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# Reasons for the stability of the steppe ecosystems of the Republic Tyva (Russia)

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**Abstract.** The steppe region of Central Asia, to which the steppes of Tuva belong, has supported human culture for thousands of years and during this period has been subjected to serious climatic and social changes. In the past, this area was sparsely populated and the low productivity of the herbage fully provided livestock products to the local population leading a nomadic lifestyle. Folk customs strictly regulated the nature of grazing – its timing, cycles and duration. Having played an exceptionally important role in the history of mankind, the steppe was the first of all other landscapes to be on the verge of completely losing its original appearance and natural potential due to the replacement of grass ecosystems with agricultural landscapes during the Soviet period. Both in the past and at the present time, land use in the Republic of Tyva is due to the peculiarity of natural and climatic conditions and the development of pasture cattle breeding. Animal husbandry is still the main traditional branch of the economy. This article analyzes the reasons for the stability of steppe ecosystems, which are due to a number of reasons, the main of which are: changes in species composition, the presence of various survival strategies of organisms, high productivity of dominant plant species, as well as the spatial and temporal mosaic of available nutrients in the soil.

## 1 Introduction

The modern appearance and organization of the steppes was largely influenced by the grazing of wild animals, then domesticated, i.e. under pasture load. When grazing stops or, conversely, when overgrazing occurs, abrupt changes occur in phytocenoses [1, 2, 3, 4, 5]. Steppe vegetation is experiencing strong anthropogenic pressure as a result of the resulting imbalance between pasture productivity and pasture loads, the process of pasture digression begins.

Steppes in Tuva occupy intermountain basins with heights of 550-1250 m above sea level, the lower parts of mountain slopes, high terraces of river valleys. According to the gradient of latitudinal zonality, Tuva is located in the steppe zone. The latitudinal distribution of the steppe zone, as in Southern Siberia, is interrupted by mountain uplifts, between which steppe areas of varying area are preserved [6, 7].

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From the point of view of botanical geography, according to E.M. Lavrenko et al. [8] the research area belongs to the Eurasian steppe region, the Central Asian steppe subdistrict, where the steppes of Mongolia, Transbaikalia, Gorny Altai, Khakassia and Tuva represent a single whole within the extracontinental sector of the Palearctic. Different authors distinguish desert, desolate, real, dry, meadow and cryophytic (high-altitude) steppes, as well as their various variants [9].

## 2 Materials and methods

The steppes of Tuva, which are a continuation of the steppes of Mongolia, differ significantly from the steppes of the European part of Russia, because they are distributed on cold soils, in conditions of dissected mountain relief, insufficient moisture, low temperature conditions of air and soils, and the spread of permafrost. Currently, under the influence of cattle grazing, both directly (eating, trampling) and indirectly (changing growing conditions), the steppe vegetation of Tuva is at different stages of pasture digression.

The increased continentality of Tuva's climate creates a wide variety of phytocenoses belonging to high-mountain tundra, forest, steppe, meadow and swamp vegetation types. Forests occupy 49% of the territory of the republic and are associated with mountain rises. Steppes in Tuva are a widespread type of vegetation, occupy 17% of the territory and are located mainly in hollows [10].

The object of the study is the vegetation of the steppe and forest-steppe belts of the intermountain basins of Tuva. The key sites are located in the steppe ecosystems of the Turano-Uyukskaya, Central Tuvan and Ubsunur basins. The hydrothermal parameters and coordinates of the basins are shown in Table 1.

**Table 1.** Hydrothermal parameters and coordinates of the intermountain basins of Tuva.

| The basin | Coordinates | Altitude, m | Annual precipitation, mm | Average annual temperature, °C | | |
|---|---|---|---|---|---|---|
| | | | | year | January | July |
| Turano-Uyukskaya | 52°077' N 94°173' E | 800–1000 | 350–400 | -3.7 | -30.0 | 18.0 |
| Central Tuvan | 51°20'–51°33' N 90°22'–94°25' E | 500–1100 | 250–350 | -4.5 | -33.7 | 19.6 |
| Ubsunur | 49°50'–50°05' N 95°03' E | 800–1250 | 180–290 | -5.7 | -31.5 | 17.7 |

## 3 Results and discussions

The stability of steppe ecosystems is due to a number of reasons, the main of which are: the rapid change in species composition, the presence of various strategies for the survival of organisms, the high productivity of dominant plant species, as well as the spatial and temporal mosaic of available nutrients in the soil.

