Study of off-road vehicle trails impact on tundra landscapes by field and remote-sensing methods, Central Yamal, Russia

Artem Khomutov[1,2], Marina Leibman[1,2], Yury Dvornikov[1], Olga Khitun[3]

[1]Earth Cryosphere Institute SB RAS, Tyumen, Russia, akhomutov@gmail.com

[2]University of Tyumen (Tyumen State University), Tyumen, Russia

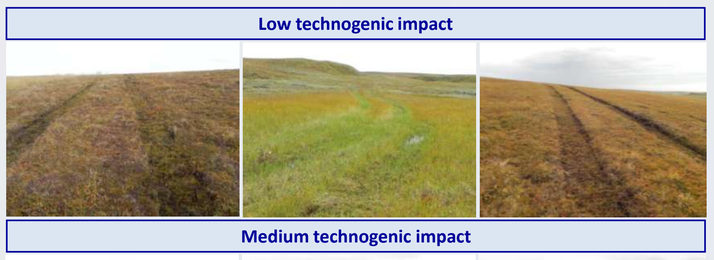
[3]Komarov Botanical Institute RAS, Saint Petersburg, Russia

Study of landscape changes caused by human impact are an important part of research in the Arctic. It was shown (Moskalenko 2012) that moisture content and ground temperature were determinants of the landscape complex evolution in the island permafrost zone of West Siberia. However, northward, in treeless locations, distribution of low-temperature continuous permafrost and massive ground ice do not allow fully extrapolation of these results to the typical tundra subzone of Central Yamal. The study of technogenic impact including off-road vehicle trails was conducted by Kumpula et al (2011) for industrial zone of Bovanenkovo gas field where all terrain disturbed by gas industry (buildings and yards, roads, sand quarries, pipelines, etc.). It was established that 5.3% of total 448 sq.km area of the gas field was disturbed by off-road vehicle trails.

Research station "Vaskiny Dachi" with long-term monitoring of permafrost and related environmental features including the dynamics of surfaces affected by off-road vehicles is a key area for the study of their technogenic impact on landscape complexes (Khomutov&Khitun 2014). In contradiction to Bovanenkovo, here off-road vehicle trails are the major disturbance of terrain.

Degree of disturbance by off-road vehicles (Khomutov&Khitun 2014)

