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# LANDSLIDE DAM SUSCEPTIBILITY MAPPING IN THE INDIAN HIMALAYAS: A RANDOM FOREST APPROACH WITH CROSS-CATCHMENT VALIDATION

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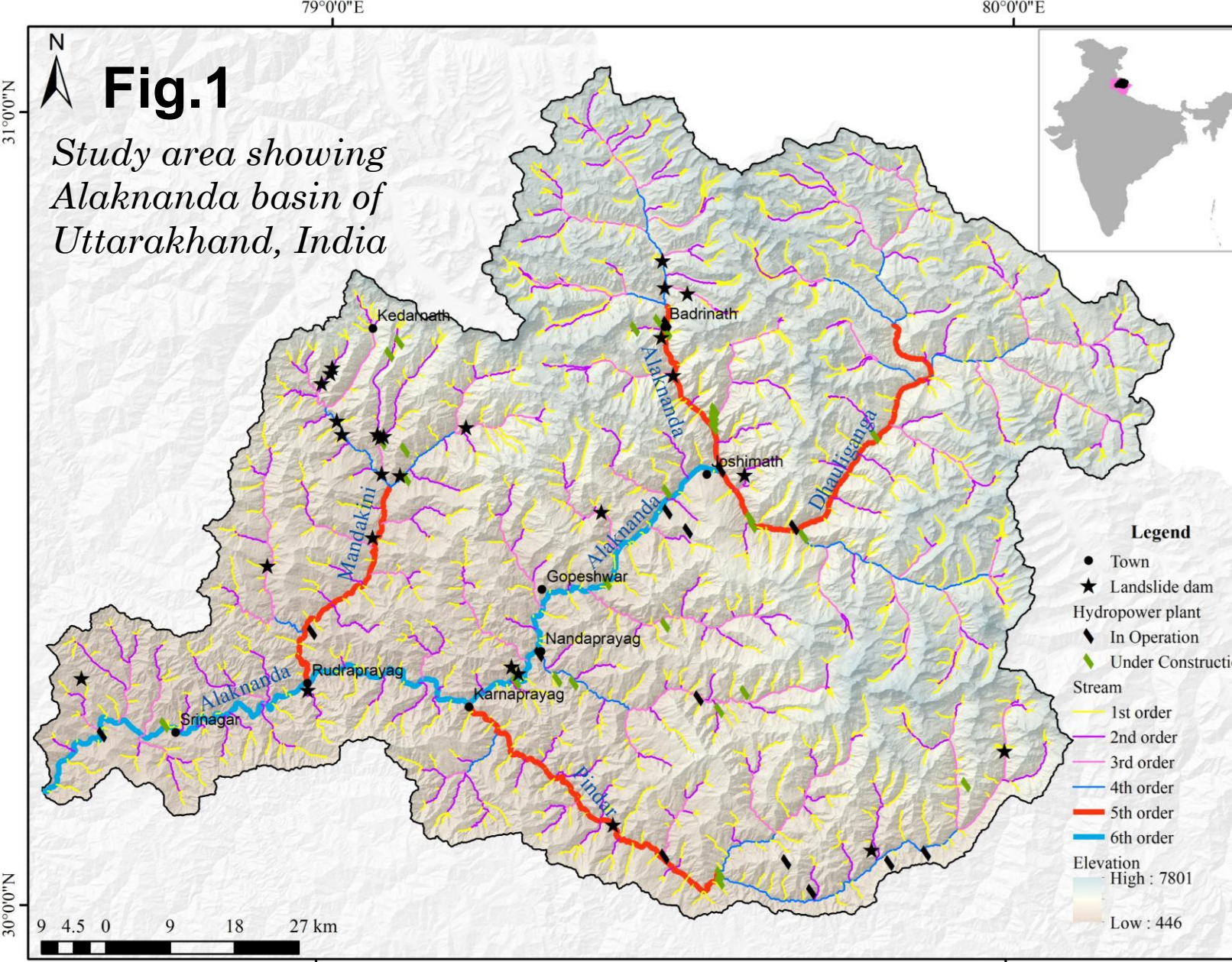
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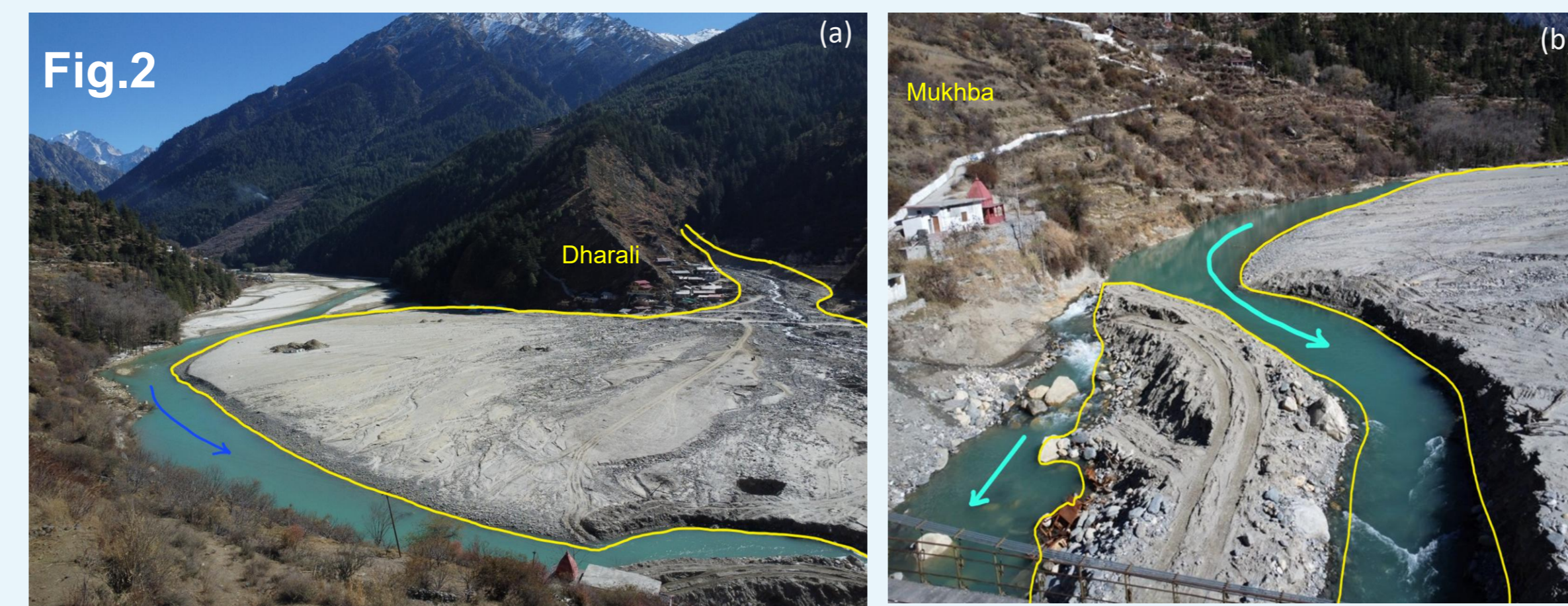
Scan for the abstract!



