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Mapping cryogenic processes and assessing the sustainability of permafrost landscapes in the North-East Arctic Siberian taiga and tundra from Landsat 8, Sentinel 2, and DEM data

Sébastien Gadal, Moisei Zakharov, Jurate Kamicaityte
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INTRODUCTION

Permafrost landscapes are one of the most vulnerable ecosystems in which humans live. The cryolithogenic and biophysical conditions are among the most important variables for classifying ecosystem vulnerability. These variables point to cryogenic processes that can be activated during permafrost degradation. Mapping their distribution based on landscape classes currently remains the main way to assess the state of permafrost and design infrastructure in permafrost landscapes. However, the problem of synthesizing the method of remote modeling and recognition of taxonomic units of permafrost landscapes remains relevant for detailing the spatial structure and accuracy of sustainability assessment for hard-to-reach mountainous areas of the Arctic.

STUDY AREA

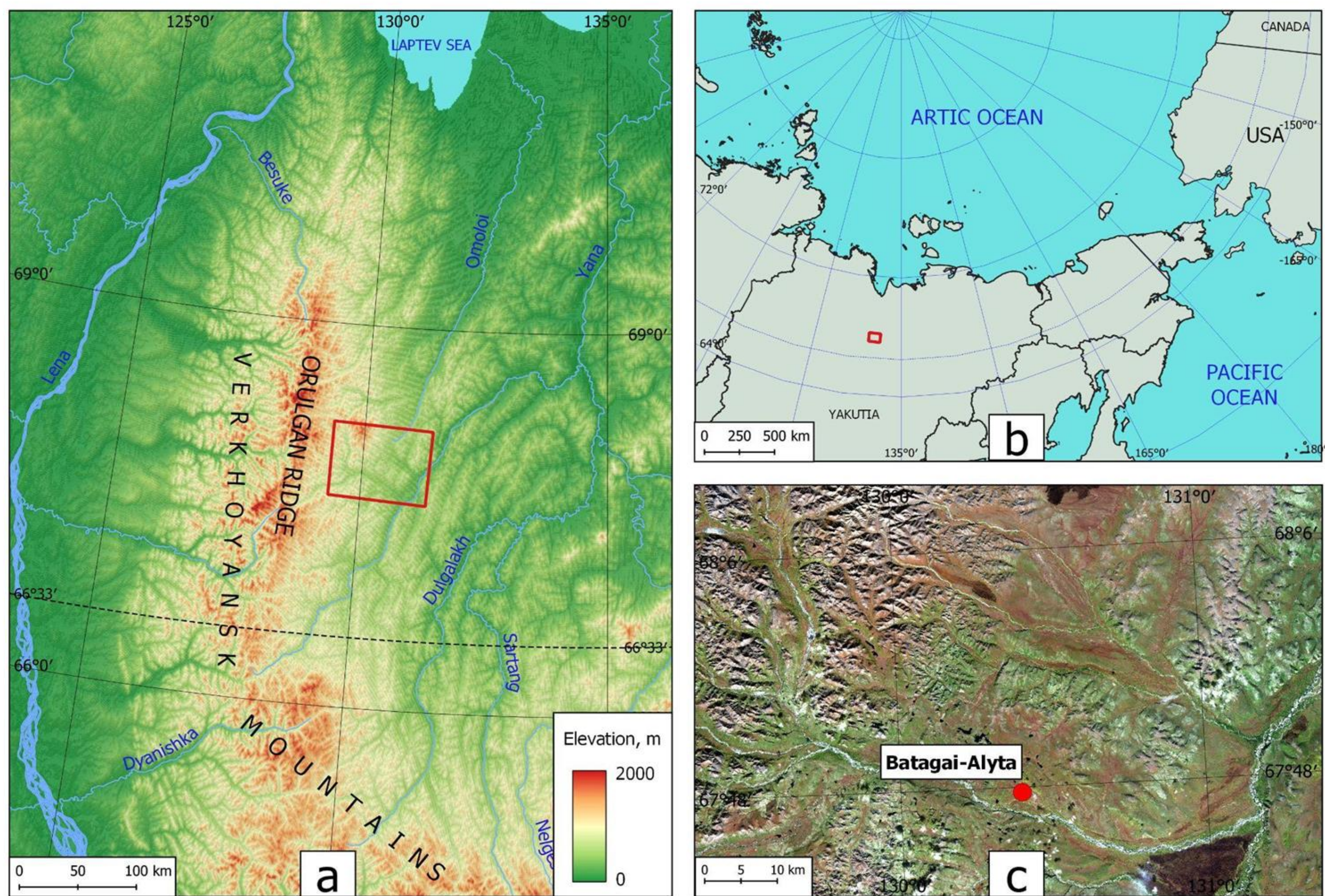


Fig.1 a) Physical map of Orulgan Ridge; b) Localisation of study area c) Study area RGB of Sentinel 2 July 2019

OBJECTIVES

The **aim of this study** is to assess the sustainability of mountain permafrost landscapes of various types (stony mountain deserts, tundras, sparse mountain forests and northern taiga in valleys) based on data from Sentinel 2, Landsat 8 and ASTER GDEM.

