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Anthropogenic changes in Meadow and Steppe Vegetation and their Assessement

The plant cover of our planet is changing rapidly under the influence of human activity. The process of anthropogenic changes, or vegetation synanthropization (FALINSKI 1971, 1972; GORCHAKOVSKII 1979; KOSZROWICKI 1982; OLACZEK 1982) has many undesirable consequences: the extinction of a number of plant species, a general impoverishment of the flora, a decline in the genetic diversity of certain species, structural simplification, unification, and a decline in the productivity and stability of the plant cover.

Synanthropization is essentially a process of the adaptation of the plant world to environmental conditions changing under the influence of man. During the course of this process, the species most adapted to the new, man-made conditions survive and disperse. Synanthropic species should include both local and nonlocal plants whose position in the composition of plant communities is intensified when anthropogenic pressures increase. In most cases these are less productive and valuable species, less desirable for man.

Botanists and ecologists must study thoroughly the patterns of vegetation synanthropization for the utmost delay or cessation of the process of the exhaustion of plant resources and to assure the preservation of the riches of the plant world in all their diversity. Of great significance in this connection is the organization of a service for monitoring the condition of the vegetation, the development of methods for evaluating the degree of the anthropogenic degradation of essentially natural plant communities, and also the prognosis of the likely changes in the plant cover under human influence.

Grassland (meadow and steppe) vegetation has been subjected rather severely to anthropogenic transformations in the temperate zone of the northern hemisphere. Long-term inappropriate exploitation in many regions and habitats resulted in the degradation of grass stands and a decrease in their agricultural value.

With excessive anthropogenic loads, changes in grass stands in some areas became irreversible, plant communities degenerated, and almost barren anthropogenic wastelands were formed in the place of meadow and steppe communities that had had a specific agricultural value.

Trends in the change of structure of the vegetation cover in the forest-steppe Region

The character and direction of the main changes in the vegetation cover of the trans-Ural forest-steppe region under the effect of anthropogenic factors are illustrated by the series of geobotanic maps for the "Galkinskii" key tract (Kamyshlov region of the Sverdlovsk district) (see Fig. 1). The map of the reconstructed (preagricultural) vegetation (see Fig. 1a) shows the structure of the vegetation cover in the period preceding agricultural development of this territory (end of the 17th century). At that time birch (Betula pendula, Betula pubescens) and partly aspen (Populus tremula) forests predominated in the trans-Ural forest-steppe region, having occupied 70,7 % of the area; furthermore, uremas (riverine deciduous forest strips of Salix spp. and Padus racemosa (1,5 %) were widespread in river valleys and closed shallow depressions. Even then primary meadows existed here: steppe meadows and the halophilic variant of peaty meadows; the share of their participation was 16 %. Bulrush-reed lowmoor bogs (2 %) were distributed in the closed basins. Thus a vegetation cover characteristic for the northern forest-steppe existed in the region of investigations in the preagricultural period.

Later, with agricultural development of the territory, as the map of actual vegetation (Fig. 1b) shows, a considerable part of the forests were felled and the forest coverage decreased to 24,3 %. The decrease in forest coverage occurred mainly as a result of deforestation and partly under the effect of forest fires. All meadow steppes, steppe meadows, and forest lands were transformed into plowland, and the remaining territory began to be used for cattle grazing and haymaking. To prevent reforestation of the haylands and pastures, their clearing of brush and regrowth of trees was widely practices. In the key tract the uremas were not touched by cutting and were preserved in a littlechanged form, though in certain regions a part of them was cleared and these lands to be used as haylands. In the key tract plowland presently accounts for 45,4 % of the area. In the investigated region plant growing plays the leading role, but animal husbandry, mainly cattle raising, is also widespread. A considerable part of the land is under pasture and hay (28,5 % of the area). Long-term grazing and haymaking had a substantial effect on the character of the current vegetation cover. Part of the lowmoor bogs retained their original appearance (0,3 % of the area), and the remaining swampland after conducting drainage works were transformed into haylands.