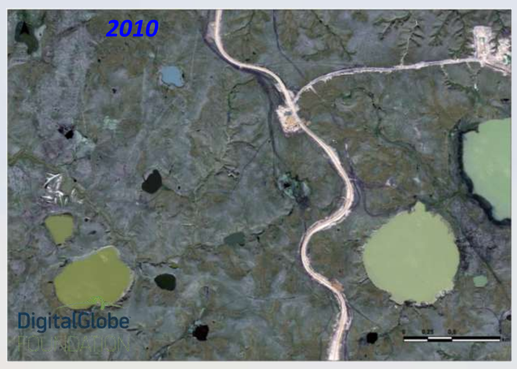
Low technogenic impact

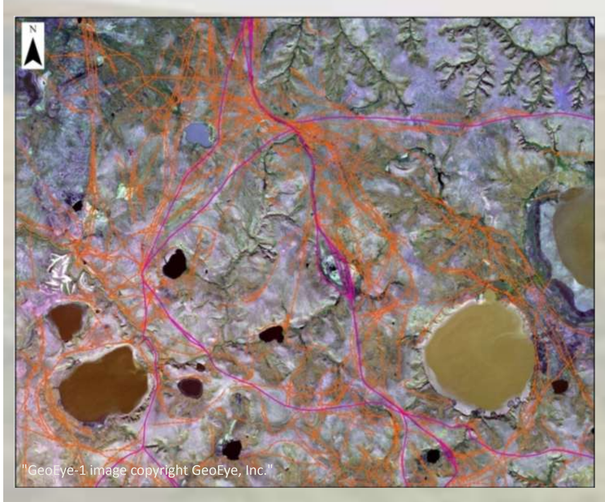


Medium technogenic impact

High technogenic impact

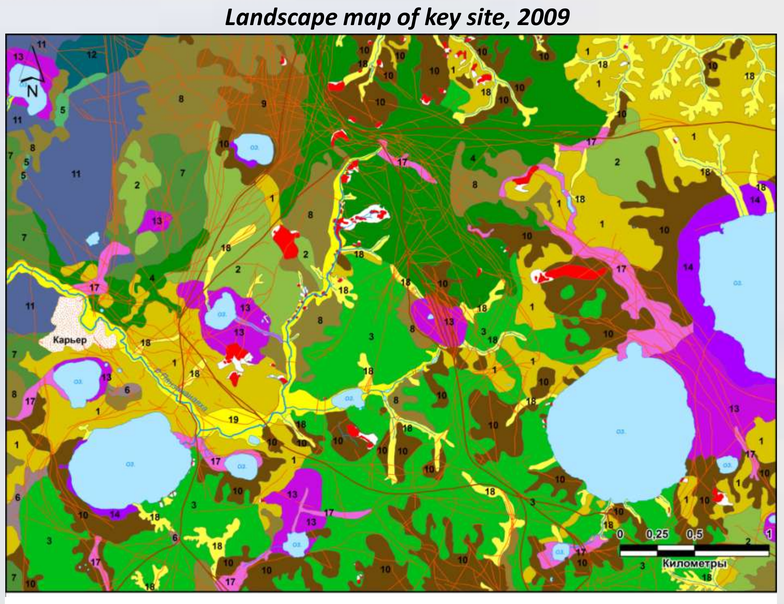
Disturbance of landscapes with off-road vehicle trails is assessed for the period prior to railway Obskaya-Bovanenkovo construction (2010) in the study area. Visually determined are trails that were not used for a long time and those used recently. Disturbance is defined as an area of the trail versus area of the landscape unit. Trail area calculated from a satellite image is linear dimension multiplied by 5 m for abandoned or rarely used trails and 8 m for actively used ones.





Total trail length 243 km; used 24,5 km; S = 1,04 km² (~5% of total area)

Landscape map of key site, 2009

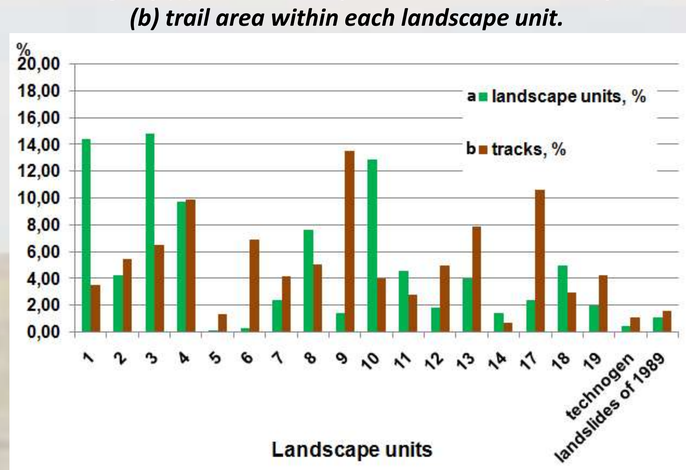


1 - 17 Landscape indices

Cryogenic translational landslides of 1989: а – landslide body, б – shear surface

Off-road vehicle tracks: а – used and recent, б – old and rarely used/not used

Percentage of (a) each landscape unit area in total study area; (b) trail area within each landscape unit.

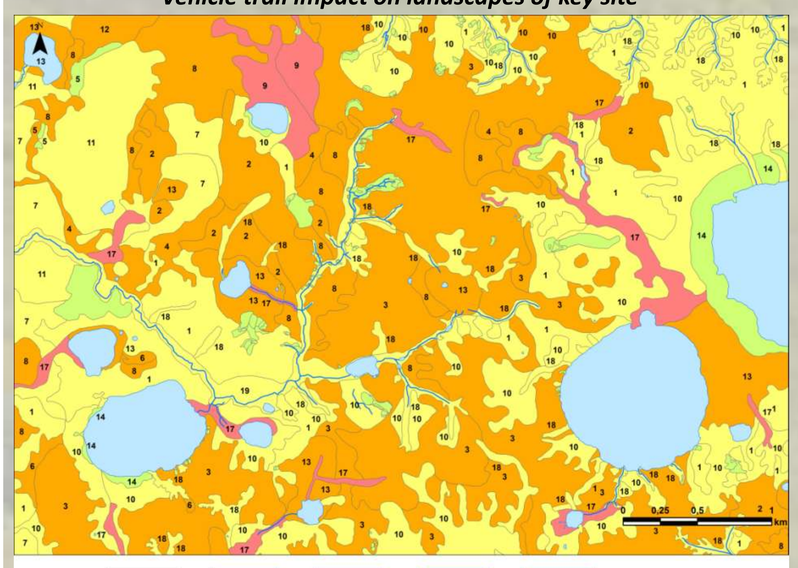


1 convex hilltops and adjacent slopes with polygonal dwarf shrub-herb-lichen tundra
2 flat subhorizontal watersheds with hummocky herb-dwarf shrub-moss-lichen and tussocky shrub-herb-moss tundra
3 flat subhorizontal watersheds with herb-shrub-moss tundra
4 flat subhorizontal watersheds with hummocky-tussocky shrub-herb-moss tundra
5 peripheral zones of flat subhorizontal surfaces with hummocky polygonal herb-dwarf shrub-moss-lichen tundra
6 polygonal peat plateaus
7 flat slightly sloping surfaces with herb-moss-shrub tundra
8 flat gentle slopes with tussocky herb-grass-moss willow thickets
9 flat gentle slopes with tussocky shrub-sedge-sphagnum communities
10 concave gentle slopes with ancient landslide shear surfaces, overgrown by herb-grass willow thickets
11 concave subhorizontal surfaces with dwarf shrub-sedge-sphagnum and cottongrass-sedge-moss bogs
12 flat subhorizontal surfaces with cottongrass-sedge-moss bogs
13 drain lakes (khasyreis) 14 low lake terraces
17 drainage hollows 18 gullies and ravines
19 small stream valleys