## Introduction



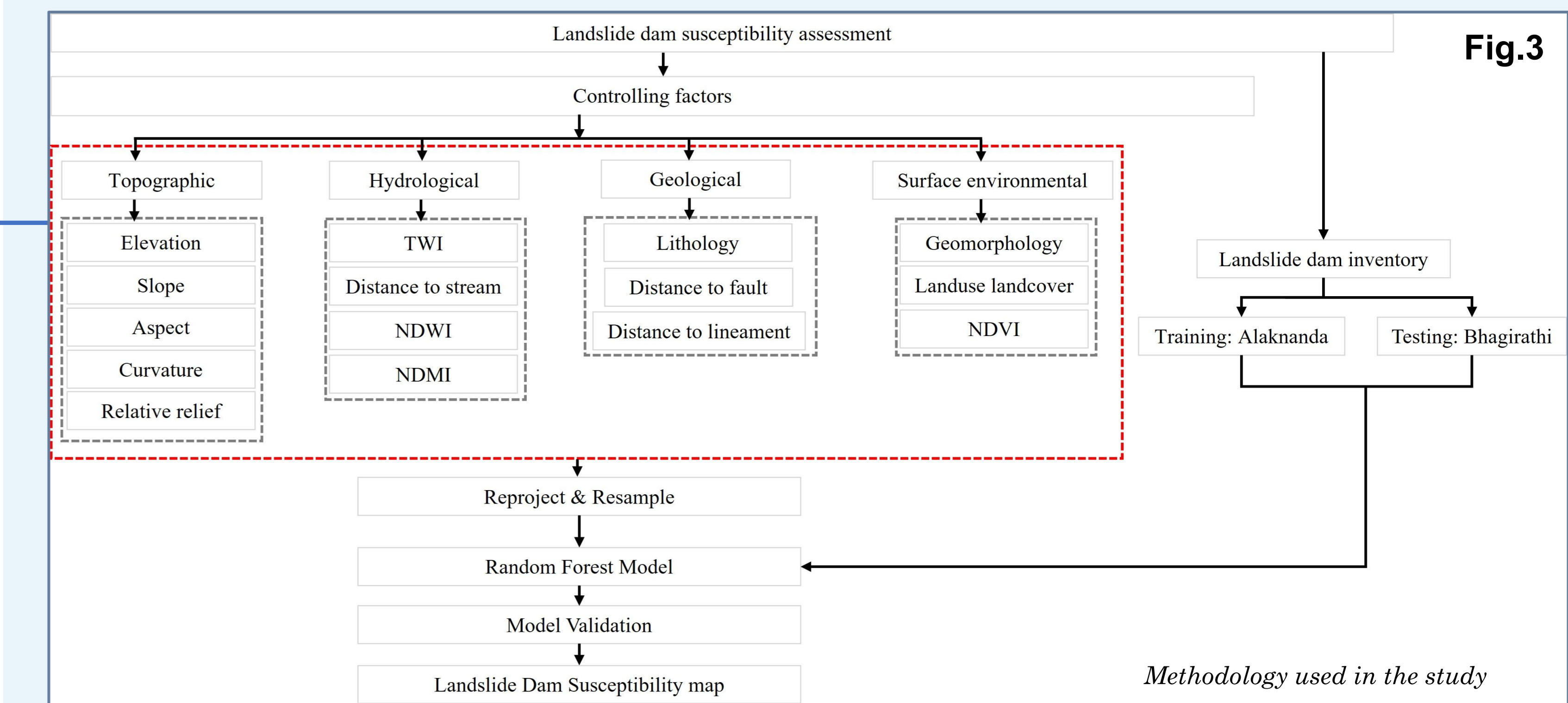
- The **landslide dams** are the landslides that block the river stream, forming a 'landslide-dammed lake' upstream, which reduces river discharge downstream and poses a threat of catastrophic breaching, which can lead to flash floods (Costa & Schuster, 1988; Fan et al., 2019, 2020).
- Breach-induced inundation can disrupt the developing critical infrastructure networks, including transportation corridors, hydropower facilities, healthcare systems, and educational institutions, even at considerable distances downstream (Joshi & Siva Subramanian, 2025).
- Despite their importance, landslide dam susceptibility remains underexplored compared to conventional landslide hazard assessment in India.
- This study addresses this gap by developing a machine learning-based susceptibility model specifically targeting landslide dam, with the evaluation of spatial transferability between adjacent river basins of India.



Dharali debris flow. Image (a) shows the debris fan formed engulfing the almost entire Dharali village and blocking the Bhagirathi river partially. Image (b) shows the pathway formed to breach the landslide dam/debris fan formed, changing the course of the river toward the Mukhba village.

