakh, India, where the city has sustained massive damages in the flooding events of 2010. The city of Leh is at an elevation of 11,562 ft. above mean sea level. The low temperature and high relative humidity lead to the formation of dense low clouds in the valley. The orography at such altitudes often results in cloud burst and flash floods downstream the valley. Spatial analysis in GIS environment has been applied for the estimation of flood hazard zones, in which nine relevant physical factors have been selected namely, curve number, slope, time of travel, height above nearest drainage, topographic wetness index, plan curvature, drainage density, distance from stream and manning's roughness coefficient. In order to achieve the objective, multicriteria decision analysis is used to build a flood hazard map of the study area. The analytic hierarchy process (AHP) is applied to extract the weights of nine factors influencing flood hazard. The results of the study reveal that there are five degrees of flooding hazard along the Ganglas river at Leh, ranging from very high to very low. Topographic wetness index, curve number and height above nearest drainage were identified as the most influential criteria in preparing the flood hazard map with weightages of 25.4, 20.2 and 18.2, respectively. Plan curvature had the least impact on final hazard map. Flood hazard map will serve as catastrophic product, which will help policymakers to take suitable measures to reduce the risk of flash-floods.

Keywords: Flood Hazard Map, AHP, GIS, Topographic Wetness Index, Leh floods