Indicators of the state of forage ecosystems arid and semi-arid territories of Siberia and Kazakhstan

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Abstract. Science-based management of forage ecosystems of arid and semi-arid territories and the fight against their degradation, carried out on the basis of systematic monitoring, assessment and accounting of their state and dynamics, are becoming actual state problems in Russia and Kazakhstan. As a result of studying, evaluating and agro-landscape-ecological zoning of territories of Siberia and Kazakhstan, creating databases of land resources and natural forage lands, using literary and stock data, the authors developed indicators of the state of forage ecosystems of arid and semi-arid territories. One of the most important ways to improve the effectiveness of assessments of the state and dynamics of degradation of forage ecosystems, as well as the most accurate diagnosis of negative processes is to solve the problem of creating and using a system of geobotanical and soil indicators of degradation of forage ecosystems. The full assessment of the state and development of the process of degradation of forage ecosystems can only be provided by using the entire system of indicators compiled on the basis of a combination of a number of main indicators of forage ecosystems. Geobotanical indicators of forage ecosystems include the following main indicators: change of plant communities, degradation of pastures, projective cover of indigenous and ruderal vegetation, productivity of natural pastures, etc. Soil indicators include: the area of allotments disturbed by erosion, the degree of destruction of surface soil horizons by erosion, the intensity of erosion, etc.

Science-based management of forage ecosystems of arid and semi-arid territories and the fight against their degradation, carried out on the basis of systematic monitoring, assessment and accounting of their state and dynamics, are becoming actual state problems in Russia and Kazakhstan \cite{1–5}.

Mapping and monitoring, assessment and accounting of the state of forage ecosystems of arid and semi-arid territories in both Russia and Kazakhstan should be based on a scientific regulatory and methodological basis. Such a framework should contain a common terminology and regulate the interpretation of terms that characterize the state of forage ecosystems. It also should include a System of indicators to assess the status and dynamics of forage ecosystems; the Classification of the dynamical state of degradation of forage ecosystems; Methodological guidance on the assessment, mapping
and monitoring forage ecosystems; uniform statistical reporting form to characterize the degradation of forage ecosystems [6–11].

The lack of a unified terminology system of indicators and criteria, classification and methods of specific areas of Russia and Kazakhstan, leads to a different interpretation of the degradation of forage ecosystems, interferes with their mapping and monitoring, hampers their assessment and consideration. For arid and semi-arid territories of Siberia and Kazakhstan that are similar in their natural conditions, it is possible to create a unified regulatory and methodological framework for controlling the degradation of forage ecosystems. One of the most important ways to improve the effectiveness of assessments of the state and dynamics of degradation of forage ecosystems, as well as the most accurate diagnosis of negative processes is to solve the problem of creating and using a system of geobotanical and soil indicators of degradation of forage ecosystems.

The solution to the problem of controlling the degradation of forage ecosystems is seen in the way of the combined use of data obtained from different indicators. None of the indicators taken separately does not fully reflect the state and development of the process of degradation of forage ecosystems. It is important to use the entire indicator system, which is based on a combination of a number of main indicators of degradation of forage ecosystems.

The presence or absence of these indicators, their number, or changes in state recorded by ground-based observations or remote surveys, indicate the nature, type, extent, causes, and dynamics of degradation of forage ecosystems (the direction and speed of processes). The requirements for selecting indicators are simplicity and reliability in use, cost-effectiveness and efficiency of monitoring the degradation of forage ecosystems [12–17].

As a result of studying, evaluating and agro-landscape-ecological zoning of territories of Siberia and Kazakhstan, creating databases of land resources and natural forage lands, using literary and stock data, the authors developed indicators of the state of forage ecosystems of arid and semi-arid territories.

Geobotanical indicators the status of forage ecosystems includes the following key indicators (table 1):

- change of plant communities of forage ecosystems under the influence of degradation,
- downed pastures,
- projection coverage of indigenous and ruderal vegetation,
- the number of species in plant communities and the participation of halophytes in them,
- yield and productivity of natural pastures,
- vegetation cover of the soil surface.

| Indicators | Undisturbed or slightly damaged | Weak | Moderate | Strong | Very strong |
|------------|--------------------------------|------|----------|--------|-------------|
| 1. Change of plant communities of forage ecosystems under the influence of degradation | Grass, wormwood-grass, grass-wormwood, grass-forb | Grass-wormwood, grass-forb | Wormwood, thistle-wormwood | Annuals, thistle, ephemeral | Ruderal, annuals, ephemeral, thistle sparse or missing vegetation is absent |
| 2. Downed pastures | Absent or weak | Weak | Medium | Strong | Very strong or absolute failure |
| 3. Projection coverage of native vegetation | 30–50 or more | 25–30 | 15–25 | 0–10 | 0–0.1 |
4. Projection coverage of ruderal vegetation, %  
| Coverage level | 0–0.1 | 0–5 | 5–15 | 15–30 | 0–30 |

