Productivity of pastoral ecosystems on the sand lands of the south of the European part of Russia

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Abstract. On the sandy tracts in the South of European territory of Russia there are 842 species of psammophytes, 25% (209 species) are obligate forms. Many of them are endemics. Species composition, structure and productivity of plant communities depends on the degree of overgrowing of the Sands (open sands, medium-overgrown sands, overgrown sands). Their abundance varies depending on the exposure and the part of the slope. The existence of species occurs as a result of continuous and close interaction with each other and as a response to irritation of various environmental factors. The development of vegetation in this area is limited by the lack of precipitation, strong desiccation of the upper soil horizons due to high summer temperatures, low snow cover, low temperatures of air and soil in winter, the poverty of the sands with nutrients, their mobility, and occasionally strong salinity. The process of natural overgrowing of sand can last more than 50 years. Unorganized unsystematic use of pastures significantly increases these periods. Active use of pastures with low productivity destroys natural ecosystems and causes desertification. As a result, the area of full forage land is reduced, and environmental and socio-economic tensions are increasing. One of the methods for restoration and improvement of sandy areas is the regulated grazing of farm animals in accordance with the productivity of pastures.

1. Introduction
Despite the fact that the biodiversity and integrity of the landscapes (landscapes integrity) preservation of the south of European territory of Russia (ETR) main sand massifs (Near-Don, Lower-Dnepr, Volga, Terek-Kuma and Caspian sands) is largely promoted by the landscape zonal areas system of the nature reserve fund, the current situation shows unfavorable trends in the change in preserved territories. Taking into account the available natural and socio-economic resources most of the steppe zone of the ETR is characterized by low efficiency of agricultural nature management. Specific relevance and practical importance to the issues of the adaptive nature management scientific foundations is attached by the growing environmental crisis and the need to increase the production of environmentally friendly products in Russia. Rational pastoral nature management in this sense has a huge social, economic and environmental focus, because fodder land provides sustainable economic and economic development.
Pasture ecosystems are dependent on the elemental forces of nature and anthropogenic pressure, but they are the first to resist the processes of desertification and deflation. The most obvious and significant indicators of desertification, displaying the condition and dynamics of land bioproductivity, are such signs of the pasture vegetation condition as projective cover, productivity, species composition of communities, etc.

A change from one type of vegetation to another on sandy massifs occurs over time and the process of natural self-growth can continue for more than 50 years. Overgrazing and unorganized unsystematic use of pastures significantly increase these terms. Excessive pasture digression leads to formation of multiple “islands” of anthropogenic desertification, the lifetime of which is determined by precipitation fluctuation and further human influence [1, 2]. With intensive breaking up of sandy soils, hills of loose sand are formed. A huge role in stabilizing and improving the ecological situation is played by substantiated land reclamation works. Fixation of sandy areas accelerates sand overgrowth by 2–3 times. Regulated grazing, even distribution of livestock in accordance with the productivity of pastures, and the fight against weeds and harmful grasses on sandy lands allows restoring and improving sandy territories [3]. Cattle grazing is best done during the period of maximum plant growth at a rate of removal of no more than 39 % phytomass [4]. A regulated grazing farm is also necessary to intensify the processes of groundwater accumulation and reduce the occurrence of steppe fires.

2. Materials and methods
The relevance of research. Today, the issue of restoring soil fertility, productivity and ecological stability of pastoral ecosystems, creating environmentally sustainable, highly productive biocenoses on sandy lands continues to remain important. The issues of unsatisfactory quality condition of pastures, functioning and restoration of soil-plant systems on sandy lands in unfavorable climatic conditions while reducing the culture of land cultivation and forage production are still relevant. The active use of low-productive pastures destroys natural ecosystems and causes desertification, as a result of which the areas of full forage land are reduced, and environmental and socio-economic tensions increase. In areas where there is an intensive wind regime, biological degradation is associated with wind erosion, which reduces the fertility of the land and accelerates the degradation processes of ecosystems. Soils annually lose tens of tons of fine earth per hectare. Due to the fact that desertification leads to undermining the potential of ecosystems and increases the vulnerability of stakeholders within them [5], it is necessary to carry out a scientifically-based set of measures that will improve the economic condition and increase the fertility of pastures, consolidate large areas of moving sands and restore pasture land [6].

