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PERMAFROST LANDSCAPE'S STRUCTURE CATEGORISATION BASED ON LAND COVER, DIGITAL ELEVATION MODEL AND LAND SURFACE TEMPERATURE ON VERKHUYANSK MOUNTAIN RANGE

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Introduction

The Orulgan ridge is the highest northern part of the Verkhoyansk mountains system, where cryogenic processes occur in the conditions of continuous permafrost distribution and landscapes with altitudinal zonation. The mapping and sustainability assessment of which is also complicated by the lack of constant geocryological observations. Methods of image processing and interpreting various remote sensing data increases the spatial and temporal capabilities of integrated monitoring of landscape and permafrost activities [Jorgenson & Grosse, 2016].

Comprehensive monitoring of the permafrost has become one of the key mechanisms for frost protection (the Law "On protection of the permafrost in the Republic of Sakha (Yakutia)", 2018). Remote sensing data can significantly improve the ability to determine the spatial structure of landscapes permafrost.

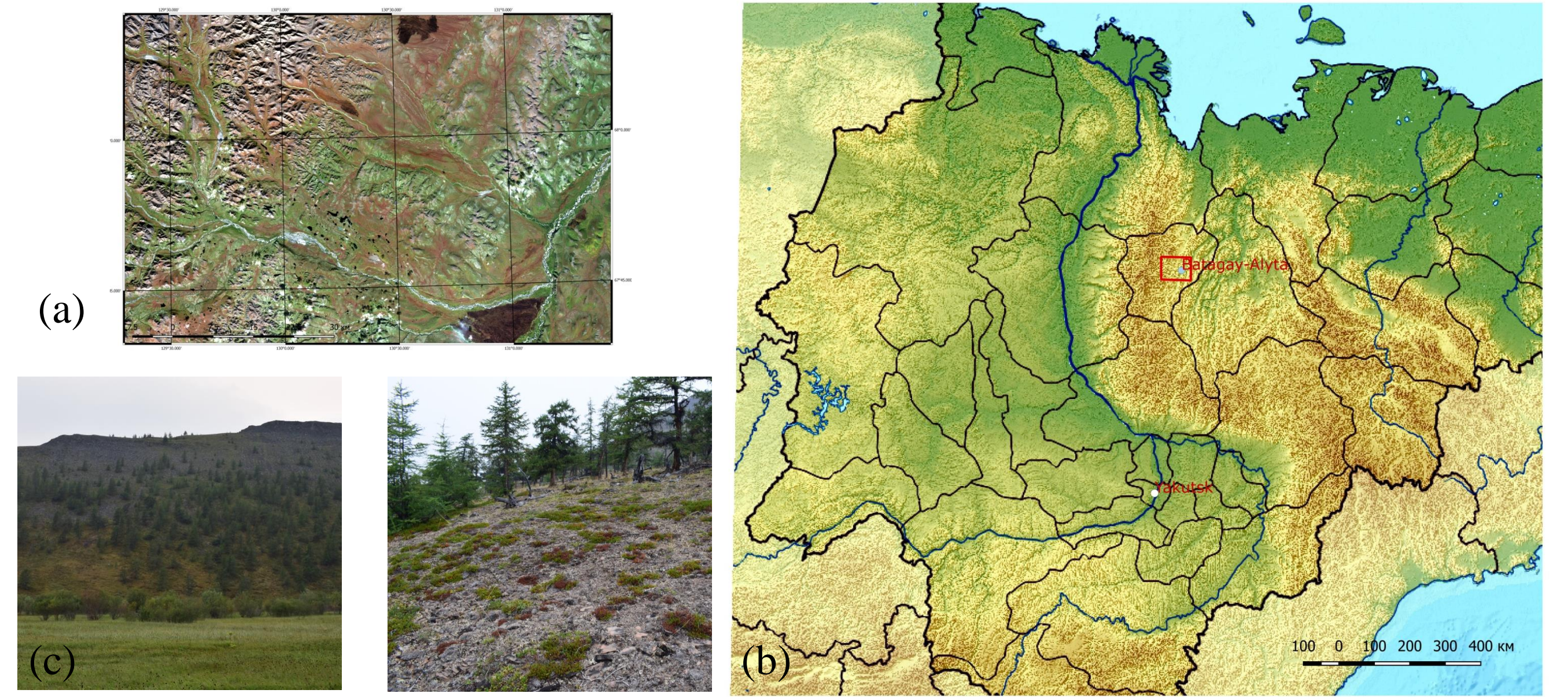


Figure 1. Study area: a) RGB Sentinel 2 b) Localization c) type of landscapes (July 2019)