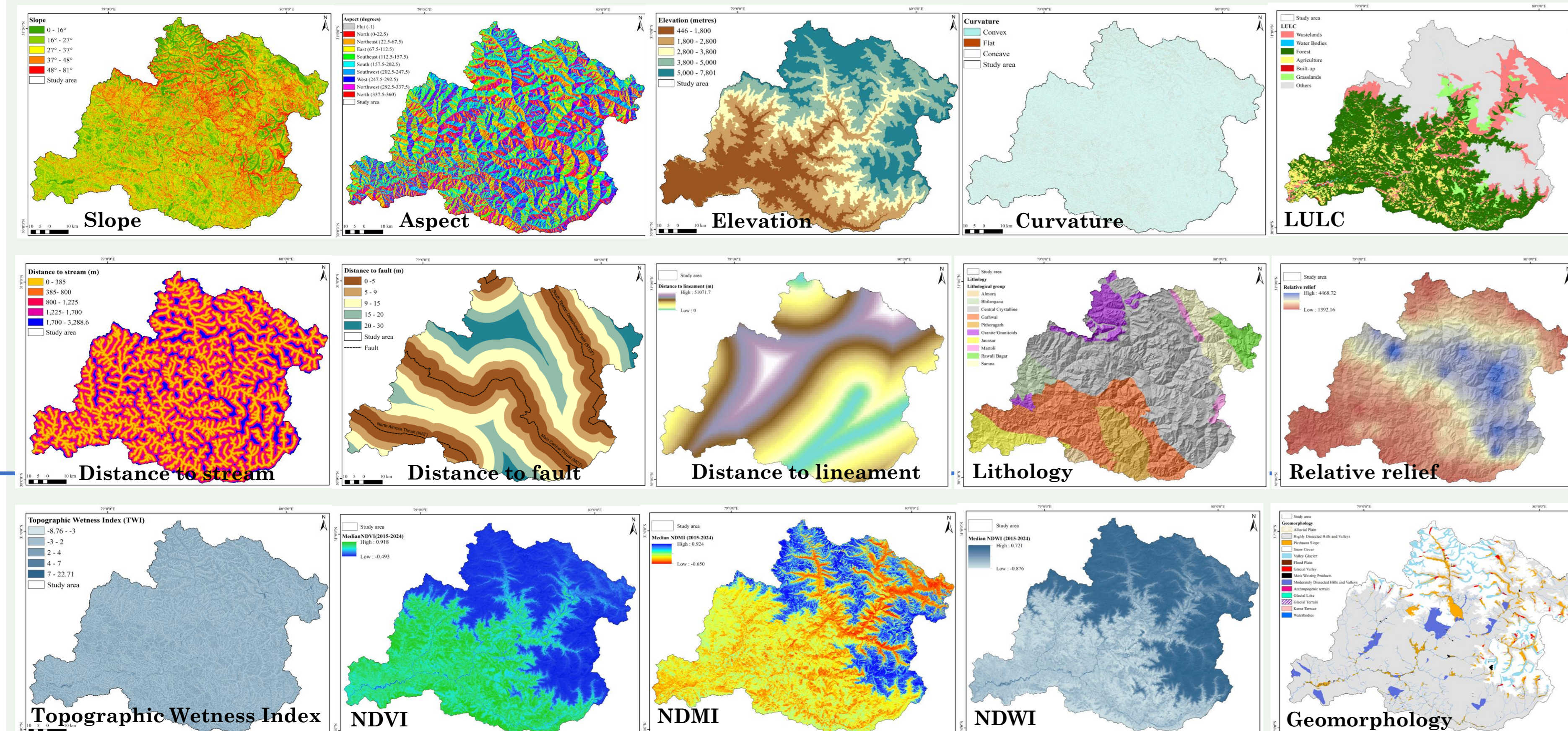
## Methodology

- All controlling factors were reclassified, resampled, and projected to a common spatial reference system (UTM Zone 44N), and subsequently clipped to the Alaknanda basin to ensure spatial consistency and alignment.
- The landslide dam inventory was rasterized into a binary target layer (dam = 1, non-dam = 0) using the same grid resolution and extent as the predictor variables to maintain pixel-level correspondence.
- To address class imbalance, a stratified sampling strategy was adopted in which all landslide dam pixels were retained, and non-dam pixels were randomly sampled at a **1:10 ratio**.
- A **Random Forest** classifier was trained on the Alaknanda basin using 500 trees to improve model stability and reduce overfitting.



## Results

Fig.4 Controlling factors for the landslide dam susceptibility assessment



- Landslide dam susceptibility map shows only **3.6% of the region comes under high and very high susceptibility zone** (which seems true because the landslide dam events are not as frequent as landslides itself!).
- The **moderate risk zone consists of 5.7%** of the region, rest 90.6% are under low and very low susceptible zone.
- Model performance was evaluated using ROC-AUC, confusion matrix metrics, and out-of-bag validation, and further tested for transferability by applying the trained model to the Bhagirathi Basin and analyzing success and prediction rate curves.

