Aga Khan Agency for Habitat

ADAPTATION FUND

Cryosphere and related hazards in High Mountain Asia in a changing climate

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Permafrost-thaw related hazards in Humla Valley, Western Nepal

Cryosphere hazards in the HKH

Widespread consequences of changes in cryosphere, mainly due to rising temperatures, are visible in the high mountains of the Hindu Kush Himalayas (HKH).

Mountain communities are vulnerable as they are living in a high-risk environment due to increased probability of occurrence of cascading hazards and extreme events.

These risks are largely associated with retreating glaciers, thawing permafrost, and extreme snowfall events.

Increased frequency of cascading disasters, changes in hydrological regimes, and alterations in livelihood and ecosystem services are some of the major impacts observed due to changing cryosphere. Changes of the cryosphere also impact transformations in social and cultural dynamics of mountain communities in the region.

Study site

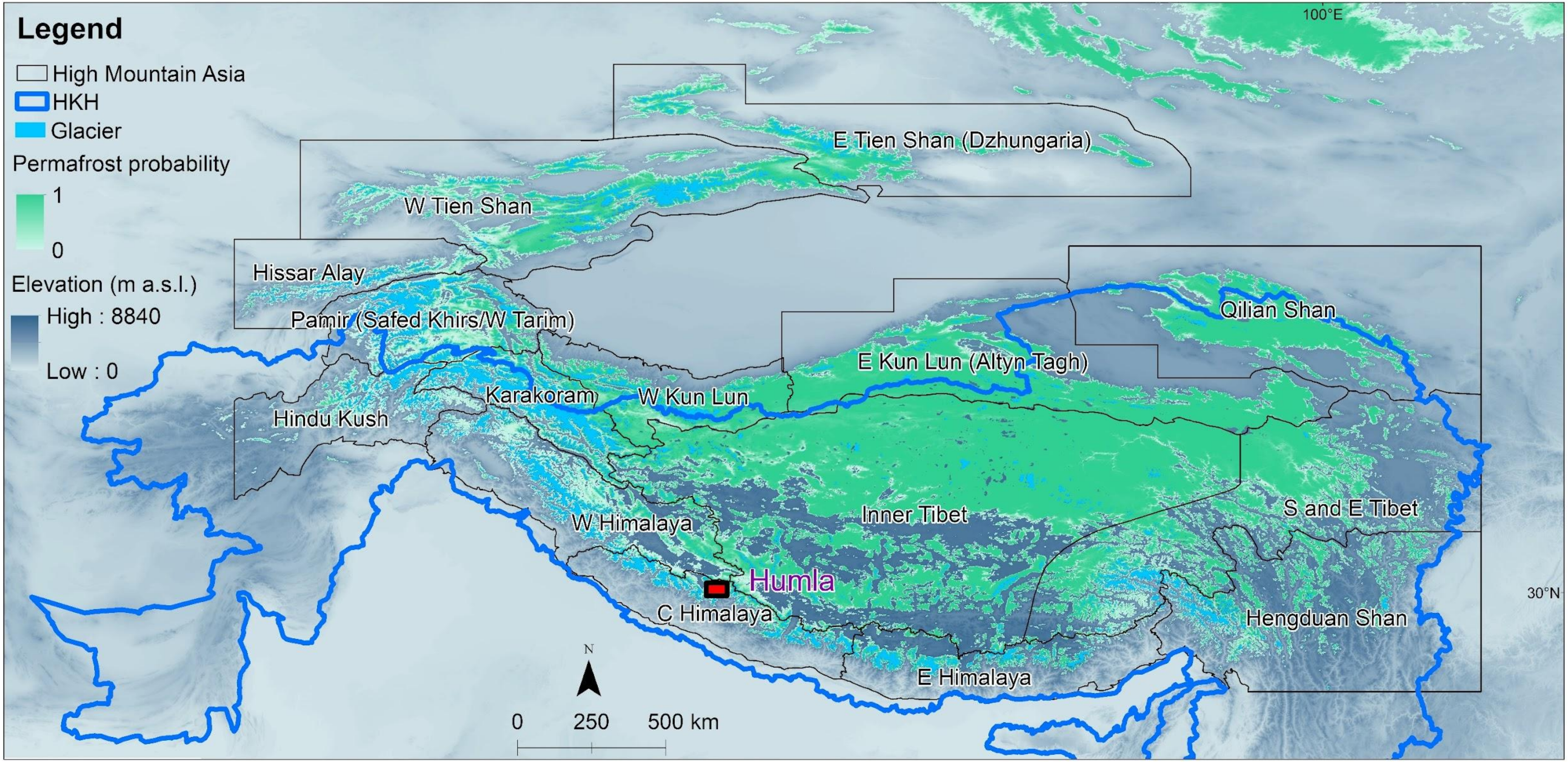
There is very little knowledge on the status and evolution of the cryosphere in western Himalayas of Nepal.

Humla district in the Western Himalayan region is the second largest district of Nepal. The elevation ranges from 1100 to 7000 m a.s.l.

About 70% of the total area of Humla lies above 4000 m a.sl. Permafrost map for the Northern hemisphere (Obu and others, 2019) indicates that more than 60% of Humla is underlain by permafrost.