To process, analyze and present the results, standard methods of statistical analysis, graphical interpretation, scientific generalization, etc. were used. The real picture of the condition and species diversity of the vegetation cover evaluation, its changes in time and space were estimated using inventory methods of preserved and restored plots, determining their area, assessments of the current state, comparison with the previous condition. Under unfavorable geoeconomic conditions, the use of geobotanical approaches contributes to the development of scientific foundations and helps solve the problems of organizing the rational use of landscapes, especially on sand.

3. Results and Discussion
Inhabitants of sand are united in an ecological group of “psammophytes”. Their floristic and phytocenotic essence are limited by the physicomechanical properties of sand. Sand for psammophytes is an ecological niche necessary for existence and reproduction [2]. Obligate (forming on moving sands) and facultative psammophytes (can grow not only on sand) are distinguished according to characteristics of the substrate. In the European territory of Russia, 842 psammophyte species are found, 25 % (209 species) of which are obligate forms. Many of them are endemic. The specialization of psammophyte plants is such that some first-order pioneer plants even die when the mobility of the sands is lost. In relation to moisture supply, they are divided into succulents (accumulate water in vegetative organs), sclerophytes (capable of drastically reducing transpiration in
conditions of lack of water), hemixerophytes (with devices for water extraction) and mesophytes (living with a sufficient amount of water in the soil) [7].

The existence of species occurs as a result of continuous and close interaction with each other and as a response to irritation of various environmental factors. As a result of long-term natural selection, such relationship leads to adaptation of species and succession changes. There are a large number of hypotheses explaining the species diversity of psammophytes. Factors affecting its formation are numerous and are in a complex interaction. In various phytocenoses, their role is ambiguous. The main factors are water, temperature and wind regimes, anthropogenic pressure, endoecogenetic processes and succession status of associations, which in dynamics reflect the environmental processes that occur during sand overgrowth, and features of environmental factors.

The species composition, structure, and productivity of phytocenoses depend on the degree of sands overgrowing (open or undergrown, medium-grown and overgrown sands). Psammophytic vegetation on waving sands (Psammophyton) is characterized by a sparse cover and is specified by an azonal nature. The species composition of psammophytic communities is represented by pioneers of overgrowing of waving tuberous sands and species that prefer loosely sandy and weakly coherent sandy soils.

Humus accumulation and moisture, corresponding to the stages of sand overgrowth (waving loose sands, half-grown sands) are the important environmental factors of the species diversity of phytocenoses on sand. Of great importance is the hydrological regime (groundwater level), which determines the hydration of low terraces, where shrubs and meadow steppes dominate [8].

In psammophytic associations of sand massifs of the Don River basin, steppe zone together with turfgrass cereals (*Festuca beckeri, Stipa boryshtenica, Koeleria sabuletorum*), rhizome cereals and sedges (*Carex colchica, Agropyron tanaitecticum*) take up a significant percentage. Shrubs (*Genista tinctoria, G. sibirica, Spiraea crenata, Chamaecytisus ruthenicus, Ch. Boryshtenicus*) and semi-shrubs (*Thymus pallasianus, Artemisia austriaca, Artemisia marschalliana and Artemisia arenaria*) are widely spread, which are often accompanied with cereals. These communities develop on sands and so-called "gray sands" [5, 9].