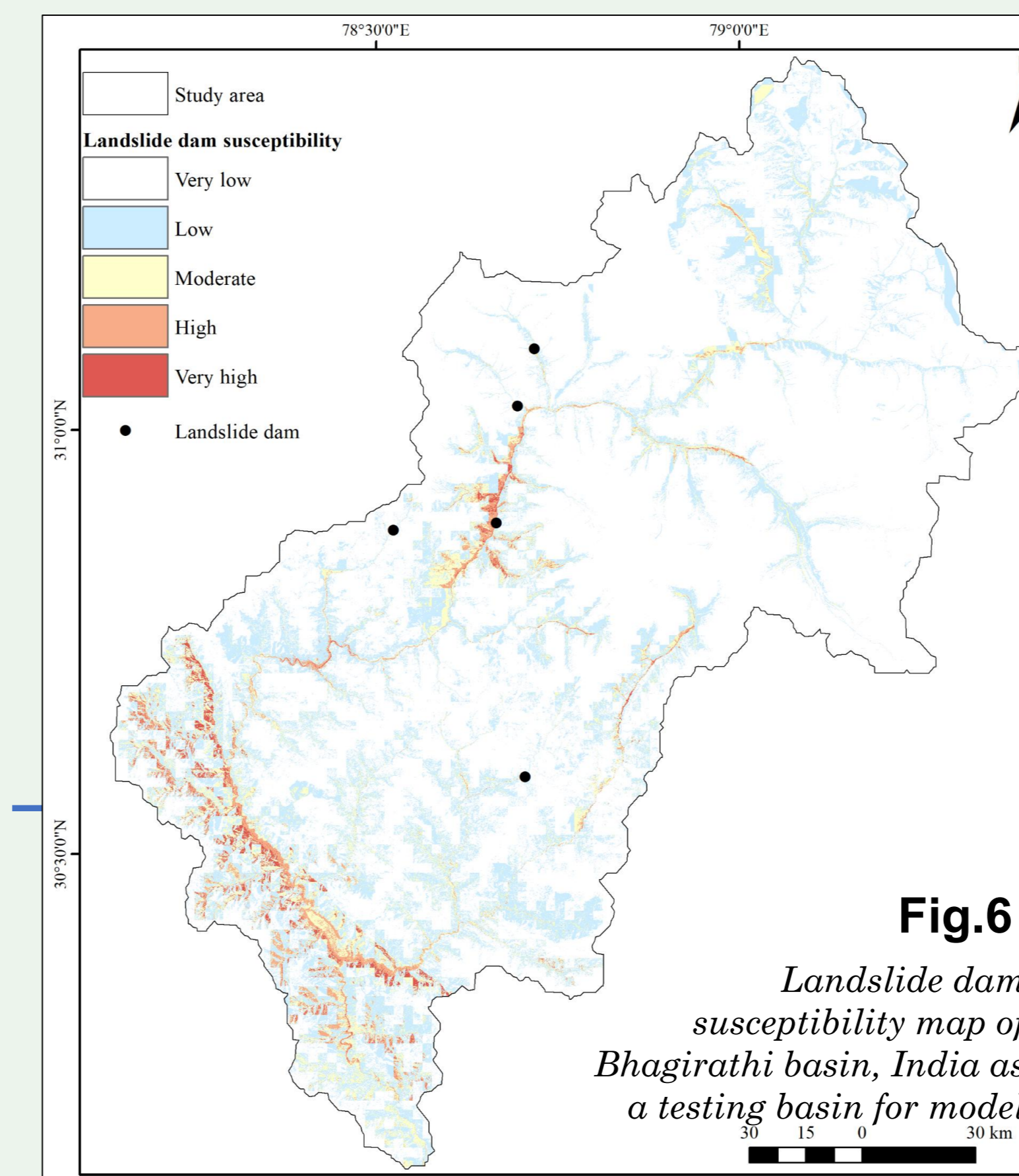


Fig.6 Landslide dam susceptibility map of Bhagirathi basin, India as a testing basin for model

## Conclusions

- This study demonstrates that landslide dam susceptibility can be robustly predicted and spatially transferred across basins, providing a scalable tool for hazard assessment in data-scarce mountain regions.
- This study represents a significant step toward addressing and evaluating landslide dams in the Uttarakhand Himalayas by preparing the landslide dam susceptibility map.
- Using a random forest model across 15 controlling parameters, based on an effectively prepared landslide dam inventory, the resultant map identifies 3.6% of the terrain as high and very high susceptible zones along few river valleys.
- The findings indicate that the significant controlling factors that influence the occurrence of landslide dams in Uttarakhand are Elevation, Normalized Difference Moisture Index, Aspect, Relative relief and Distance to stream.