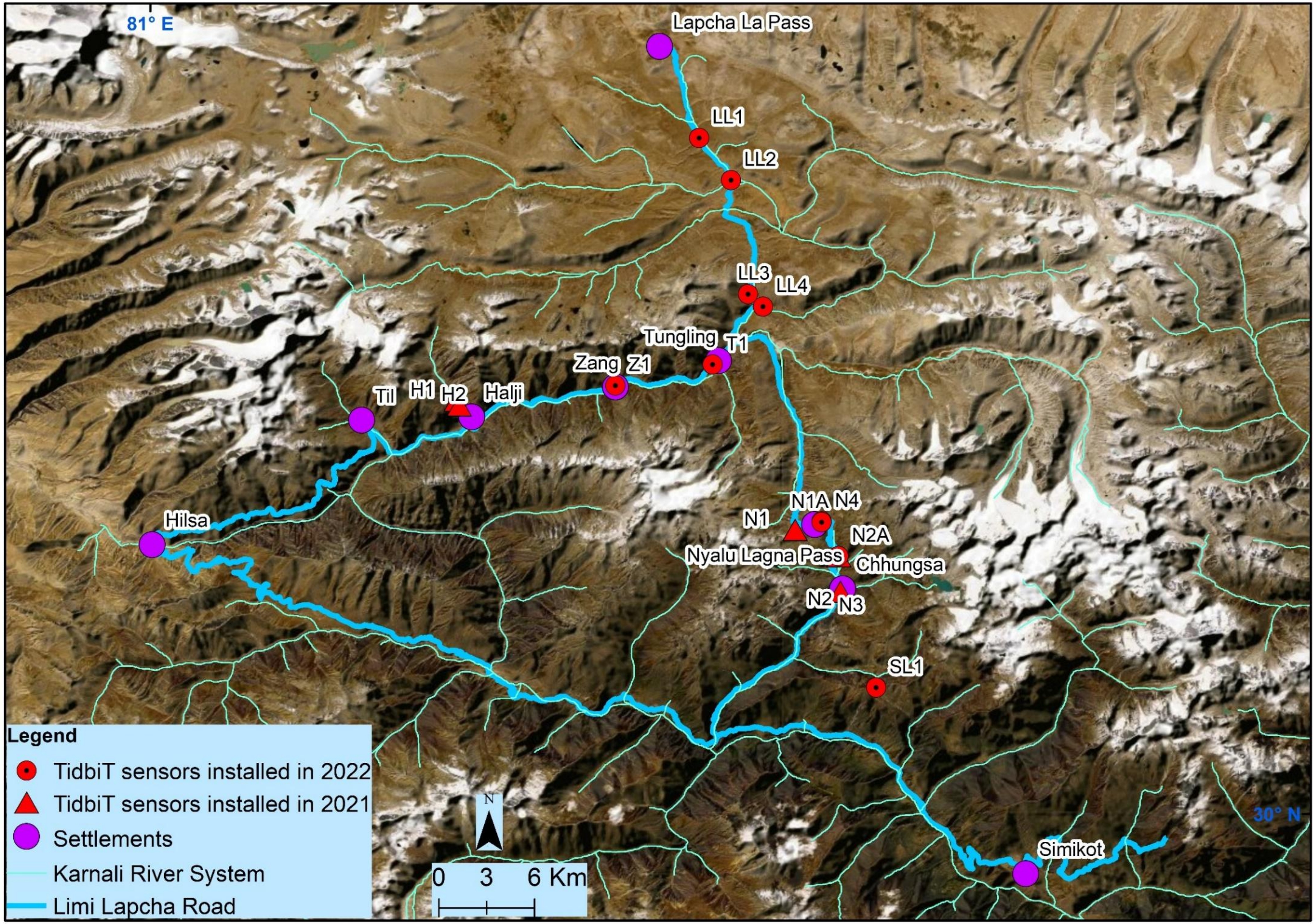
Cryosphere Initiative at ICIMOD started monitoring changes of cryosphere, mainly permafrost, in Humla since 2021.

Permafrost probability



Map of High Mountain Asia with distribution of glaciers (RGI 6.0) and permafrost (Obu et al., 2019).

Study site



Map of Humla with settlements, road system, river system and sensors installed in 2021 and 2022.

Permafrost mapping in Humla

Permafrost in Humla was observed using global permafrost maps.

Permafrost was also mapped using remote sensing, machine learning and global climate data.

Rock glaciers were used as visual indicators to indicate the presence or absence of permafrost.

Permafrost mapping in Humla

Global climate data from WorldClim 2.0 was used to generate mean annual air temperature (MAAT) grid. Solar radiation was simulated using digital elevation grid.

Logistic regression function and one-dimensional convolutional neural network were applied to generate permafrost probability distribution maps.