Field measurements combined with remote-sensing data showed the range of disturbance in the study territory between 0.7 and 13.5% depending on the landscape properties. Subdivided 21 landscape units were aggregated in 4 groups with relatively narrow range of disturbance:

low (<2.0%), medium (2.0-4.9%), high (5.0-10.0%), and very high (<10%) of trail area.

Vehicle trail impact on landscapes of key site



1 - 17 1 2 3 4 5

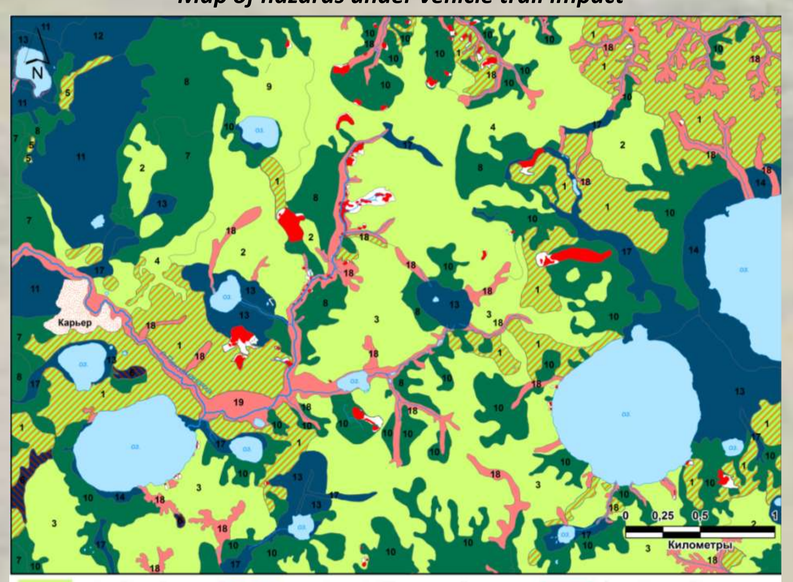
1 - landscape indices
Range of disturbances: 2 – low, 3 – medium, 4 – high, 5 – very high

Main controls of degree of disturbance are complexity of topography and waterlogging in highly dissected rolling hills and flat-bottomed valleys and lake depressions, hindering cross-country driving. Less hindering are high shrubs often combined with complex topography of landslide affected slopes. Most favourable for driving and thus most disturbed are dry flat watersheds, well drained. At the same time, very highly disturbed are flat waterlogged landscape units because one can't use the same trail for the second time and zone of the disturbance by trails in such units are extremely wide.

Landscapes (briefly)

1-5 – convex and flat rather drained surfaces
6 – peatlands
7-9 – flat shrubby slopes
10 – concave landslide slopes
11,12 – overwet surfaces
13 – khasyreys
14 – low lake terraces
17 – drainage hollows
18 – gullies
19 – small river valleys

Map of hazards under vehicle trail impact



Several years after the main technogenic impact resulting from Bovanenkovo gas field development stopped and one year before railway embankment construction started when no further technogenic impact was applied, more than one-half of affected surfaces was consistently overgrowing. 10.3% of such surfaces (0.11 sq.km) were characterized by high probability of wind-blown sands. Degradation and slow recovery of shrub cover were characteristic of 20.3% (0.21 sq.km) of surfaces affected by off-road vehicles. Increase of moisture content and swamping with higher risk of thermokarst were observed on 16.3% (0.17 sq.km) of trails. The risk of thermal erosion and cryogenic landsliding due to technogenic impact increased by 4.8% (0.05 sq.km) of affected surfaces.

Thus, the total disturbance by vehicle trails on the area distant from Bovanenkovo gas field is almost the same as in Bovanenkovo itself (5.5% against 5.3%). Probably impact in Bovanenkovo was much higher at early stages of development but trails were partly covered by construction and drilling pads and embankments.

Landscapes affected by vehicle trails in Vaskiny Dachi are characterized by different initial conditions of recovery of landscape components, or further technogenic activation of cryogenic processes. More than one half of affected surfaces is consistently overgrowing when no further technogenic impact is applied.

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