The predictive map (see Fig. 1c) shows the probable character of vegetation which should be formed provided optimization of the use of natural resources as a result of implementing planned measures on the rational use of the vegetation cover and increase of its productivity. In working out the norms of the use of natural resources we proceeded from the need to maintain the forest coverage of the territory at about the current level (24,3 %). However, conversion of part of the territory covered by birch forests of quality class IV (on chernozem-meadow soils) to forage lands is envisaged. Conversely, it is considered adviseable to eliminate certain low-productivity pastures in open woodland from the forage land fund and by natural regeneration to convert them to the category of forests. The share of lands allocated for plowlands is also preserved at the former level (45,4 %).

Since uremas and bogs perform an important hydrological role in the region of investigations, it is considered adviseable to keep them approximately within the current limits (respectively 1,4 and 0,3 % of the area). Substantial changes in the total area for forage lands is not planned, and in the key tract 28,6 % of the territory is allocated to their share. However the relationship of the categories of plant communities differing in degree of their anthropogenic transformation and productivity will change considerably. Ecosystems and plant communities can be divided into the following categories depending on the degree of man's impact on their composition and structure (WESTHOFF 1952): natural, quasi-natural, semicultural, and cultural.

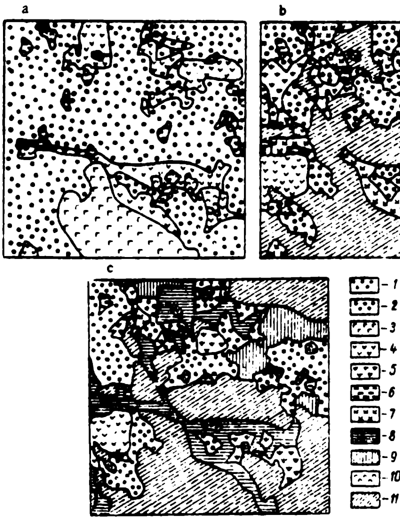

Fig. 1. Change in the vegetation cover of the key tract of the trans-Ural forest—steppe region. Vegetation: a) reconstructed; b) actual; c) transformed (prediction); 1) small-leaved forests; 2) uremas; 3) meadow speppes; 4) steppe meadows; 5) peaty meadows; 6) same, halophilic variant; 7) true meadows; 8) semi-cultural meadows; 9) cultivated meadows; 10) lowmoor bogs; 11) plowland.

Actually, natural plant communities no longer remained in the trans-Ural forest-steppe region. Meadow communities affected by grazing and haymaking belong to the category of quasi-natural. Meadow communities which were natural in their origin but into the composition of which cultivated components - herb species more valuable in a forage respect were introduced by undersowing (so-called surface improvement) belong to semicultural. Cultural meadow communities are represented by sown meadows created as a result of radical improvement with complete elimination of the natural herbage that existed here earlier. At present the entire meadow vegetation on the "Galkinskii" key tract is represented by quasinatural communities; in other places, along with quasi-natural, there are also seminatural communities, which account for up to 10 - 15 % of the area.

It is planned to implement the complex of measures aimed at improving meadows and increasing their productivity. It is assumed that after conducting the planned amelioration works from 50 to 70 % (66 % in the "Galkinskii" key tract) of the forage lands will be represented by semicultural and cultural communities. As a result of surface improvement semicultural communities will from at the place of quasi-cultural, and the yield will increase by a factor of 2 - 2.5. An increase of yield by a factor of 3 - 5 is expected after conducting radical improvement works. On the whole for all key tracts with preservation of approximately the former area of forage lands the average yield (usable part of the above ground phytomass) will increase from 9.9 to 24.5 centners/ha (by a factor of 2,5).

An increasing replacement of quasi-natural meadows by semicultural and cultural is observed of late everywhere in the trans-Ural forest-steppe region. However, this process should be limited to a certain scope, since the complete elimination of quasi-natural meadows would involve an irretrievable loss of genetic resources of the aboriginal meadow flora. To preserve the gene pool of meadow flora it is necessary that the quasi-natural meadows account for at least 30 % of the area of all forage lands.

Origin and stages of anthropogenic degradation of meadows in the forest-steppe region

A large part of the meadow communities of the trans-Ural forest-steppe region has a secondary origin: the arose at the site of other types of plant communities (forests and uremas). The exceptions are the steppe meadows, which belong to the category of primary, having formed naturally and having existed in this region before the start of agricultural development of the territory.

The formation of meadows and their subsequent degradation occurred under the effect of such factors as deforestation, forest fires, clearing of bushes, grazing, and haymaking.