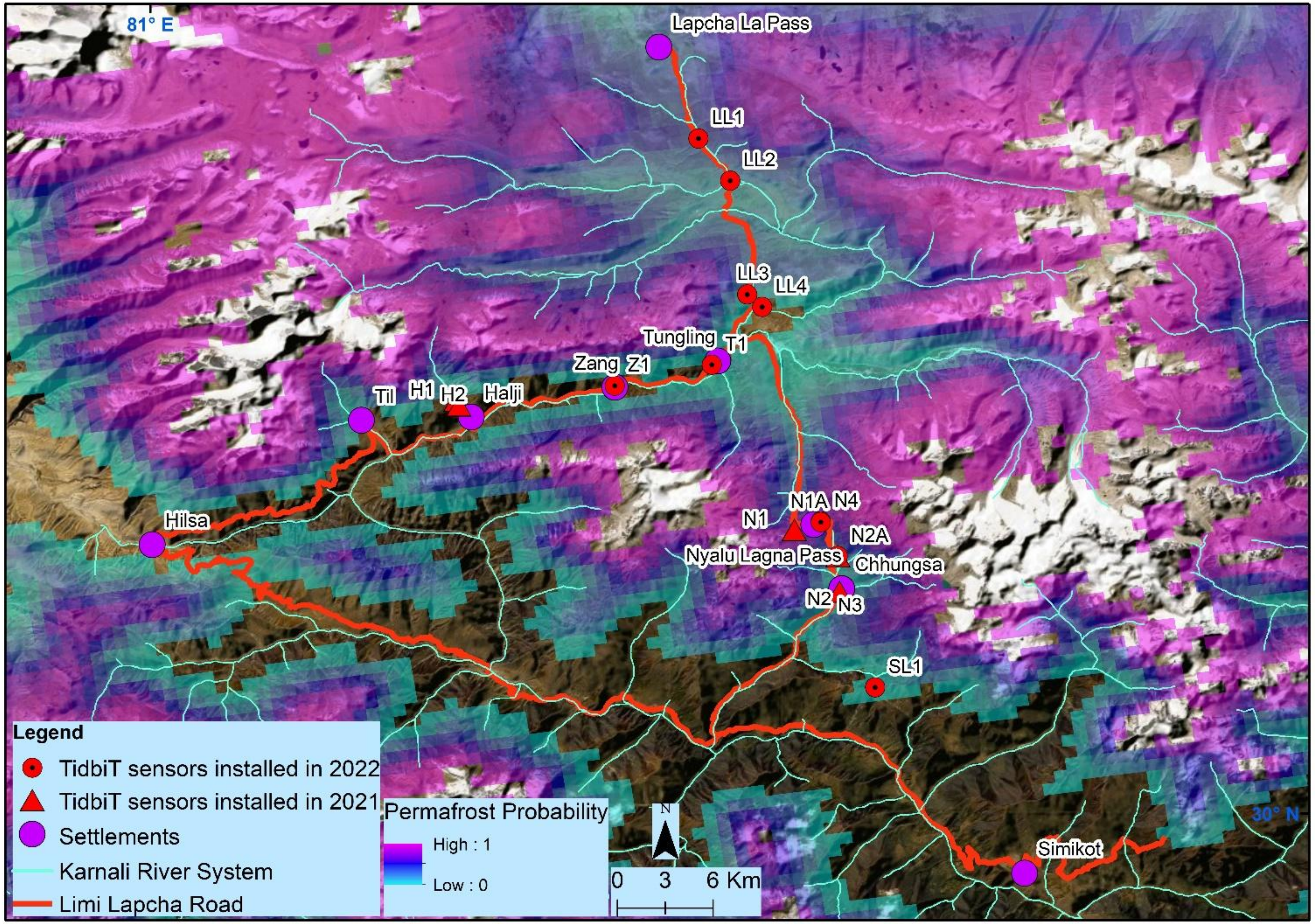
Permafrost in Humla

Permafrost map from Obu and others, 2019.

Temperature at the top of the permafrost (TTOP) model applied at a circum-Arctic scale.

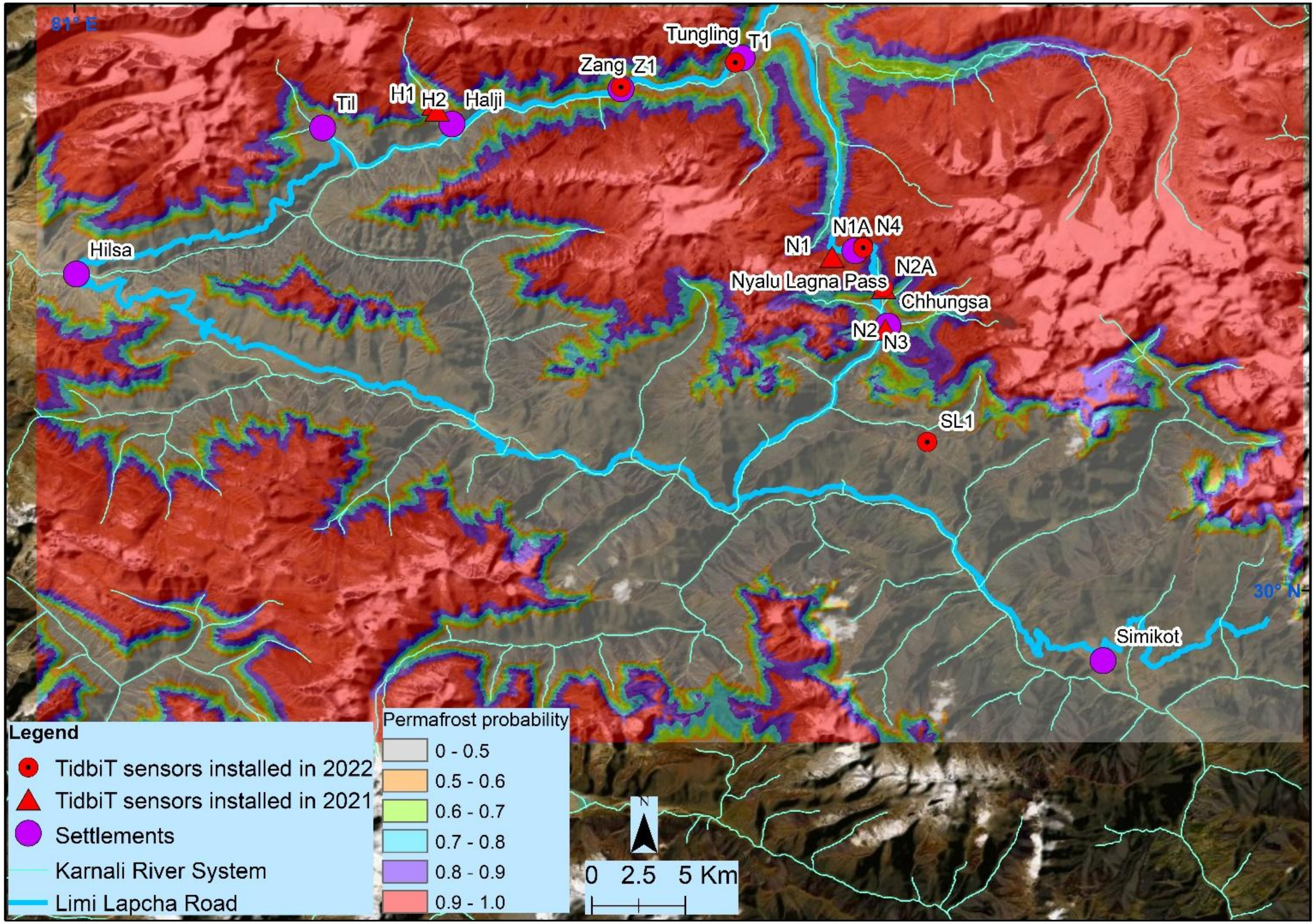
Remotely sensed LST, ERA Interim climate reanalysis, and landcover information are used.