Data and Methods

Landscape. The recognition of landscape types is mainly based on vegetation cover, namely, a combination of groups of vegetation associations, the selection of which is possible when assessing the difference in the photosynthetic activity of dominant plants during the vegetation season (Stytsenko, 2018). We used low-cloud multispectral Sentinel 2A images from August 29, 2019, July 12, 2019 and June 15, 2019. Using the supervised classification with learning the maximum likelihood algorithm, we obtained land cover maps (Fig. 2)

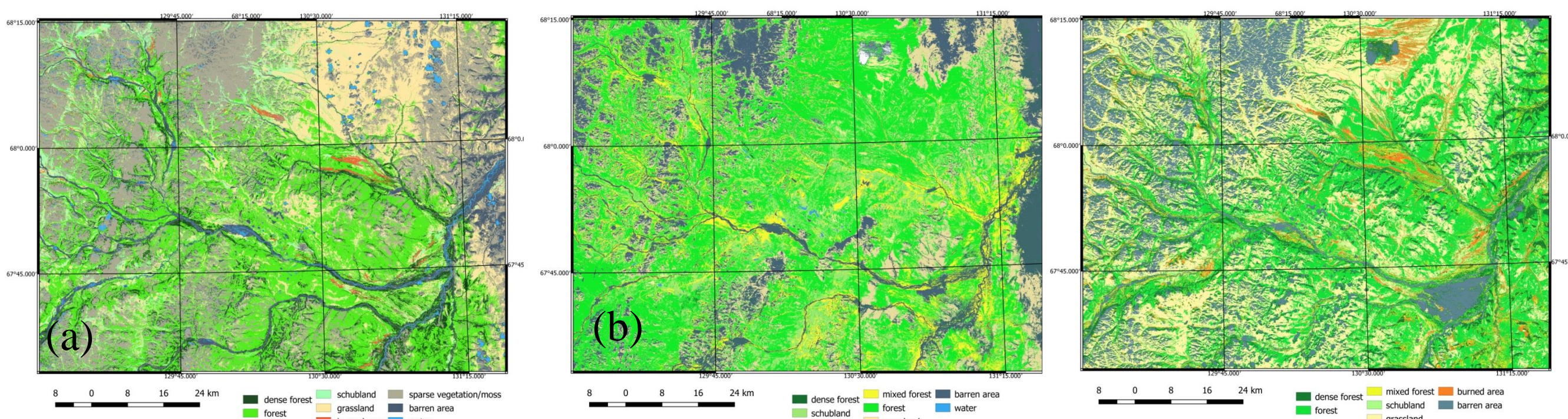


Figure 2. Land cover classification (a) June 2019 (b) July 2019 (c) August 2019

Terrain. The main criterion for identifying the types of terrain is the complex of lithogenic complexes of surface deposits and the degree of their drainage and the nature of ravine-girder dissection (Fedorov, 1994). These external features are well reflected in digital elevation models. In this study, we used the TPI and the data obtained with compiled ASTER GDEM data for the semi-automatic output of meso-relief elements (Fig 3).