5. Number of species in plant communities  
| Number of species | 15–30 | 10–20 | 5–15 | 5–10 | 0–5 |

6. Harvest vegetation, %  
| Harvest vegetation | 100 | 90–100 | 70–90 | 30–70 | Less 30 |

7. Gross yield of air-dry weight of the pasture, t/ha:  
- on loamy soils  
  | Yield level | 0.5–0.6 or more | 0.5–0.6 | 0.6–0.7 | 0.3–0.5 | 0–0.3 |
- on saline and saline soils  
  | Yield level | 0.35–0.45 or more | 0.35–0.4 | 0.3–0.4 | 0.1–0.6 | 0–0.6 |
- on sandy and sandy loam soils  
  | Yield level | 0.5–0.6 or more | 0.5–0.6 | 0.6–0.7 | 0.3–0.5 | 0–0.3 |

8. Pasture productivity, C feed units / ha:  
- on loamy soils  
  | Productivity | 2.0–2.5 or more | 2.0–2.5 | 1.5–2.0 | 1.0–1.5 | 0–1.0 |
- on saline and saline soils  
  | Productivity | 1.5–2.0 or more | 1.5–2.0 | 1.0–1.5 | 1.0–1.5 | 0–1.0 |
- on sandy and sandy loam soils  
  | Productivity | 1.5–2.5 or more | 1.5–2.5 | 1.5–2.0 | 1.0–2.0 | 0–1.0 |

Soil indicators the status of forage ecosystems includes the following key indicators (table 2):  
- the area of allotments where the surface of the soil cover is disturbed by erosion,  
- the degree of destruction of surface soil horizons by erosion,  
- the depth of linear erosion forms and their number per unit area,  
- intensity of erosion.

**Table 2. Soil indicators the status of forage ecosystems.**

| Indicators | Undisturbed or slightly damaged | Degree of degradation |  |
|------------|--------------------------------|-----------------------|--|
| 1. Soil surface blackness, % | More than 50 | 30–50 | 10–30 | 0–10 | -- |
| 2. Disturbance of the soil surface by wind erosion, % of the total area of allotment | Less than 5 fixed deflation ulcers | 5–10 fixed deflation ulcers | 10–30 developed ulcers of deflation. Presence of ripples on the surface | 30–50 mass deflation of the soil surface. The presence of hills, dunes, | 50–100 solid deflation |
Forage ecosystems of arid and semi-arid territories of Siberia and Kazakhstan were formed in the conditions of arid climate, low precipitation and high air temperatures, salinity of soils. Extremely harsh natural conditions of their existence are aggravated by intensive economic use, high anthropogenic loads [18–21].

The characteristic features of vegetation in arid and semi-arid territories are its low growth and sparseness, low productivity, complexity, the predominance of drought-resistant, salt-tolerant and grazing-resistant perennial grasses and semi-shrubs, as well as a significant number of annuals, ephemera and ephemerals in the vegetation cover.

Low growth and sparse vegetation contributes to the openness of the soil surface to the effects of arid climate, high temperatures and strong winds. Vegetation weakly anchors the soil of arid and semi-arid territories, which increases the risk of forage ecosystems degradation.

| 3. The degree of destruction of the surface horizons of the soil profile by wind erosion: | Blown out to 20% of horizon A | Blown out 20–50 of horizon A | Blown out 50–100 of horizon A | Blown out 50–75 horizons A and B | 75–100 horizons A and B |
|-----------------------------------------------|-----------------------------|-----------------------------|-----------------------------|-------------------------------|-----------------------------|
| 4. Disturbance of the soil surface by water erosion, % of the total area of allotment | Less than 5 | 5–10 | 10–30 | 30–50 | 50–100 |
| 5. Type of water erosion and the number of watercourses, washouts, potholes, ravines per 1 km perpendicular to the direction of the slope | Weak planar washout, single watercourses | Weak planar washout, separate watercourses, washouts and potholes less than 5 | Moderate erosion. Planar washout, 6–10 washouts and potholes, the beginning of the formation of ravine | Strong erosion. Strong flat washout, 10–15 washouts and potholes, separate ravines | Very strong erosion. Strong flat washout, more than 15 washouts, potholes and ravines |
| 6. Depth of linear erosion forms, m | In the horizon A less than 0.2 | In the horizon A 0.2–0.5 | In the horizon A and B 0.5–2.0 | In the horizon A, B and C 2.0–5.0 | More 5.0 |
| 7. The degree of destruction by water erosion of the surface horizons of the soil profile: | Less than 20% of horizon A | 20–50 of horizon A | 50–100 of horizon A | Up to 75% of the horizon B | Flushing the horizon C |
| 8. Intensity of wind erosion, t / ha / year | Up to 10 | 10–15 | 15–50 | 50–200 | More 200 |
Vegetation's ability to react sensitively even to weak changes in moisture content, salinity, wind and water erosion of soils, and anthropogenic loads makes it an extremely valuable indicator of the forage ecosystems state.