METHODS & MATERIALS

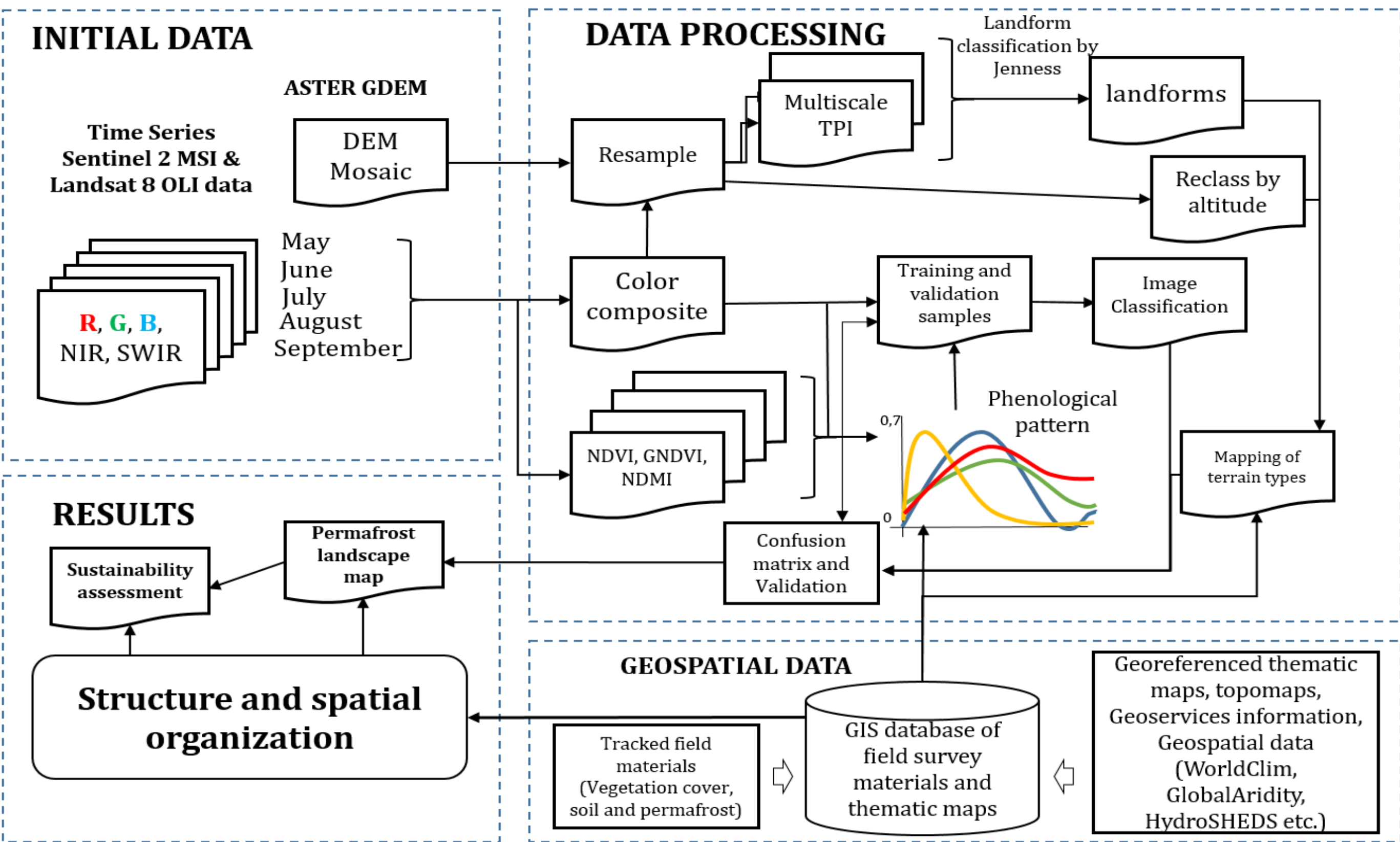


Fig.2 Methodological workflow of modeling

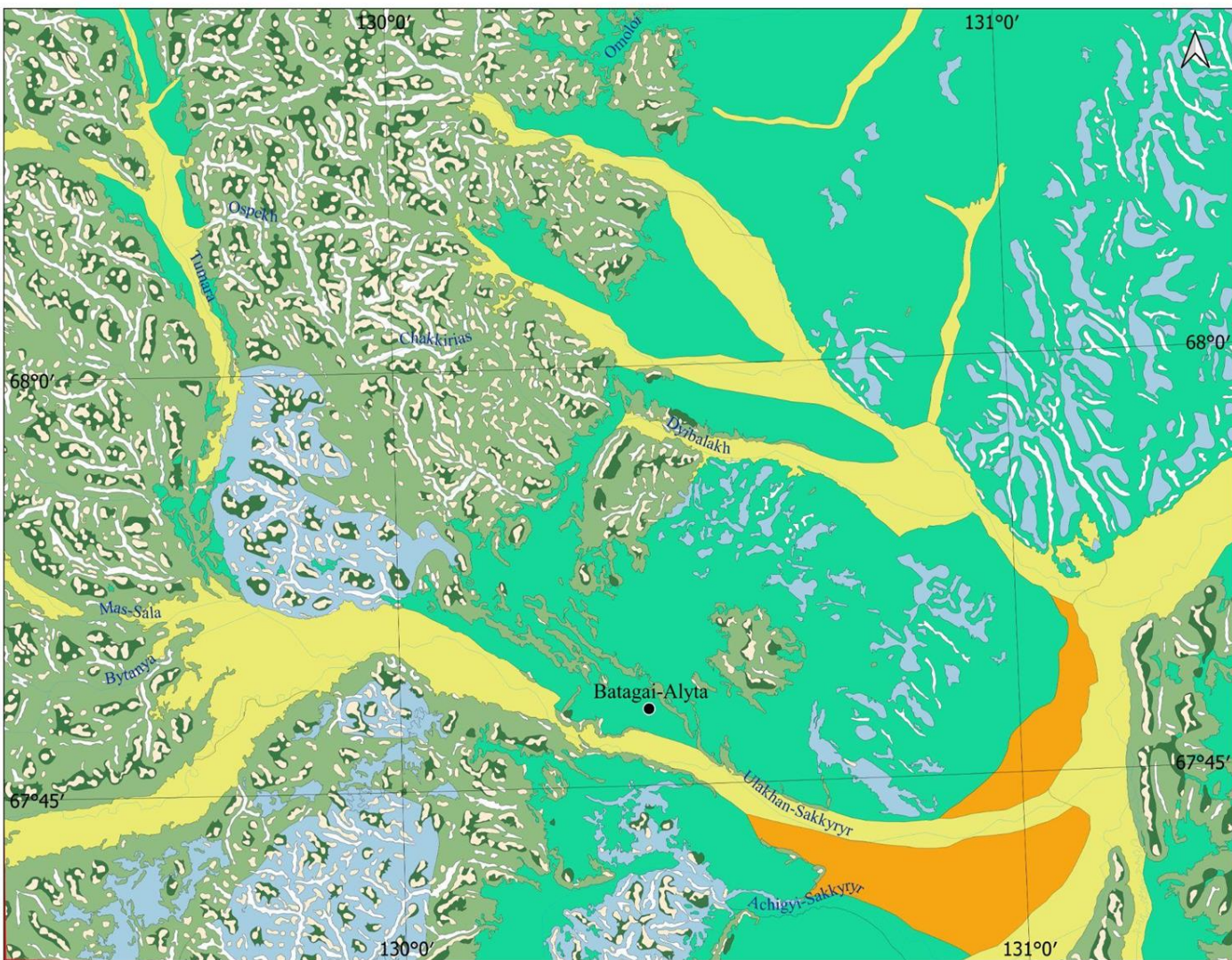


Fig.3. Terrian types by landform classification

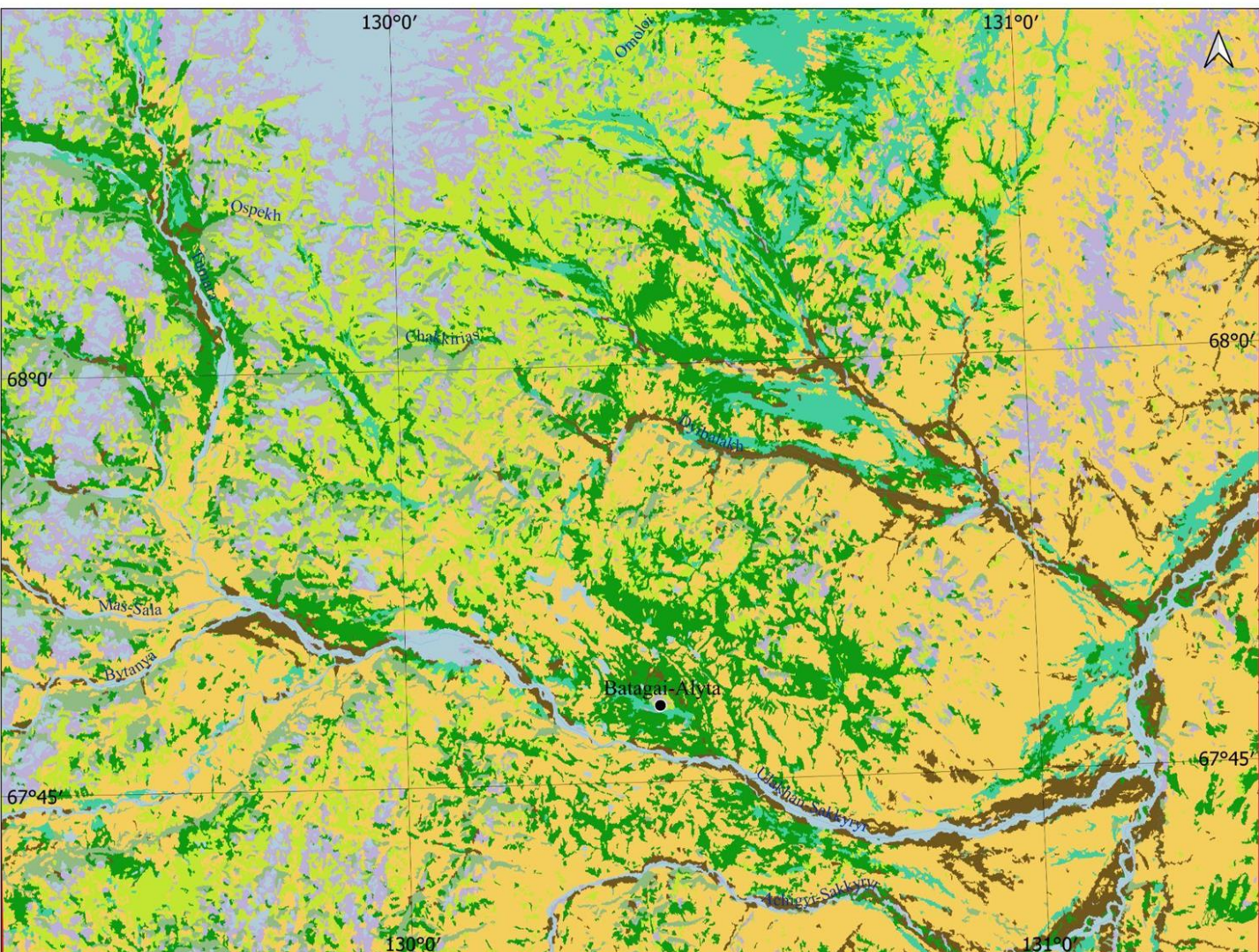


Fig.4. Land cover classification by Random Forest

RESULTS

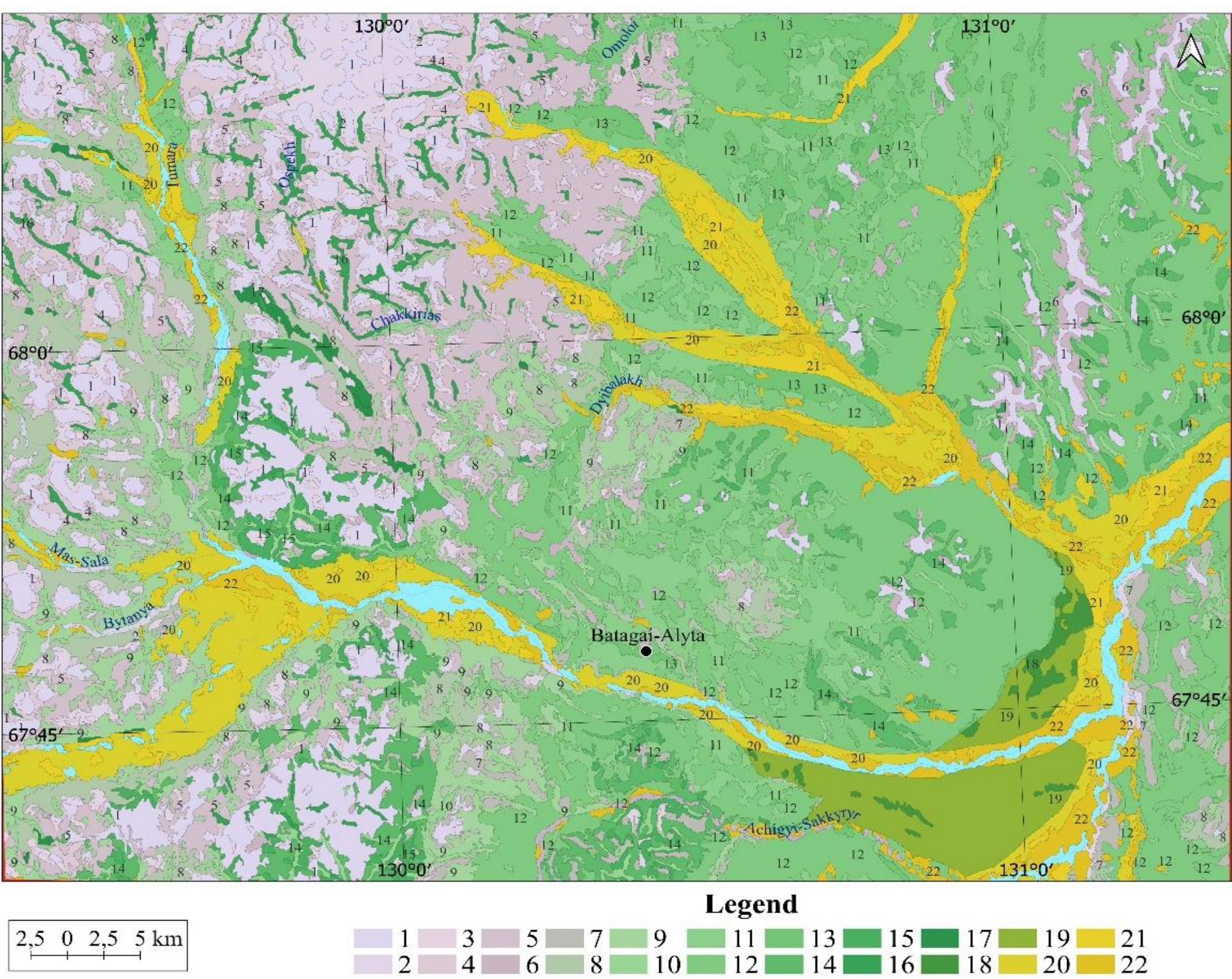


Fig.5. Permafrost landscape map.

Table 1. Sustainability of permafrost landscape

Mountain desert	Tundra	Sparse mountain forest	Mountain valleys	Boreal forest valleys
1. High sustainability, low ecological potential, low ice content				