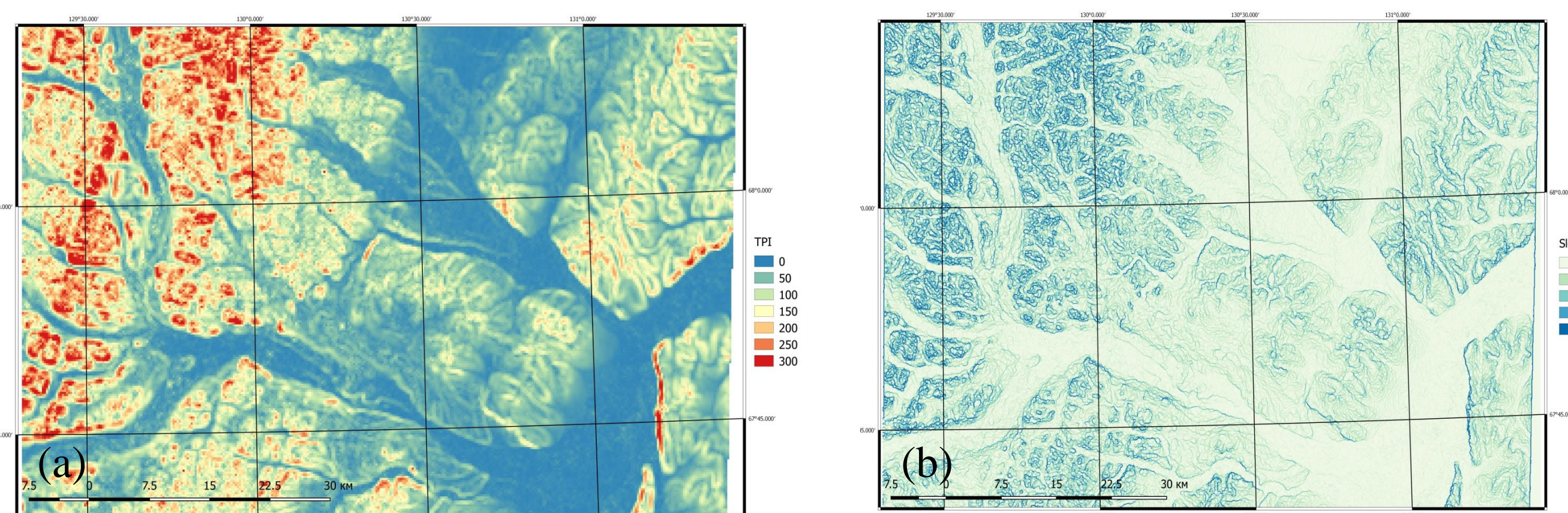


Figure 3. (a) Topographic position index and (b) Slope degree

Permafrost pattern. Rock temperature formation affects complex factors, most of which are physiognomic and therefore are reflected in remote sensing data (elevation, slope and exposure, vegetation and snow cover) (Kalinicheva, 2018). Land surface temperature reflecting the landscape conditions of the area (with a certain choice of shooting time), is one of the reliable criteria in the allocation of permafrost and thawed rocks in mountainous areas.