Maps (1 km^2 spatial resolution) provide MAGT at TTOP, and permafrost probability.



Permafrost in Humla

Permafrost map based on simulated climate data from WorldClim 2.0, remote sensing of topoclimatic variables, and machine learning.

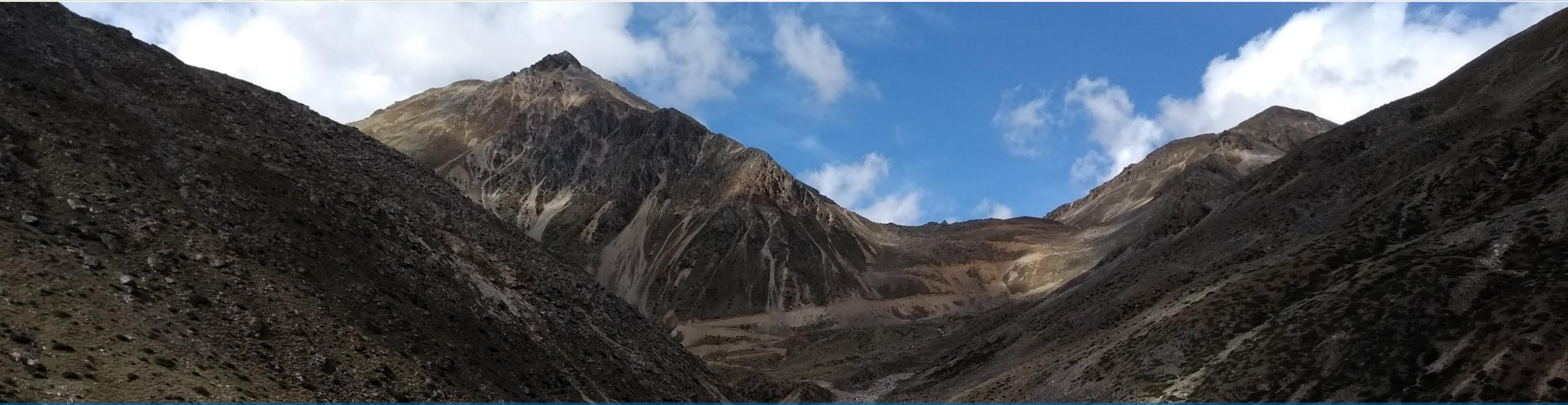


Impacts of thawing permafrost

Seasonal and permanent human settlements are at risk of shallow landslides, rockfalls and debris flows due to destabilizing mountain slopes.

Destabilising side walls and ground subsidence are commonly observed at several sections along the Limi Lapcha road.