Compared to certain other types of vegetation (forest, bogs), the meadows in the trans-Ural forest-steppe region have been subjected to more intense anthropogenic effects. At the same time, meadow plant communities have a high anthropotolerance, they are able to withstand long and intense anthropogenic pressures to a greater degree than forests and bogs.

Our investigations showed that in the trans-Ural forest-steppe region the formation and anthropogenic degradation of meadows occur on the base of three initial types of plant communities - steppe meadows, small-leaved forests. and uremas. The successions of plant communities of the trans-Ural forest-steppe region under the effect of anthropogenic factors are shown in the following schematic diagram (Fig. 2).

The initial change of the vegetation cover involves the formation of meadow communities that are in the I stage of anthropogenic degradation. They are characterized by a negligible participation of synanthropic plant species (from 1 to 7 species with an abundance not greater than sol.and in rare cases one of the species reaches abundance sp.). With intensification of the pressure of anthropogenic factors more substantial changes occur in the composition and structure of the meadow communities (II stage of degradation). Some synanthropic plant species (Deschampsia caespitosa, Plantago media, Potentilla anserina) at this stage figure in the role of codominants (abundance sp.-cpp.), the number of synanthropic species reaches 7 - 23. Meadow communities that experienced the longest and strongest effect of an-

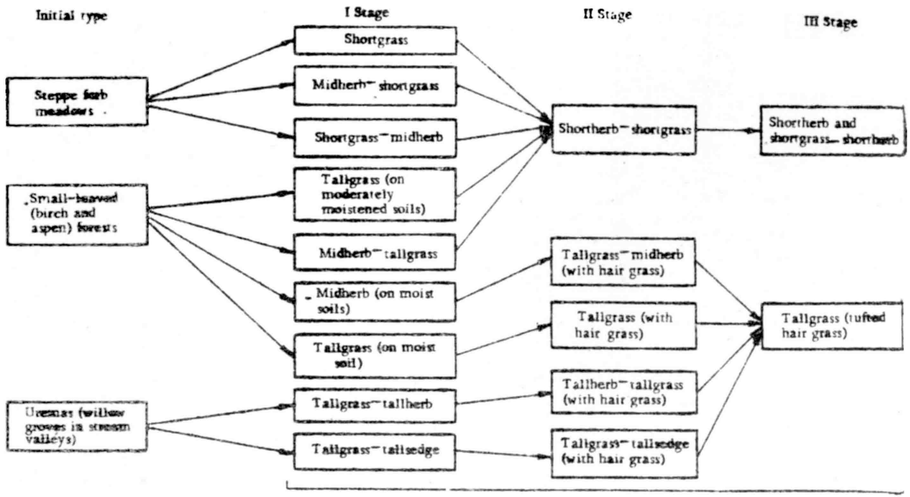

Fig. 2. Stages of anthropogenic deradation of dry meadows in the forest-steppe region

thropogenic factors belong to the III stage of degradation. In the composition of such communities one of the synanthropic species already occupies the position of dominant (abundance cop.$_2$-cop.$_3$). The overall species composition of the communities at this stage is impoverished, the number of synanthropic species is lover (7 - 11) then in preceding stage.

A. P. SHENNIKOV (1929) indicated long ago that meadow plant communities differing in soil conditions and character of the vegetation cover gradually converge in their characters under the effect of intense pastural use and ultimately become practically indistinguishable. He called this phenomenon convergence of plant communities.

In the case being considered convergence of plant communities is expressed quite distinctly. During anthropogenic degradation the former diversity of communities substantially declines and at the III stage is reduced to shortherb, shortgrass-shortherb, and tallgrass meadows with dominance of tufted hair grass. Communities originating from both steppe meadows and small-leaved forests on moderately moistened soils, with their mesophilic herbage from time immemorial, become practically indistinguishable. The differences between communities in exactly the same way.

The most general trends of the change on the composition of the leading components of the herbage of meadow communities during their degradation reduce to the following. On moderately moistened soils grasses and forbs are displaced by shortherbs, which are most resistant to trampling. In this case mesophilization of the primary steppe meadows and their transition to the category of true meadow occur. The shortherb and shortgrass-shortherb meadows form both at the site of steppe and true meadows associated with more drained places. On moister soils intense grazing entails compaction, deterioration of aeration, and depletion of soils. This process is accompanied by dispersal and transition to the dominance of tufted hair grass. Secondary communities with dominance of tufted hair grass belong to the class of formation of peaty meadows. However, they form not only at the site of tallgrass-tallherb peaty meadows but also at the site of certain categories of true meadows on moist soils - midherb and tallgrass meadows. The passage of some tnue meadows during degradation to the category of peaty meadows is explained by the fact that intense grazing causes compaction of the soil, deterioration of its aeration, and this hinders the decomposition of dead plant material and promotes the formation of a peat layer in the soil.

