Specific Structure of the Vegetation Cover of the Starozavodskoe Solfataric Field (Baransky Volcano, Iturup Island) in Terms of the Development of Hydrothermal Resources

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Abstract. The paper describes the vegetation cover of the Starozavodskoe solfataric field, assesses the role of technogenic intervention in the formation of its complex spatial-species structure. Using the gradient factor analysis, the influence of the degree of technogenic disturbance on the formation of plant field groupings is determined. The conclusion is drawn about the dynamically equilibrium state of the field vegetation.

1. Introduction

Starozavodskoe solfataric field is one of two large clusters of solfatars and thermal mud, located on the western slope of the Baransky volcano (Iturup Island) (figure 1) [1, 2]. Being more accessible and promising, this field became at the end of the last century an object within which the work on the development of hydrothermal resources began. After the exploration and land planning, part of the landscape within the field was buried with dump soil, and new outlets of thermal waters and muds were formed at the drilling sites. As a result, the initial appearance of the field, and previously distinguished by spatial heterogeneity of vegetation cover, became much more complicated, and today its central part is a complex floristic ensemble, forming sharply and randomly intermittent various plant groups. Of course, a significant increase in floristic wealth contributes to the complexity of the organization and environmental links between the various components of the local ecosystem. At the same time, due to unregulated anthropogenic load, there is a risk of oppression of individual field components due to mechanical destruction of soil and vegetation cover by trampling. Due to the fact that quantitative analytical works devoted to the analysis of the spatial-species structure of a field formed after anthropogenic interference and under the influence of anthropogenic press have not yet been published, the purpose of this work was to determine the modern stage of field vegetation development violations, as well as the assessment of the current anthropogenic load on the soil-plant components of the field.
2. Materials and methods
The description of the vegetation cover was made after its preliminary division into components, differing mainly in aspect and general addition of species, by edaphic conditions [3, 4]. The final analysis included descriptions of 39 selected facies. Borders were tied to geographic coordinates using a satellite navigator. At each counting area, the species composition of vascular plants, the coverage of each species was revealed [5]. Disruption of microsites was evaluated visually on a five-point scale (1 - undisturbed microsites). Refinement and determination of vascular plant species was carried out using vascular plant determinants [6, 7], the names are given according to Barkalov [8]. To assess the biodiversity of vegetation, the values of the Shannon diversity index [9] and Simpson domination [10] were also calculated. Creation of vegetation maps of the Starozavodskoe solfataric field was carried out in QGIS. When analyzing the distribution of vegetation cover, the resulting sites were divided into clusters by the Ward method in Statistica [11] and DCA ordination was performed in PC-ORD [12–17]. The results of interpretation of the obtained data were confirmed by gradient analyzes of the relationships of various phytocenotic indicators and biodiversity indices.

3. Results and discussion
The results of the description of the vegetation cover of the field were clustered (figure 2). The Euclidean distance, approximately equal to 100, was chosen as the boundary for the selection. According to the dendrogram, 10 clusters are distinguished.
1. Sites of **cereal-forb** and **cereal-bulrush-forb** meadows, growing in sites where the vegetation was completely destroyed in the recent past. *Calamagrostis langsdorffii* (Link) Trin. (coverage up to 95%), *Juncus decipiens* (Buchenau) Nakai (up to 50%), *Aster glehnii* F.Schmidt (20–60%), *Equisetum sylvaticum* L. (10–30%) prevail in the herbage.

2. Sites dominated by **cereals** are also *Calamagrostis langsdorffii* (coverage 95% on one of the sites and 40–50% on the other two), growing together with *C. sachalinensis* F.Schmidt in the second site and *Miscanthus sinensis* Andersson and *Sasa spp.* on the third. The soil in these sites is characterized by high humidity to a water-logged state.

3, 4. The third group is **reed beds** dominated by *Phragmites australis* (Cav.) Trin. ex Steud. (coverage 90–98%). The fourth group, which includes three sites located on well-drained slopes, is also characterized by the dominance of another cereal (coverage 70–90%) – *Calamagrostis sachalinensis* (**reed grass** communities).

5. Sites characterized by increased soil moisture (located near the creek and stream channels), dominated by *Juncus filiformis* L. (coverage 70–95%) (**bulrush** communities).