Increasing sediment load in rivers is a major



Limi Lapcha Road near Chungsa Valley

Slope destabilization

Limi Lapcha Road


Loss of livestock

Sediment load

Debris flows

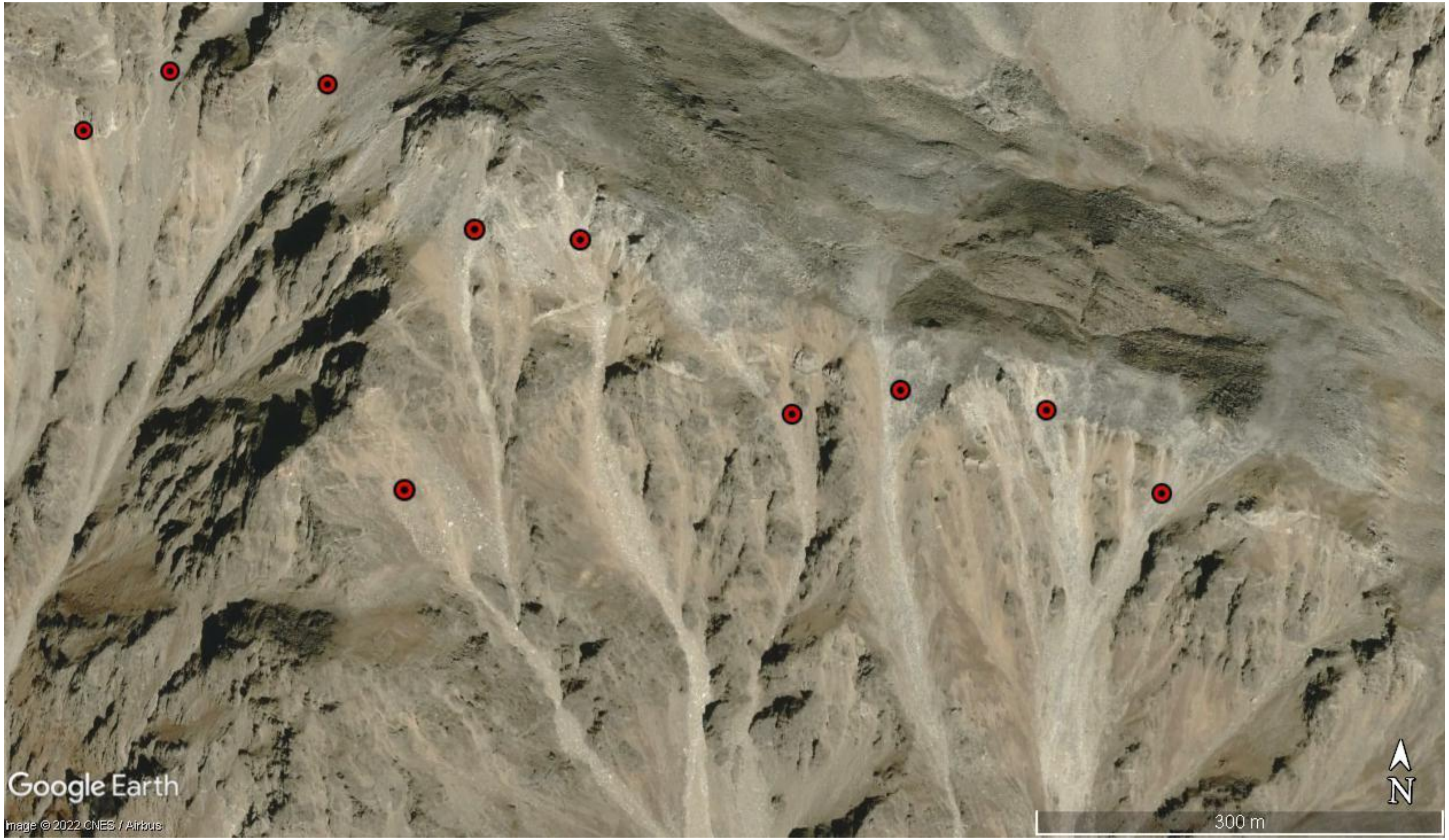
Large number of debris-flow events in many parts of Humla were observed.

Debris flow initiation areas were mapped and their potential association with thawing of permafrost was analyzed.

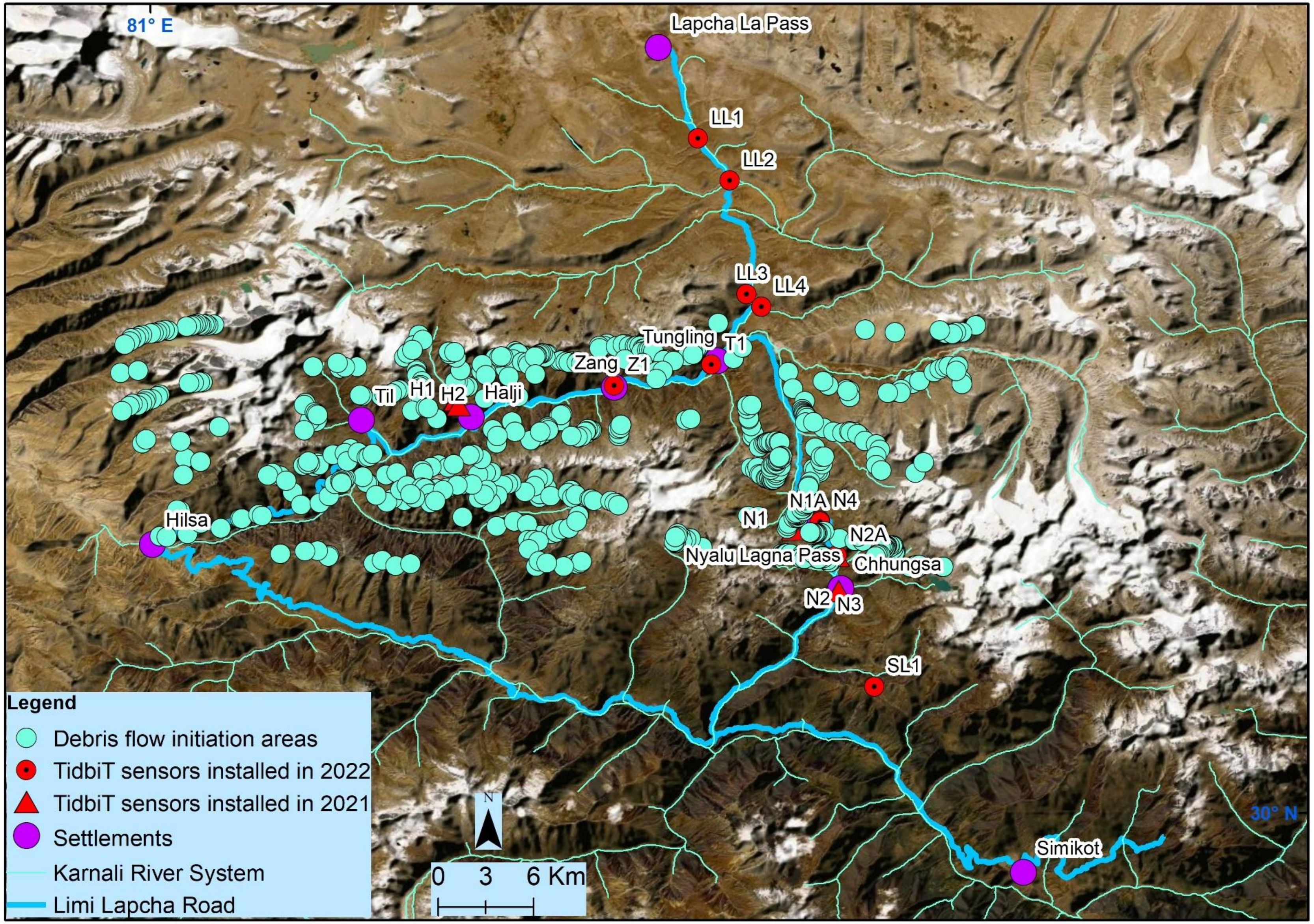
Debris flow initiation areas

Debris flow initiation areas mapped using Google Earth.