Anthropogenic degradation of meadow vegetation leading to the formation of shortherb and shortgrass-shortherb meadows is accompanied by impoverishment of the floristic composition and decrease of productivity. Thus, for example, 78 species with a yield of 16 - 18 centners/ha were noted in the meadow fescue-slimtop meadow association (I stage) and 32 species with a yield of 3 - 4 centners/ha in the silverweed (III stage). In the meadow foxtail association there were 67 species with a yield of 24 - 25 centners/ha, whereas in the tufted hair grass-bluegrass association (III stage) there were 43 species with a yield of 8 - 9 centners/ha. Along with a decrease in productivity the forage value of the herbage depreciates. As degradation progresses the species composition of the meadow communities becomes simpler, synanthropic species occupy the position of dominants **(Deschampsia caespitosa, Potentilla anserina, Polygonum aviculare, Leontodon autumnalis)**

An analysis of the preceding data shows that during anthropogenic degradation (primarily under the effect of grazing and haymaking) there occur simplification of the ecological and phytocoenotic diversity of meadows, impoverishment of the species composition and convergence of the plant communities that differed in character of biotopes and composition of dominant species, and a decrease of productivity. At the same time communities little resistant to anthropogenic effects are succeeded by communities that can withstand considerable anthropogenic pressures (i.e., are more anthropotolerant). However, a considerable increase of the pressure of anthropogenic factors compared to the actual can entail complete destruction of meadow communities and the appearance in their place of waste land with sparse ruderal vegetation.

Grazing degradation of floodplain meadows in the southern taiga subzone

The investigations were performed within the southern taiga subzone of the trans-Ural peneplain in the valley of the Ambarka River, a tributary of the Neiva River (Tura River basin), near Nizhni Tagil.

The original types of floodplain meadow communities had not been preserved in the study region. All meadow associated with alluvial loamy, meadow soils were to some extent subjected to anthropogenic degradation with cattle grazing acting as the major factor. In the first stage of degradation, the major coenosis-forming species, typical for natural floodplain meadows, still retain the position of dominants; their vitality is rather high, and they are capable of regeneration by seed. With the transition to stage II, these species lose their dominant position, their vitality declines, and synanthropic species more resistant to grazing enter the community. In the third stage, synanthropic species become totally dominant.

Meadow communities in the first stage are represented by three basic associations (see Fig. 3). One of these, meadow fescue (Festuca pratensis association), occupies the higher and drier areas (high floodplain) and the others, meadow geranium (Geranium pratense association) and giant bent grass (Agrostis gigantea association) are found in relatively low and extremely wet areas (middle and low floodplain).

In the second stage of degradation, a yarrow-white clover association (Trifolium repens + Achillea millefolium association) forms in higher areas of the floodplain in place of the meadow fescue association. Only a silverweed cinquefoil-white clover association (T. repens + Potentilla anserina association) forms in middle and low floodplain in the place of the two associations, meadow geranium and giant bent grass. As the soil becomes compacted and its aeration deteriorates, earlier differences in ecotopes disappear, and this results in convergence.

In the third stage of degradation, a yarrow association (A. millefolium association), replacing the yarrow-white clover association, forms in higher areas of the floodplain, and silverweed cinquefoil (P. anserina association), replacing silver-