6. Sites with **very sparse** vegetation cover. The coverage of most species does not exceed 20–30%. Up to 70% of the surface in some sites is bare soil, footpaths and placer stones from dump rocks. In such vacant lots, in some places, the synusias of *Miscanthus sinensis*, *Emetrum sibiricum* V.N.Vassil., *Ledum hypoleucum* Kom. grow and there are pioneer species in these conditions.

7. The site occupying an independent cluster is a community of *Solenostoma vulcanicola* (Schiffler) Nyushko, located near the exit of the thermal spring flowing into the stream, in which the liverhead occupies the entire area free of water – 85% of the area (**moss** community).

8. 9. The sites, formed mainly by *Miscanthus sinensis*, are characterized by a variety of ecotopic conditions – these are dry riverbed slopes, and wetlands, and small seals (**miscanthus** communities). *Ledum* and *ledum-cereal* thickets, growing on 5 plots, 60–95% of *Ledum hypoleucum* are folded (**ledum** communities).

10. **Sasa** thickets with an aspecting *Sasa spp.* (coverage 92–100%), occupying significant areas with a poor floral diversity. At the same time, this cluster is distinguished by the smallest differences between the sites that form it.

Figure 3 shows the spatial structure of the vegetation cover of the field.
The data obtained as a result of cluster analysis were used to display groups of sites in the ordination diagram (figure 4). The diagram shows that, like in the cluster analysis, the sasa communities are rather strongly separated, all the same with minimal differences among themselves. According to the results of the calculation of the Pearson correlation coefficient, a close relationship was established between the first axis of variation and the disturbance index – the coefficient \( r \) was \( \approx 0.70 \) (at \( p <0.001 \)), which, despite the obvious environmental effect of endogenous factors, demonstrates the strong regulatory role of the disturbance in the distribution of plant cover field.

To analyze the location of plant clusters to differently disturbed areas and the dynamics of their coverage and floristic wealth indicators, span diagrams were constructed (figure 5). The data obtained demonstrate the absence of signs of technogenic disturbances in communities dominated by sasa, reed and cereals along the periphery of the field, as well as in a single site with a solenostoma. The greatest scatter and maximum absolute values are characteristic for the central areas with a highly sparse vegetation cover, which are experiencing modern pressure from visitors. Silent inferior to them and the dominance of miscanthus. For the remaining clusters, a smaller scatter of values is characteristic, however, fluctuating within moderately high values. Comparative analysis of indicators of disturbance with indicators of cover showed significantly less coverage of the types of areas where the disturbance reaches 4–5 points. On the contrary, the highest coverage was observed in areas with disturbance indicators within 2–3 points, which is caused by multi-species groups without overwhelming domination (as opposed to overgrowth of sasa, reed, etc.).
Taking into account the strong influence of technogenic disturbances and anthropogenic stress noted on different microsites, it was logical to assume that there was no relationship between the dominance and biological diversity indicators within each value of the degree of disturbance. However, from the diagrams of the magnitude of these values for each group of plots with different degrees of disturbance, the opposite follows: trends in the dynamics of median and average values, as well as quartiles, mirror each other, which is characteristic of dynamically equilibrium communities (figure 6). It is very difficult to single out any significant differences between the extreme values of the indices within the various indices of disturbance due to the presence of factors of an endogenous nature that to a large extent determine the spatial-species structure of the field.
Figure 6. Dynamics of Shannon-Weaver H (left) and Simpson S (right) indices along the microsite disturbance gradient.

4. Conclusion
The plant communities of the Starozavodskoe solfataric field are represented by ten different groups of associations. The combined effect of endogenous forces and factors of a technogenic nature led to the formation of a unique mosaic microzonation of the vegetation cover of the central part of the field. According to the results of the calculations of the projective cover of vegetation and indices of $\alpha$-diversity, it was found that field communities are characterized as dynamically equilibrium. At the same time, the central areas are experiencing a serious burden from the visitors of the field, which resulted in low rates of cover. Given the high vulnerability of the field landscape components, there is a potential risk of similar processes of soil degradation and subsequent erosion in other areas that are not currently depressed. In this regard, there is a need to assign environmental status to a geographical object in order to preserve its uniqueness and integrity.

5. References
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