More than 600 points representing debris flow initiation zones were mapped using Google Earth Pro.



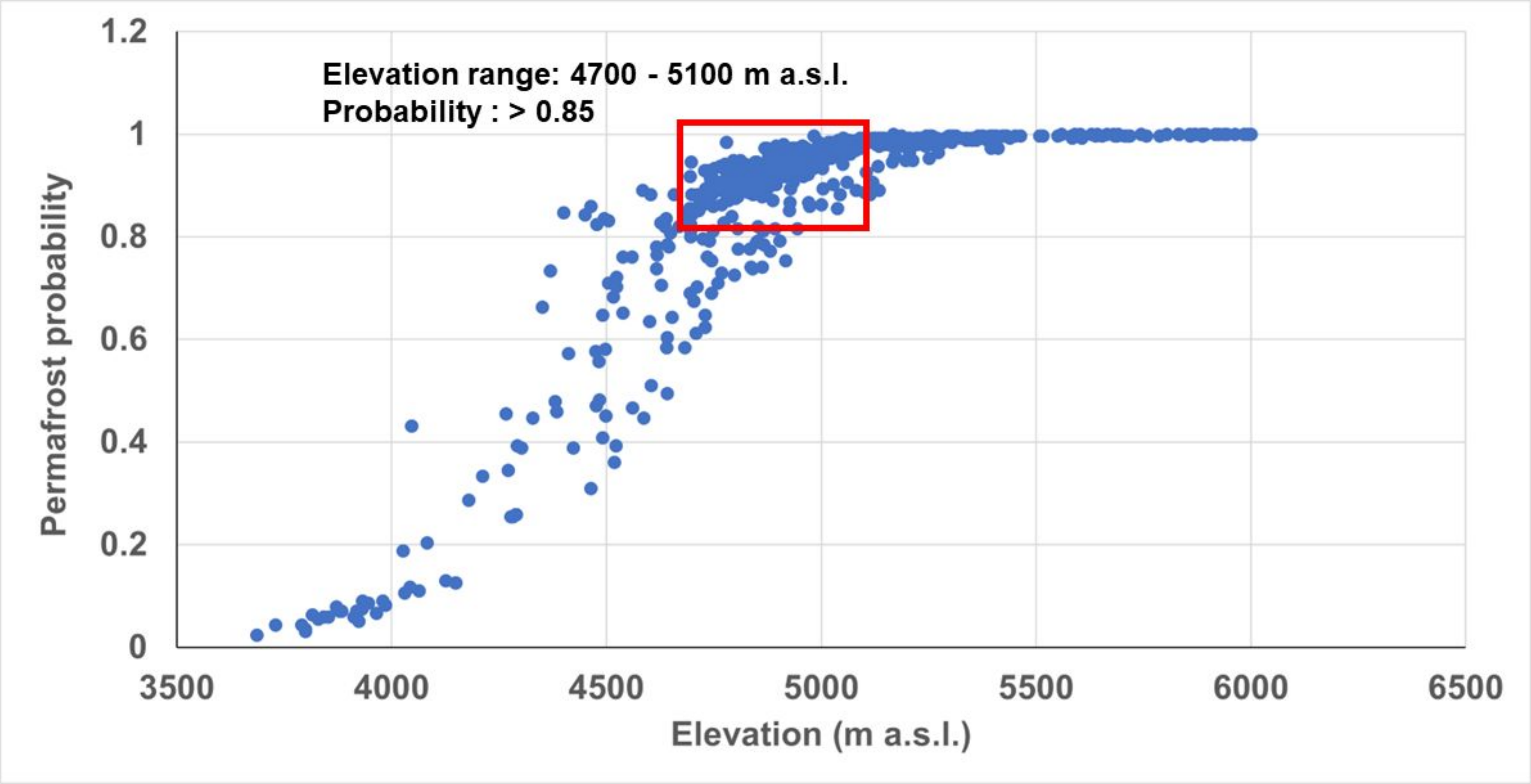
Debris flow initiation areas



Debris flow initiation areas mapped using Google Earth

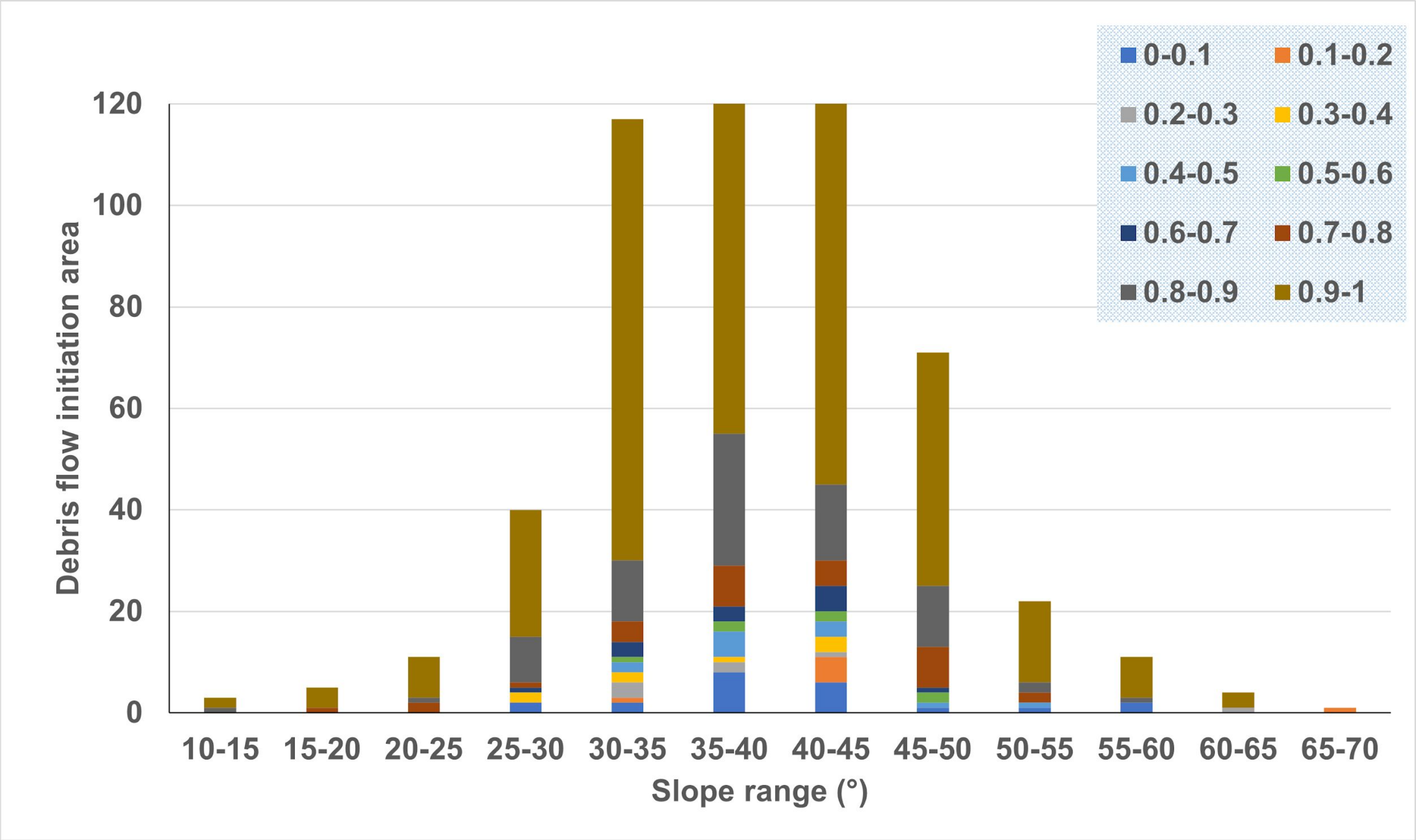
Debris flow initiation areas

(Permafrost probability and elevation range)