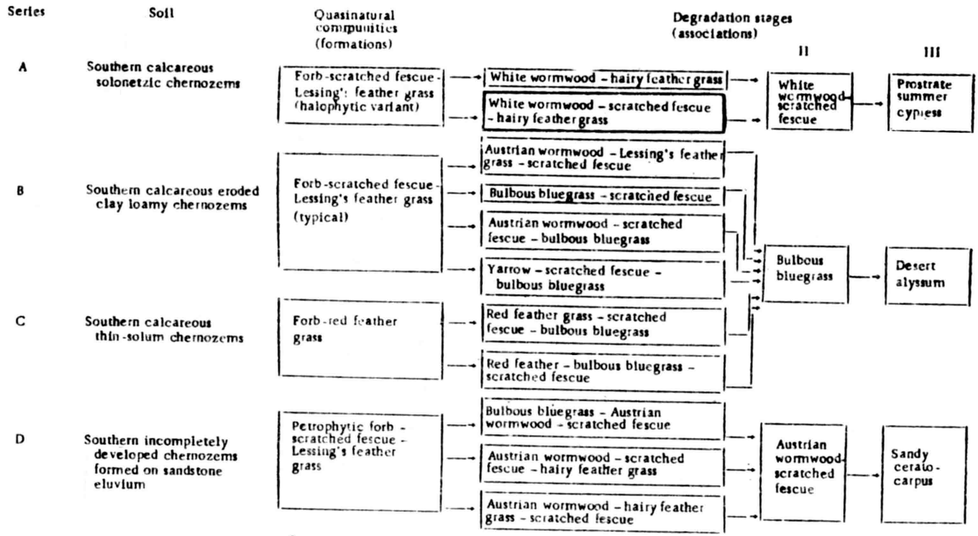

Fig. 3 Pasture degradation of steppe vegetation.

weed cinquefoil-white clover, in lower areas.

A relatively broad floristic range is typical for meadow associations in the first stage of degradation. Their grass stand included 41 to 46 species. Common meadow grasses (F. pratensis, A. gigantea) or certain forbs (G. pratense) predominate. The group of grasses is represented by 9 - 10 species, legumes by 5 - 7 species and forbs by 26 - 29 species. The 7 - 9 synanthropic species represent a minor addition, and their abundance does not exceed a rating of sol. or sp.

In the second stage of degradation the total number of species in individual associations declines to 33 - 34, and of grasses to 7 - 8. The number of legume species in certain association declines to three, and remains approximately unchanged in others; there are fewer forbs (20 - 23 species). There are a greater number of synanthropic species in this stage (11 - 13) than in the previous stage; some grazing resistant species (T. repens) become dominant, and others (P. anserina, A. millefolium) codominant.

In the third stage of degradation, the overall species composition of meadow associations is even lower (18 - 23 species), and the proportion of grasses and legumes declines (in abundance and in some associations in number of species); the number of synanthropic plants remains unchanged or increases slightly (to 13 - 14), but their proportion with respect to total species composition increases considerably, to 78 %. Synanthropic species have the dominant position in relation to abundance in meadow communities in the third stage of degradation.

Among communities in the first stage of degradation, highest overall phytomass standing crop (1025 g/m^2) was noted in the meadow fescue association, which cover higher areas of the floodplain; somewhat lower standing crop (851 g/m^2) was found in the meadow geranium association which covers the middle area of the floodplain, and even lower standing crop (641 g/m^2) was found in the giant bent grass association, typical for the lowest areas. A decrease in total phytomass reserves along the ecological series of increasing soil moisture is explained by the fact that root systems of plants in wetter areas of the floodplain are less developed and underground phytomass reserves are reduced accordingly. With degradation, total phytomass reserves (aboveground and underground) decline to 505 - 602 g/m^2 ih the second stage and to 486 - 580 g/m^2 in the third. This is primarily due to the decrease in underground phytomass reserves (from 533 - 762 g/m^2 in the first stage to 293 - 408 g/m^2 in the third) as a result of soil compaction and unsufficient soil aeration.

Our study demonstrated that the ratio of aboveground to underground mass varies from 1 : 1.5 to 1 : 2.9 in communities of floodplain meadows in the first stage of degradation. The somewhat higher reserves of underground mass in comparison with aboveground mass are explained by the fact these communities in floodplain meadows have a rather adequate supply of water. Water moves through the soil here, and for this reason, plant root systems do not experience an oxygen deficiency; dead underground fragments of plants decay rather rapidly. The minor differences in the ratios of aboveground to underground mass for individual associations are explained not so much by differences in moisture supply as by the different morphobiological features of dominant species.

The role of grasses in the formation of aboveground phytomass declines with the transition from the first to second stage of degradation, and that of legumes increases. T. repens, which is resistant of moderate grazing, becomes the dominant species. In the third stage, the proportion of legumes declines considerably, and the increase in the contribution of forbs to the composition of aboveground phytomass is especially evident. Nevertheless, the steady increase in the proportion of synanthropic species in the aboveground phytomass is most demonstrative (11.8 --13.9 % in stage I, 48.7 - 51.8 % in stage II, and 81.1 - 87.0 % in stage III).