1. Rocky peaks with epilithic-lichen; 2. Steep colluvial slopes with epilithic-lichen	3. Flat peaks and high colluvial-sloval slopes with lichen tundra; 4. Steep colluvial slopes with dwarf shrub-lichen-moss tundra		16. Glacial-accumulative glacial mountain valleys with tundra meadows and participation of dryad-moss-lichen tundra	
2. Low sustainability, low ecological potential, high ice content				
			17. Glacial-accumulative and alluvial mountain valleys with bogs and marshy meadows	
3. Moderately sustainability, ecological potential is average, ice content is average				
		7. Gentle deluvial-colluvial slopes with larch moss-lichen; 8. Gentle deluvial-colluvial slopes with larch shrub-moss and moss with yernik; 12. Gentle outwash terraces with larch lichen and moss-lichen; 14. Gentle and medium-steep moraine slopes with larch lichen and moss-lichen;		18. Medium-altitude erosion-accumulative terraces with larch lichen woodlands and participation of meadows
4. High sustainability, high ecological potential, low ice content				
5. Gentle deluvial-colluvial slopes with forb-dryad tundra in combination with dwarf shrub-moss-lichen mountain tundra with yernik		9. Medium-steep deluvial-colluvial slopes with larch dwarf shrub-moss; 10. Steep colluvial slopes with larch dwarf shrub-lichen; 11. Gentle outwash terraces with larch shrub- moss-lichen and moss with yernik		21. Low accumulative alluvial terraces with marshy meadows and yernik; 22. Low accumulative alluvial terraces with a complex of alder-willow communities, larch and poplar
5. Low sustainability, high ecological potential, high ice content				
	6. Gentle slopes and medium moraine slopes with mixed-grass-dryad mountain tundra with yernik	13. Gentle outwash fluvio-glacial terraces with bogs and larch moss; 15. Gentle and medium-steep moraine slopes with larch dwarf shrub-moss-lichen		19. Medium-altitude erosive-accumulative terraces with marshy meadows and yernik

The most common cryogenic processes are frost cracking (69%) and thermokarst (56%) (Fig. 6). They appear on gentle slopes and valley bottoms, where glacial and moraine deposits accumulate. These cryogenic processes complicate the spatial structure of landscapes, creating a microrelief.