*Changing the species composition*

Steppes, like other grass systems, are in continuous succession, since the species composition of their biota depends on the mode of use, especially on the pasture load, which is always present and often changes. Successional changes in the species composition of the steppe community are the reason for the stability of the productive and destructive processes of the biological cycle, since photosynthesis occurs with any specific set of autotrophs and net primary products (NPP) are created. Accordingly, with any set of heterotrophs, the destruction of organic matter occurs and the batteries are released. So, using the example of the meadow steppe of the Central-Chernozem Reserve, it was shown how the species composition of vegetation and the value of NPP change when the pasture load changes from zero to strong. A steppe with moderate grazing was chosen as the initial community [11]. It turned out that the proportion of species preserved in the herbage during the change of load ranged from 33 to 66%, while the proportion of species that changed relative to the original herbage reached 45-80%. The quantitative characteristics of the biological cycle changed much less. With the weakening of grazing and conservation (zero load), the value of NPP increased by 20-30%, with increased grazing it decreased by 22%.

Thus, the foundation of the stability of the biological cycle with a change in the intensity of the disturbing factor is the continuous change in the species composition of autotrophs, the replacement of some species by others more adapted to these conditions. Similarly to the production process, it reacts to the load and the destructive process. Chemical pollution causes the restructuring of the heterotrophic complex. With organic soil pollution, the role of bacteria increases and the abundance of fungi decreases. In case of non-organic pollution, the opposite situation is observed – the growth of fungi and a decrease in the number of bacteria. However, the destructive function is carried out continuously due to the change of some destructors by others.

*Different strategies for the survival of organisms*

Steppe ecosystems were formed in the course of evolution under the direct influence of pasture load. As a result, steppe plants have developed certain functioning strategies that allow them to adapt to grazing. One of these strategies is the distribution of assimilates between green parts and underground organs with increased stress.

We studied the combined effect of two stress factors – an increase in aridity and pasture load in the steppes. All the studied species translocated more than 70% of the dry matter into underground organs. The strategy of photosynthetic distribution between aboveground and underground organs in response to an increase in pasture load turned out to be different for different species. In sedges and grasshoppers (*Stipa krylovii*), translocation to the roots increased sharply during intensive grazing. Oatmeal (*Helictotrichon desertorum*) is apparently unable to quickly transform the distribution of organic substances between organs, which leads to a decrease in its abundance under moderate load and to almost complete disappearance from the herbage during overgrazing. It is known that *Festuca valesiaca* and *Cleistogenes squarrosa* are very resistant to biting and trampling, despite the fact that the translocation of organic substances into the roots of these species decreases with heavy grazing. Their secondary growth after alienation of the green mass is determined by a large number of axillary buds, from which shoots grow, as well as the ability of terminal buds to produce two generations of leaves. Active secondary growth of shoots and leaves requires the flow of assimilates into the aboveground organs. Thus, in steppe species, interspecific variability in the distribution of organic substances between aboveground and underground organs is very high. Both translocation strategies (to aboveground and underground organs) can contribute to survival and growth with increased aridity and pasture load.

The coexistence of species with different survival strategies in response to stress ensures the functional heterogeneity of the community, supports its biodiversity and is one of the reasons for the stability of steppe ecosystems.

*High productivity of dominant plant species*

If we were considering only the aboveground production of steppe species, we would consider these plants to be low-yielding with a weak ability to compete. The new data allow us to express the exact opposite conclusion.