Communities of psammophytic and hemipsammophytic steppes are found in the Middle Don basin on Prikhopersky sands. Species of the genera *Festuca, Koeleria, Stipa, Carex, Artemisia, Thymus*, and others predominate on tuberous-hilly friable sands. Their abundance varies depending on the exposure and part of the slope. In places with a large accumulation of moisture, the appearance of *Calamagrostis epigeios* was noted. The psammophytic steppes on the fixed humus sandy soils on gray sands are represented by forbs-fescue (*Festuca beckeri*, herbs) and forbs-wormwood-fescue (*Festuca beckeri, Artemisia, herbs*) communities. The total projective coverage is up to 40 %. Grazing on these lands confirms the presence of species: *Gleistogenes sguarrosa, Eragrostis minor*, *Artemisia austriaca, Bromus japonicas, B. squarrosus, Rumex acetosella* and others.

Hemipsammophytic steppe communities are confined to sandy loam differences of ordinary and southern chernozems. Forbs-fescue-feather grass communities (*Stipa capillata, Festuca valesiaca*, herbs) are widespread here. The vegetation of the left bank of Khoper terraces is represented by psammophytic grass-cereal-feather communities (*Stipa pennata*, grasses, herbs). The species diversity and structure of the communities of psammophytic and hemipsammophytic steppes, as well as pioneer thickets of Near-Khoper sands, are similar to the vegetation of the Kazansky-Veshensky sand massif, because they are located at a small distance from each other [10]. When revealing the influence of various negative factors on the natural flora and vegetation of Prikhopersky Sands, anthropogenic factor is recognized as the leading one.

Current phytocenoses of the Kazansky-Veshensky sand massif are rich in perennial species of the families *Asteraceae, Cruciferae, Gramineae, Cyperaceae, Euphorbiaceae, Fabaceae, Lamiaceae*. On plain and sloping, sandy and sandy loamy sediments of the massif, the productivity of phytocenoses is 2.7 t/ha, on overgrown tuberous-hilly sands – 2.3 t/ha, on medium and weakly overgrown tuberous sands – up to 1.3 t/ha [11].
Species of the Asteraceae, Caryophyllaceae, Cyperaceae, Euphorbiaceae, Gramineae, Plantaginaceae, Polygonaceae, Fabaceae, Rosaceae, Rubiaceae, Umbelliferae families are found on the Ust-Kundryuchensky sand massif. The productivity of phytocenoses reaches: in the meadow biotope – 5.2 t/ha, on flatland and sloping sandy deposits – 2.5 t/ha, on overgrown tuberous-hilly sands – 2.0 t/ha, on medium and weakly overgrown tuberous sands – up to 1.0 t/ha.

The greatest load during cattle grazing is carried out by plain and sloping, weakly leaved, sandy and sandy loamy deep-sea sediments and meadow biotope. The load of sheep in the pasture (taking into account the feed consumption) should not exceed 0.6 animals/ha on medium- and weakly overgrown tuberous sands, and 3.6 animals/ha in the meadow biotope. The load of goats should not exceed 0.7 animals/ha on medium- and weakly overgrown tuberous sands, and 4.0 animals/ha in the meadow biotope. The load of cows should not exceed 0.1 animals/ha on medium- and weakly overgrown tuberous sands, and 0.5 animals/ha in a meadow biotope. The horse load should not exceed 0.1 animals/ha on medium- and weakly overgrown tuberous sands, and 0.7 animals/ha in the meadow biotope.

Species of the Asteraceae family (Cirsium arvense L., Scorzonera humilis L., Campestre L., Helichrysum arenarium L., Artemisia austriaca Jacq., Senecio vulgaris, etc.) are predominating on all types of sands of the Chirsky sand massif. More than a half of the species in the structure of phytocenoses are annuals and biennials. Fodder species make up 42.8 % of the phytocenosis, medicinal – 38.0 % on open sands, 47.0 and 35.3 % respectively on medium-overgrown sands, 47.6 and 33.3 %, respectively on overgrown sands. Poisonous and weedy species occupy up to 14.3 % of the communities’ composition. Mesophytes dominate in all sands. On open and overgrown sands, their share is 52 %, on medium-overgrown sands – 47 %. In the pasture areas of the Chirsky sand massif, the animals load should smoothly decrease from spring to autumn and vary from 0.2–0.4 heads/ha to 0.5–1.0 heads/ha, depending on the degree of overgrowing of the sands and the type of grazing animals, as illustrated in Figure 1 [12].