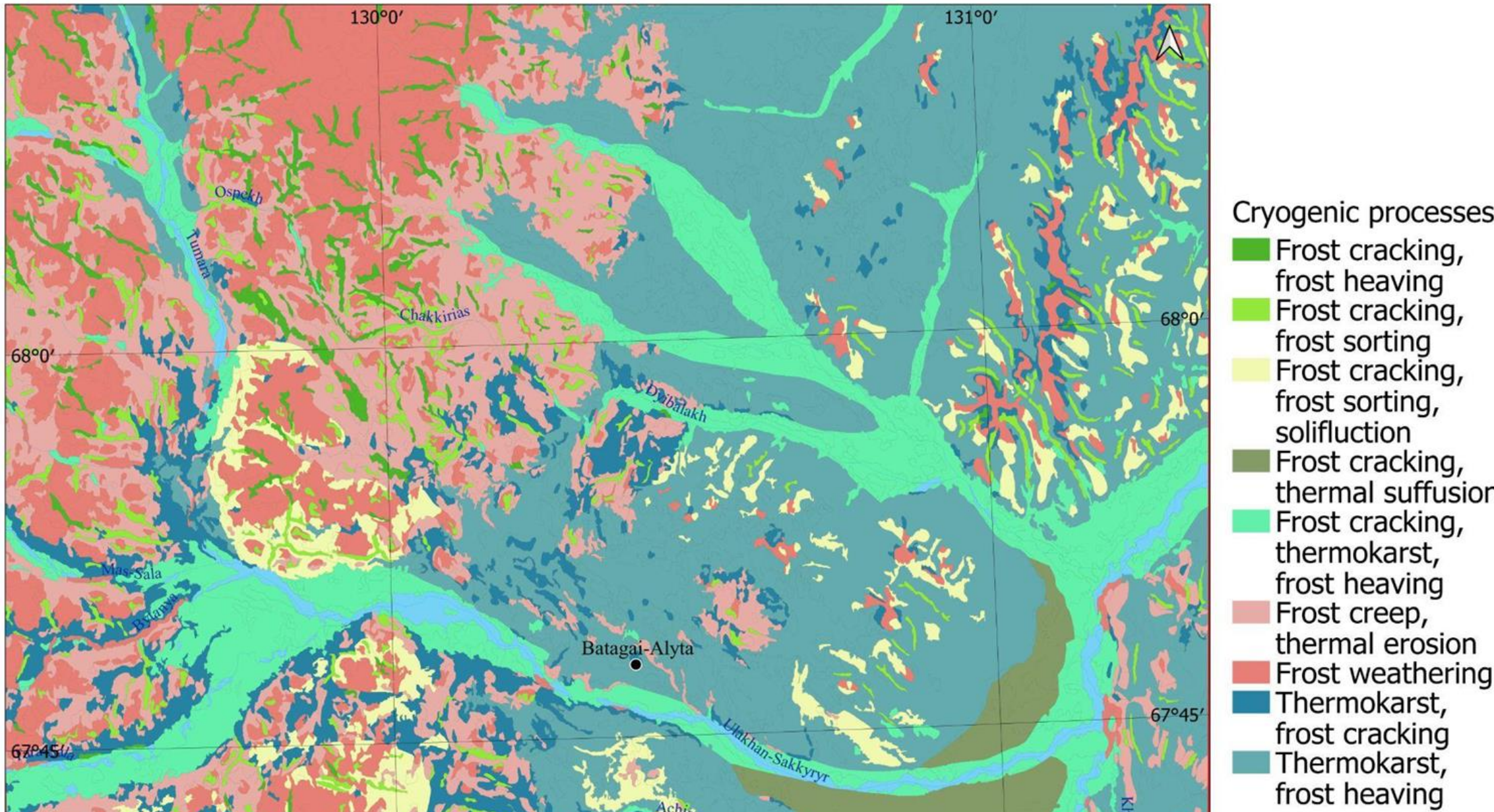


Fig.6 . Map of the distribution of cryogenic processes

CONCLUSIONS

Sustainability assessment requires a detailed inventory of landscapes and a detailed spatial structure, which we have achieved by modeling the time series of multisensor remote sensing data. The results obtained made it possible to assess the types of landscapes in five groups of stability. Cryogenic processes are mapped. The greatest danger is presented by landscapes with a strong content of ice and thermokarst. Especially in the valleys, which are the most vulnerable and valuable for traditional land use. The methodological approach is in demand in the design of road infrastructure in the permafrost zone and forecasting the dynamics of mountain permafrost landscapes in the context of climate change.

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