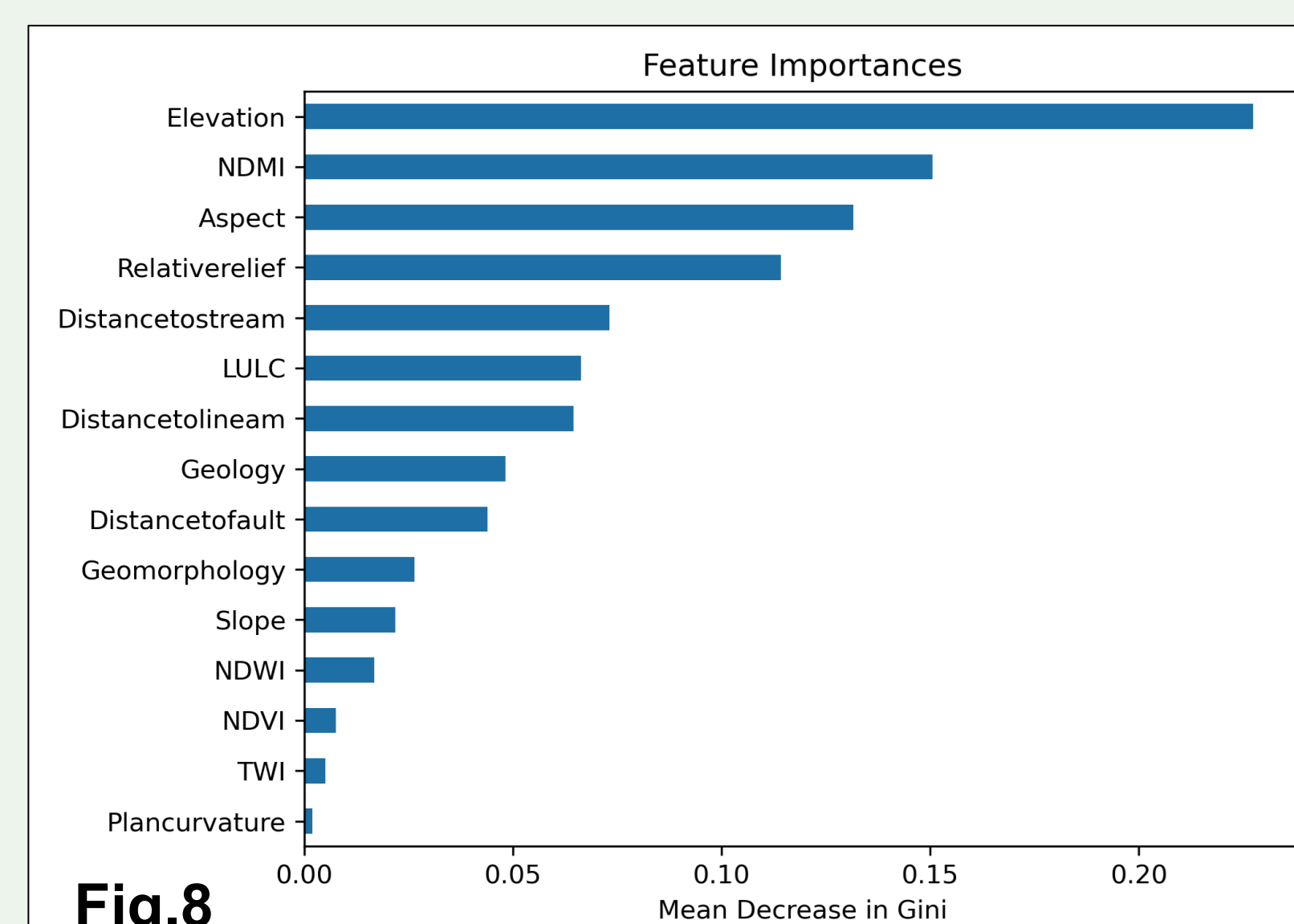


Fig.8 Feature importance ranking for the top ten contributing landslide dam controlling factors