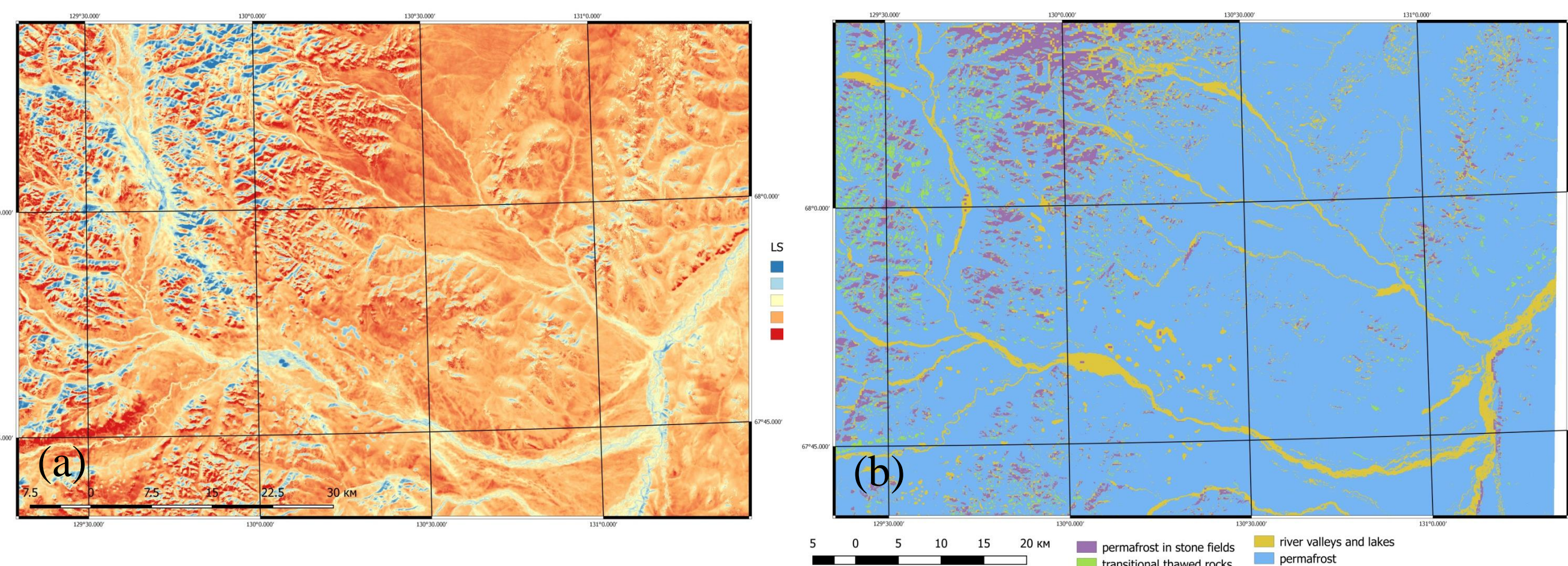


Figure 4. (a) LST Landsat 8 OLI/TIRS July 2019 and (b) Permafrost pattern map

Conclusion

This work focuses on categorization the structure of permafrost landscapes using a combination of interpretation of remote sensing processing results and landscape selection criteria. The results show the spatial structure and vertical subordination of frozen landscapes in a strict taxonomic system and allows you to work from a single methodological position. This work is an attempt to create a static model of the landscape structure by external features to assess the stability of permafrost landscapes by further integrating the dynamic model. The patterns of spatial differentiation of the landscapes of this territory will make it possible to determine the preferred anthropogenic loads and to rationally approach the use of nature management in general.

General approach

Permafrost landscapes of different generation levels have clearly defined indicative properties, which made it possible to develop a landscape-cryoindication approach in which various methods of processing remote sensing data were tested at different levels. Thus, we can combine the existing criteria for permafrost landscape selection and methods for obtaining geographical information with remote sensing.

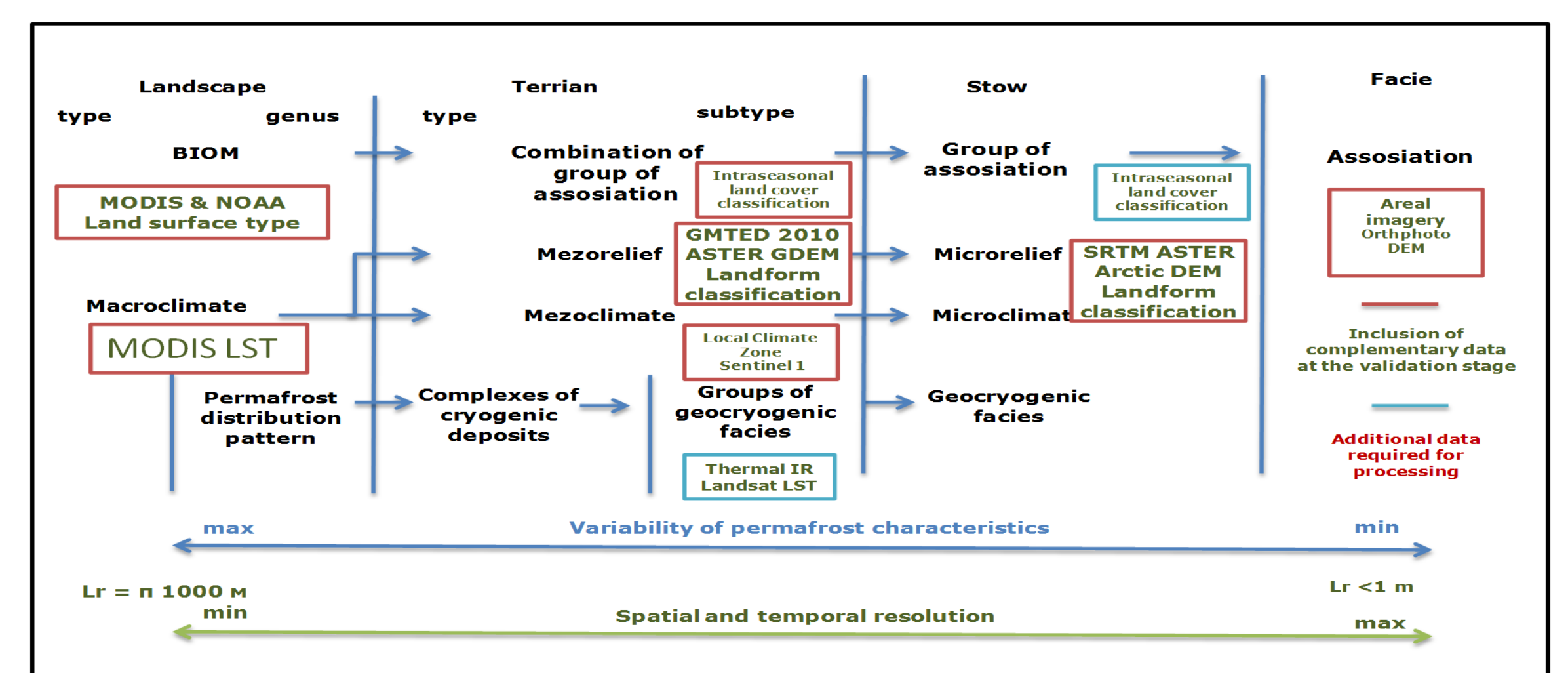


Figure 5. Conceptual schema of a multi-methodological approach to permafrost landscape structure differentiation