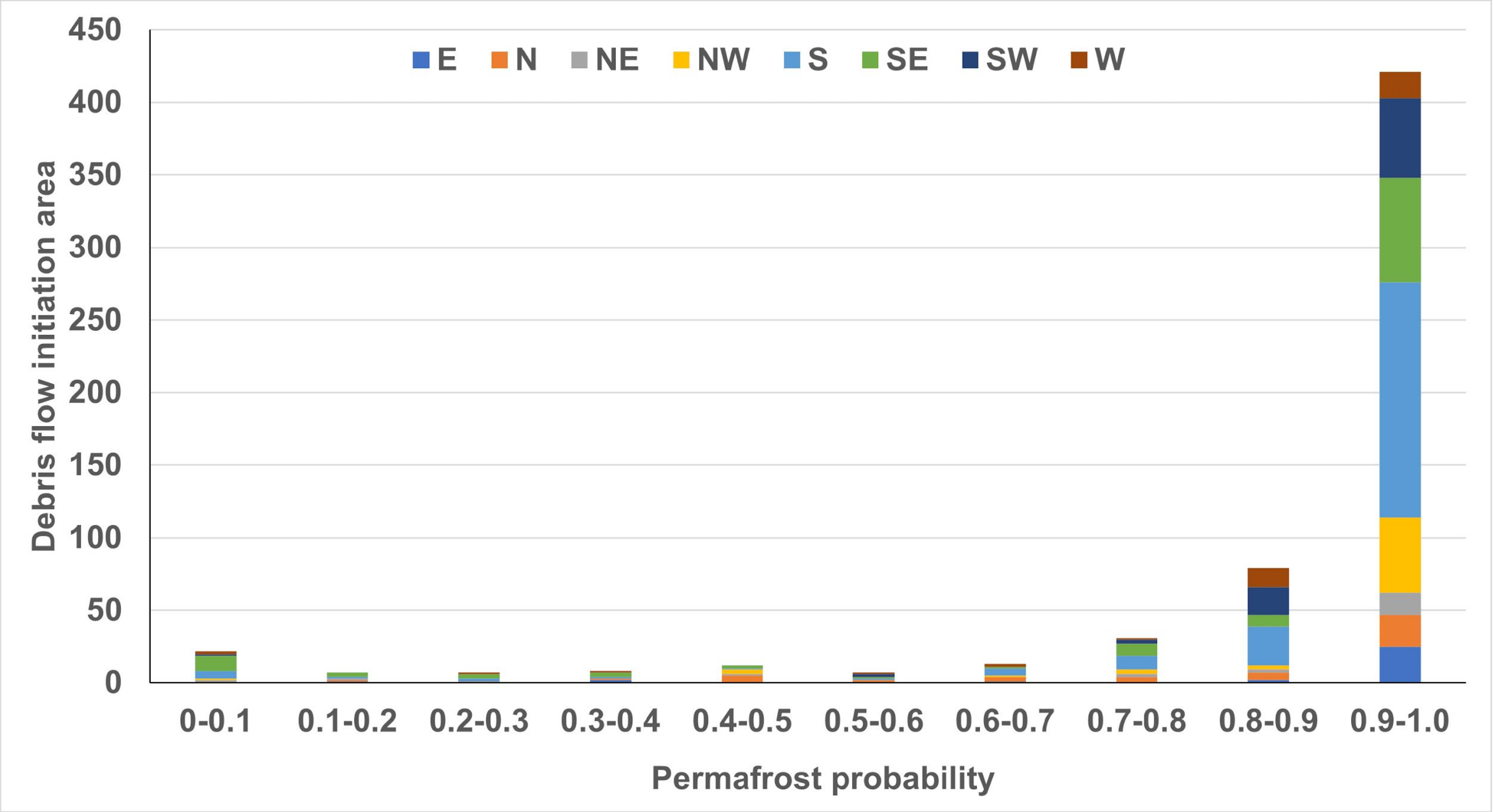


Debris flow, permafrost probability, and slope

Slopes in the range 30° – 45 ° had a high probability of the occurrence of debris flow initiation zones.



Debris flow, permafrost probability, and slope aspect

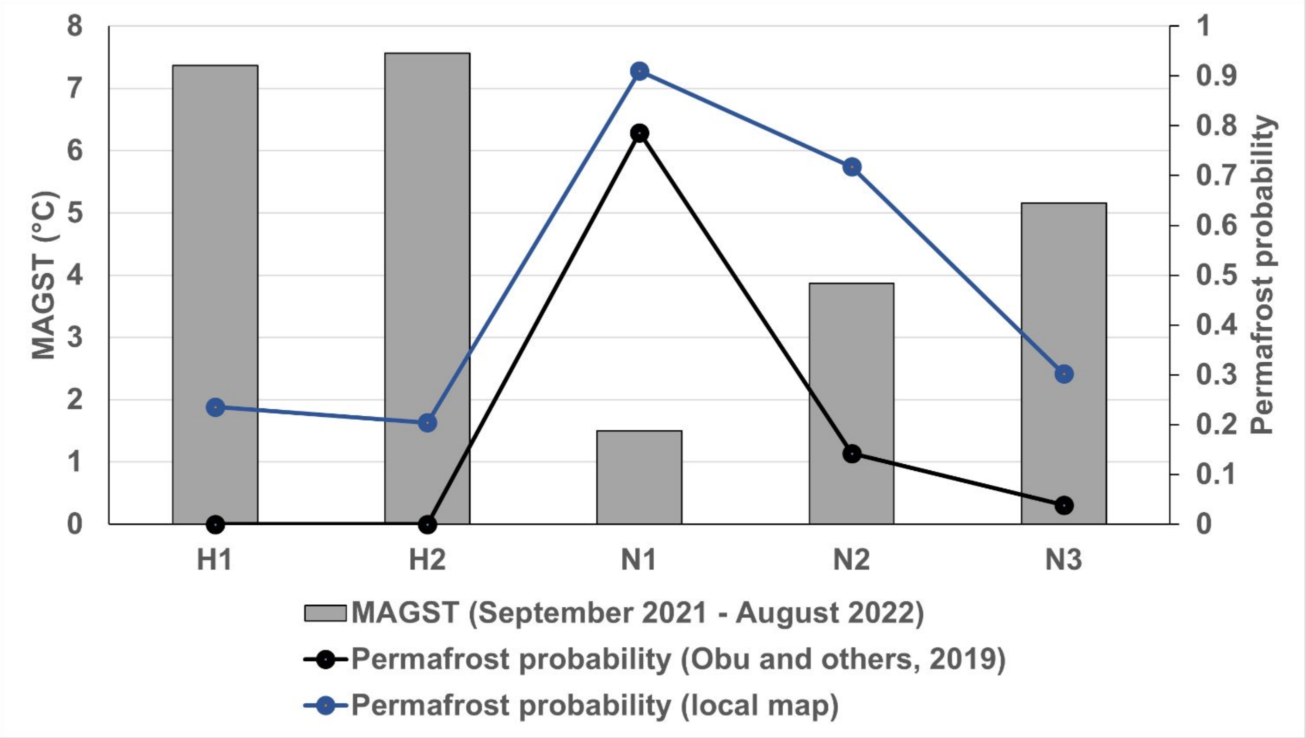


Ground temperature measurements

Sites	Aspect	Slope (°)	Elevation (m a.s.l.)	Solar radiation (KWH/m^2)	MAAT (°C)	Status
H1	S	8	3922	1237	0.5	Unlikely
H2	SW	4	3905	1234	0.9	Unlikely
N1	NW	15	4820	1380	-4.6	Possible
N2	E	03	4569	1399	-2.6	Possible
N3	NW	18	4121	1216	0.1	Possible

MAAT: Mean annual air temperature

MAGST: Mean annual ground surface temperature



Adaptation actions

Adaptation actions should begin with increasing awareness.

Local government and general public are not aware about permafrost and the impacts of thawing permafrost.

Since 2021, Cryosphere Initiative organized two field trips to install climate stations and to interact with the community leaders and the local community

School children in Yalbang

Protection structures

Climate monitoring and local participation

Increasing awareness

Conclusions

Permafrost maps generated using remote sensing and machine learning fairly represent the probability distribution of permafrost.

Data from ground surface temperature loggers is crucial to delineate permafrost boundaries.

Preliminary results indicate that debris-flow initiation areas are potentially associated with changes in permafrost.

Biophysical and socio-economic impacts of changes in permafrost are visible in Humla.

Addressing limitations in adaptation activities and research related to changes in permafrost in Humla is essential and attainable.

Thank you

Acknowledgements

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