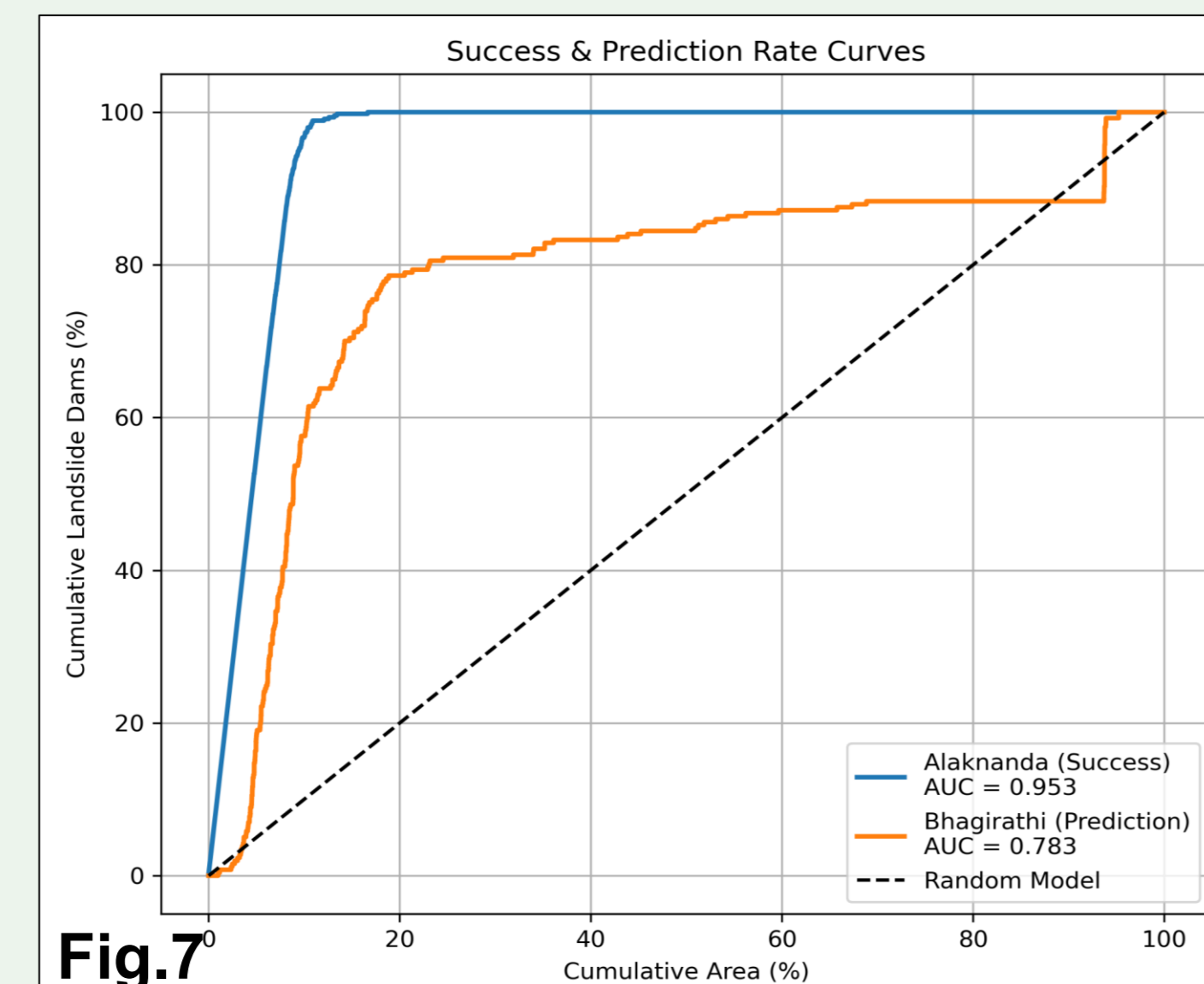


Fig.7 The success rate and prediction rate curves for the Random forest model trained on Alaknanda basin and tested on Bhagirathi basin, India