Result

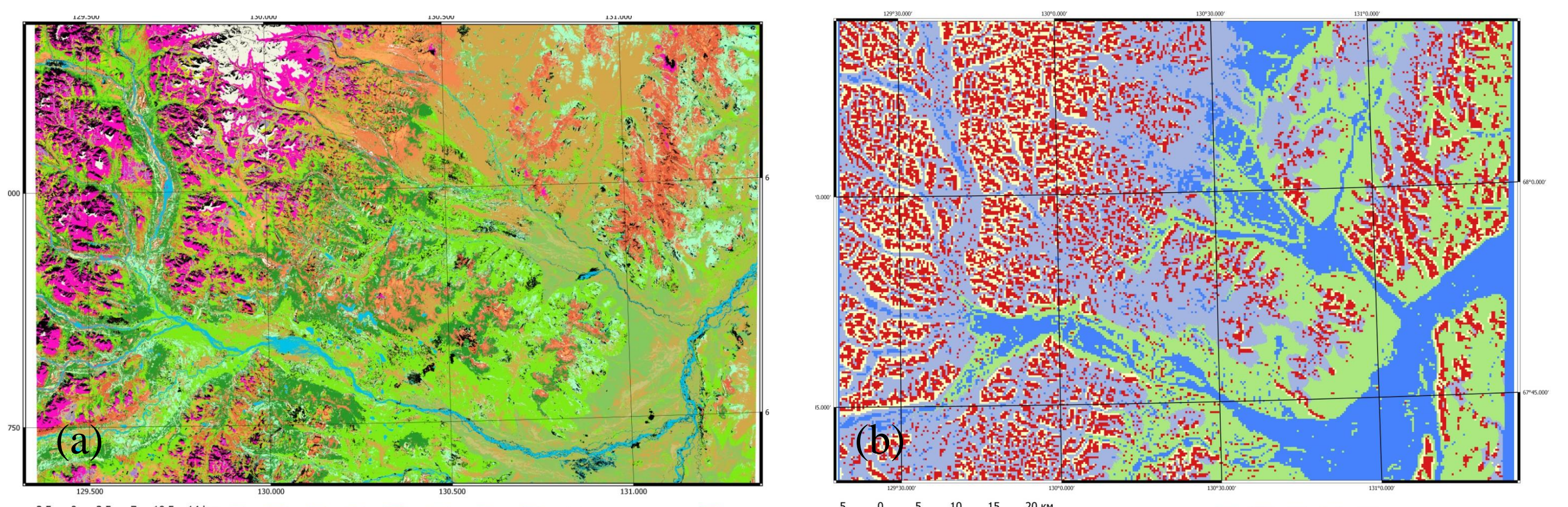


Figure 6. (a) Vegetation cover map (b) Landforms map

The post-processing interpretation results presented in the form of maps reflect the spatial structure of permafrost landscapes: a map of the vegetation cover, a map of the types of terrain, and a map of the distribution of permafrost complexes.

№	Vegetation cover	%	№	terrian	%
1	larch woodland, birch, bilberry slope	8.59	4	mid-altitude terrace	30,73
2	larch woodlands on lingonberry-ledum slope	18.25			
3	subalpine-shrubby	7.03	5	glacial valley	18
4	alm	5.96			
5	water meadow	2.10			
6	willow shrubs	2,45	3	mountain slope	10,21
7	larch woodland moss	1,21			
8	tussock meadow	7,49			
9	subalpine-lichen with juniper thickets	7,60			
10	alpine meadow slope	1,94	1	hilltop	19,53
11	meadows forbs and dryads alpine	0,97			
12	charred epilithic-lichen	2,30			
13	larch woodlands low-terraced	7,64	2	low-terrace	21,53
14	valley mixed forests	3,60			
15	willow shrub low-terraced	13,43			

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