Figure 1. Optimum load of animals on the pasture of the Chirsky sand massif, taking into account the feed capacity, heads per 1 hectare.

Terek-Kuma sands are characterized by high potential fertility. Vegetation is represented by wormwood-hodgepodge communities, which make it possible to use moisture to other plants during the growing season [13]. Halophobic, glycophilic and halotolerant sclerophytes, halotolerant hemixerophytes are most adapted to the conditions of sandy habitats. The largest group of psammophytes (sclerophytes) includes 117 species (Asparagus bresleranus, Agriophyllum...
squirrosum, Artemisia, Calophaca wolgarica, Calligonum aphyllum, Dasypyrum villosum, Ephedra distachya, Eremopyrum orientale, Eragrostis collina, Kohlrauschia prolifera, Leymus sabulosus, Limonium caspium, Imperata cylindrica, Halopeplis pygmaea, Helichrysum arenarium, Salsola australis, Onosma setosa, Poa bulbosa, Syrenia siliculosa, Festuca valesiaca, Falcaria vulgaris, Ferula caspica, Pseudosophora alopecuroides, Thymus pallastiansus, Valerianella pumila, etc.). A number of relic psammophilic species are located at the extreme borders of their ranges [2]. Unsystematic, irregular grazing on the pasture lands of Terek-Kuma sands, as elsewhere, changes the species composition of communities, leads to thinning of vegetation, exposure of sites, affects the structure of phytocenoses, leads to the loss of useful forage species and their replacement by haloxerophytes, changes the quantitative indicator of organic matter and humus content. The optimal rate of sheep grazing here is 2 animals/ha [13, 14].

The vegetation of the Chernozem overgrowing sand massifs is mainly represented by Agropyronfragile, Syrenia siliculosa, Ephedra distachya, Achillea micrantha, Euphorbia seguierana, Helichrysum arenarium, Centaurea adpressa, C. majorovii. The peripheral sections of sandy massifs with leveled relief are characterized by the communities of Stipa capillata, Carex stenophylla. In the fixed small-hilly and small-ridge sands, the Tamarix ramosissima communities are found, which belong to the meadow-saline lands. Tamarix ramosissima is found on the slopes of sand ridges. Initially, primary sandy substrates without vegetation, areas of broken sands and blowing depressions are occupied by Leymus racemosus, Calamagrostis epigeios. Then they are replaced by psammophytes and hemipsammophytes of the II order along the tops of sandy hillocks and ridges on the windward side (Artemisia arenaria, Euphorbia seguierana, Helichrysum arenarium, Syrenia siliculosa, Senecio erucifolium, etc.). The formation of the secondary sand steppe communities begins as the relief of the overgrowing massif is smoothed out and psammophilic species of the Poaseafamily and Carex stenophylla are introduced into the groups. Succession development depends on the properties of the soil, the species composition of the previous groups and the meteorological conditions of the growing season. Due to this, at one stage of the demutation series, there are communities of various associations of the secondary sand steppe (Agropyron fragile, Koeleria sabuletorum, Stipa anomala, Kochia prostrata).

4. Conclusion
Information on the basic laws of pasture ecosystems functioning and the ability to evaluate their capabilities in different soil and climatic conditions under different livestock loads is necessary for the rational use of pastures. The development of vegetation on the sandy lands of the south of the ETR is limited by the lack of precipitation, severe desiccation of the upper soil horizons due to high summer temperatures, insignificant snow cover, low air and soil temperatures in the winter, poverty of sand by nutrients, their mobility, and sometimes severe salinity. One of the methods for restoration and improvement of sandy areas is the regulated grazing of farm animals in accordance with the productivity of pastures.

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