Class	Percentage
Very low	75.468
Low	15.218
Moderate	5.700
High	2.451
Very high	1.163

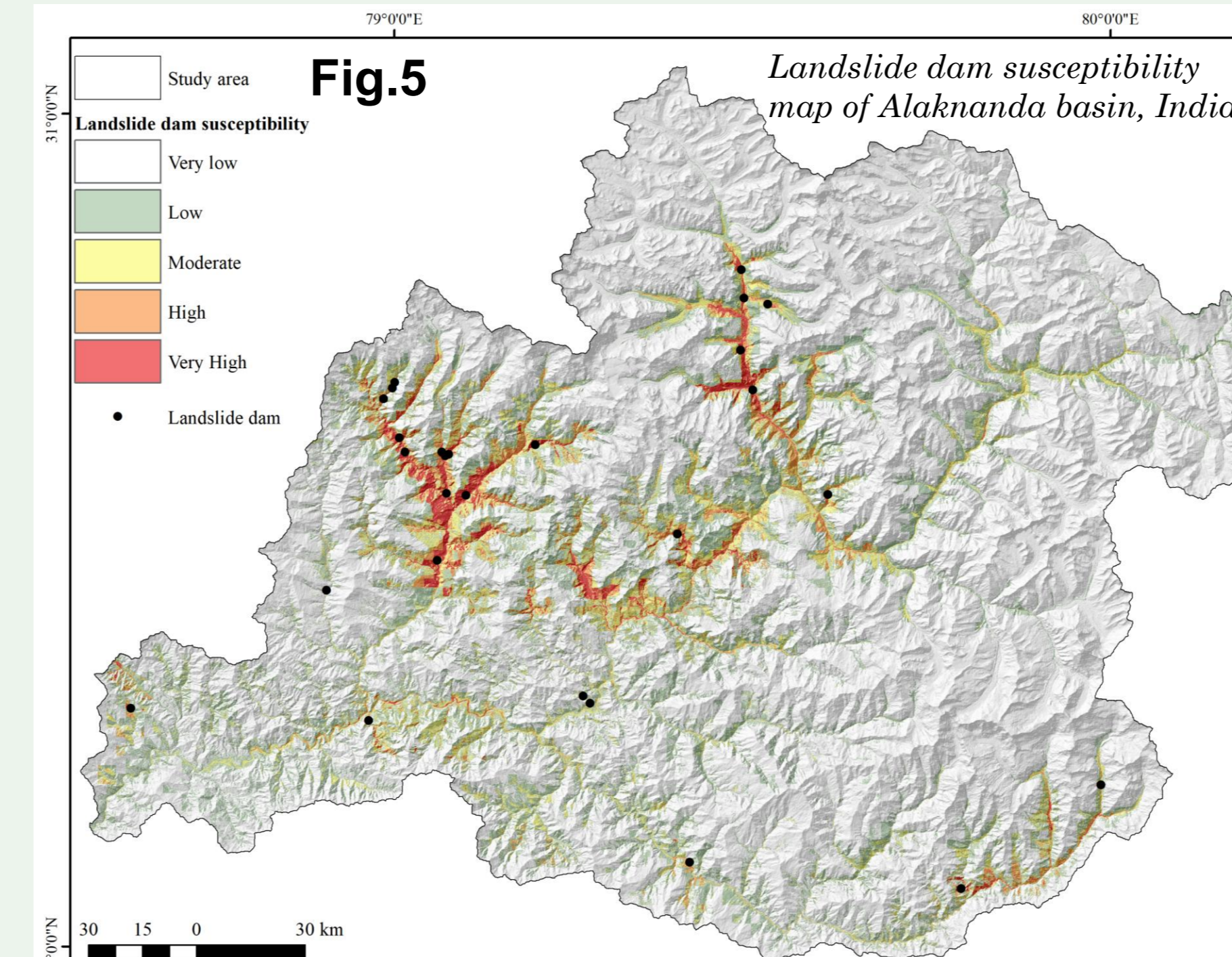


Fig.5 Landslide dam susceptibility map of Alaknanda basin, India

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