The degradation of vegetation, the increase in its disturbance, undergrowth, sparseness, and reduced productivity contribute to the development of degradation processes, increase the risk of desertification, and reduce the rate of recovery of degraded forage ecosystems.

Highly degraded grass, semi-shrub and shrub forage ecosystems that are hotbeds of desertification in the territory are almost completely devoid of vegetation cover.

On the contrary, increased productivity of vegetation, its tallness and projected soil cover reduce the risk of degradation of forage ecosystems and increase the ability of disturbed land to restore.

The complexity of vegetation and the entire land cover is associated with the features of the microrelief that redistributes the moisture of precipitation. In the semi-arid zone, steppe grass and grass-mixed communities constantly coexist with desert (semi-shrub, halophyte) communities, forming complexes with them.

The natural vegetation of arid and semi-arid territories consists of 6 main economic and botanical groups, different in their forage value, productivity and the rhythm of seasonal development (perennial grasses, sedge, sagebrush, salt marsh, various grasses and ephemera). These groups of plants are combined in different proportions depending on climatic, geomorphological, soil, hydrological, hydrogeological and economic conditions.

The increasing aridity of the climate, the deterioration of edaphic conditions and moisture are reflected in the species composition, height, projective cover and structure of plant communities. The increase in desert conditions is indicated by a decrease in species diversity and simplification of the structure of plant communities.

The processes of soil salinization are indicated by the appearance of saline vegetation, succulents.

The processes of wind and water erosion of soils, vegetation degradation are indicated by the change of perennial plants to annuals, ephemera, and ephemeroids, as well as by a decrease in the productivity of vegetation and its projective cover.

Degradation of forage ecosystems is caused by a complex of reasons, the main ones being the following [22–25]:
- depleted agricultural land use, which poses a real threat to the country's food security;
- poor quality of land use design;
- poor quality of land use management;
  - a high degree of ploughing (for example, in some regions of the steppe zone, up to 70–90% of the land is ploughed), leading to the development of deflation and water erosion, and a decrease in the humus content in soils;
  - plowing of dry soils of light granulometric composition;
- deplete practices of pastoral livestock, etc.

Water erosion and deflation are the most dangerous negative processes for agricultural land. As a result of their development, irreversible degradation of agricultural landscapes occurs, leading to land desertification. These negative processes inhibit the development of vegetation, reduce its productivity, weaken the root system and fixedness of the soil with plant roots. The weakening of the soil protection layer, fixed by vegetation, is accompanied by the creation of favorable conditions for flushing, erosion and blowing of soils, leading to the destruction of their structure, dehumification, and loss of fertility.

Land degradation and reduced biological productivity in arid and semi-arid zones of Russia and Kazakhstan, where these processes are exacerbated by drought, are particularly dangerous.

On degraded land, agricultural activities (field farming, animal husbandry, including sheep farming) are generally declining. The extent and forms of reduction in agricultural land use depend on the location and extent of degradation of forage land. Where natural pastures occupy more than 60–80% of agricultural land, pasture nature management acquires a local (oasis) character.
As a result of desertification of arid territories, natural pastures lose their productivity, the soil is subjected to erosion and salinization, the sands are exposed and move. Desertification is the result of the integral impact on the land of several negative factors (aridity of the climate, degradation of natural pastures, wind and water erosion of soils, their salinity, technogenic disturbance, etc.).

The main cause of land desertification is the irrational and improper use of land and other natural resources, which exceeds the threshold of environmental sustainability of land, followed by their destruction, often irreversible. Insufficiently regulated anthropogenic loads, combined with insufficient control over the development of negative processes, increase the risk of desertification. The development of desertification processes in one area increases anthropogenic pressure on the land and other natural resources of surrounding district, increasing the risk and extent of degradation.

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