Steppe dominant species are highly productive due to the translocation of the main part of photosynthetics into underground organs. The carbon (or energy) “cost” of 1 g of underground organs is lower than above-ground ones, since the expenditure on respiration at the roots is half that of the green parts of steppe plants. The net primary production of steppe species, which are dominant communities, varies from 80 (*Artemisia ciniformis*, Kopet-Dagh mountain steppe) to 800 g/m$^2$ per year (*Stipa rubens*, real steppe of Kazakhstan). The active production of relatively “cheap” root tissues brings a quick gain to the plant in the competition for resources, increases the adaptation of species to drought and pasture stress and contributes to the stability of steppe ecosystems.

*Spatial and temporal mosaic of batteries*

Underground organs of various species closely coexist in a small volume of soil. One dm$^3$ of the topsoil contains roots of 8-11 species. Dominant, sodominant and minor species use soil resources together. Aggregation of different species in a small volume of soil is possible only due to the spatial and temporal mosaic of available nutrients. Spatial mosaic is usually associated with an uneven distribution of plant residues of various chemical compositions, which affects the rate of mineralization and release of nutrients.

Another reason for the spatial mosaic is the “spotty” supply of nutrients to regeneration cycles, determined by the extremely heterogeneous nature of soil microbial habitats. There are at least five different spheres of influence of the reducers in the soil. This includes the rhizosphere, detritosphere, habitats of earthworms and murals, as well as the surfaces of soil aggregates. Occupying only a small fraction of the soil volume, these “hot spots" are precisely the places where most trophic connections of organisms and regeneration cycles of nutrients are carried out [12].

The rate of mineralization of organic substances and the release of nutrients in any place, including “hot spots”, is influenced by temperature, humidity and the intake of fresh plant residues. All these factors, changing during the season, change the rate of regeneration cycles, which leads to a mosaic of nutrients. Any ecosystem retains its stability only as long as the main links of the biological cycle are not disrupted.

## 4 Conclusion

Any ecosystem remains stable as long as the basic processes of the biological cycle remain unchanged. The stability of productive and destructive processes in steppe ecosystems is due to a number of reasons.

The stability of the most important parameters of the biological cycle in the steppes is based on the extreme mobility of biota components and a large biodiversity of steppe communities. The high saturation of species with different strategies for the survival of a small volume of space, the rapid production of fresh portions of organic matter and successional changes in species composition support the intensity of production and destruction processes and the functioning of the entire mechanism of the steppe ecosystem.

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## References

1. D. J. Tongway, A. D. Sparrow, M. H. Friedel, Journal of Arid Environments **55** (2003)
2. J. Qi, X. Xin, R. John, P. Groisman, J. Chen, Ecological Processes **6**, 22 (2017)
3. T. E. Khomutova, F. Fornasier, M. V. Yeltsov, E. V. Chernysheva, A. V. Borisov, Land degradation and development **32,** 17 (2021)

4. Y. Zhu, M. Delgado-Baquerizo, D. Shan, X. Yang, Y. Liu, D. J. Eldridge, Plant Soil **450** (2020)
5. M. V. Vlasenko, L. P. Rybashlykova, S. Y. Turko, Agriculture **12** (2022)
6. A. A.Titlyanova, C. S. Kyrgyz, A. D. Sambuu, Soils and the environment **3**, 2 (2022)
7. A. A.Titlyanova, A. D. Sambuu, *Successions in grass ecosystems* (Novosibirsk, 2016)
8. Z. V. Karamysheva, E. M. Lavrenko, R. I. Nikulina, *Steppes of Eurasia* (Nauka, Leningrad, 1991)
9. A. D. Sambuu, *Sustainable development of the Republic of Tyva in the context of climate change* (Climate change and carbon neutrality: Challenges and Opportunities, Khanty-Mansiysk, 2022)
10. A. D. Sambuu, A. B. Dapyldai, A. N. Kuular, N. G. Khomushku, Arid ecosystems **18**, 4 (2014)
11. N. V. Semenyuk, A. N. Gudina, *Ecology of vegetation of pasture ecosystems of the Central Chernozem Reserve* (Dynamics of biota in ecosystems of the central forest-steppe, Nauka, Moscow, 1986)
12. D. C. Coleman, Microbial Ecology **28** (1994)