Anthropogenic degradation of vegetation in the steppe region

A century and-a-half to two centuries ago, the steppes stretched across the Russian plain as a solid band from the shores of the Caspian Sea to the southern tip of the Urals (PALLAS 1772 - 1788; EVERSMANN 1840). Herds of saigas and wild horses, Tarpans, grazed on them. The grass stand of the steppes was dense and high; nomadic tribes who settled these steppes set "fires" each year in the spring, and sometimes in the fall, burning the dry grass to improve the pasture (RYNCHKOV 1762). The Orenburg steppes were particularly renowned for their fertility.

Because of agricultural development of chernozems, however, a large part of steppe vegetation on the plain was destroyed, Portions of the steppe were conserved in some natural preserves. Steppe communities were best preserved in mountains and foot hills of the southern Urals on stony land not suitable for agriculture. Particularly interesting are the extensive steppes in the southern Orenburg oblast on the interfluve between the Ural River and its left tributary, the Ilek River at the junction between the Cisural plateau of the eastern European plain and the southern Urals-Mugodzhar hills.

The steppes of the Ural-Ilek interfluve are currently used for pasturing sheep and goats and to a lesser extent, horses. The steppe communities were to some extent subjected to pasture degradation.

Natural plant communities, untouched by grazing or other anthropogenic activity, were not retained in the area studied. Nevertheless, there are quasinatural communities here (more or less like natural communities), which had a limited grazing system (random grazing in isolated years, browsing when animals were driven from one pasture to another), and also communities in various stages of pasture degradation.

Species of plants found in steppe communities may be divided into groups according to the pasture system:

1. Those whose abundance is reduced by grazing (Stipa lessingiana, S. rubens, Linosyris villosa, Sedum stepposum, Hedysarum agryophyllum, Onosma simplicissima, Clausia aprica, Dianthus uralensis, Orostachys spinosa, Thymus guberlinensis, Alyssum tortuosum).

2. Those unaffected by grazing (Astragalus tauricus, A. testiculatus, Potentilla humifusa).

3. Those whose abundance is increased by grazing (Androsace turczaninovii, Artemisia austriaca, Ceratocarpus arenarius, Ceratocephalus orthoceras, Echinopsilon sedoides, Polygonum aviculare).

In the steppes of the Ural-Ilek interfluve we noted 34 synanthropic species, which include both species that increase in abundance subsequent to grazing (Alyssum desertorum, Carduus incinatum, Artemisia austriaca) and ruderal (Capsella bursa-pastoris, Malva pusilla, Lepidium ruderale, Amaranthus retroflexus) weeds.

In addition to quasinatural communities, we established three stages of pasture degradation (I, moderate; II active; and III, excessive grazing). The type of pasture degradation of steppe communities is determined to a great extent by the properties of the substrate and the appearance of the initial vegetation. A total of four series (A, B, C, D) of pasture degradation were determined in the region studied (see Fig. 3). Dominance of Lessing's feather grass (Stipa lessingiana) and red feather grass (Stipa rubens) is typical for the quasinatural communities. Grass yield (air-dried phytomass) was 12 - 14 centners/ha on the average.

During the first stage of degradation, red feather grass almost totally disappears from the grass stand, and Lessing's feather grass remains in limited abundance (sol.-sp.). Dominance shifts to scratched fescue (Festuca sulcata), bulbous bluegrass (Poa bulbosa) in a mixture with scratched fescue, red feather grass or forbs, and on solonetzic or incompletely developed soils formed on sandstone eluvia, to hairy feather grass (Stipa capillata). Individual associations include from four to eight synanthropic plant species found as solitary (sol.) or sparse (sp.) specimens, and in some of these, the synanthropic plant species are the dominants. Yield is 9 - 10 centners/ha.

There is a convergence of steppe communities in the second stage of degradation; their diversity is reduced to three basic associations: white wormwood (Artemisia lercheana); scratched fescue, bulbous bluegrass, and Austrian wormwood (Artemisia austriaca)- scratched fescue. The synanthropic species number 8 - 15, and one of the synanthropic species is the dominant in all associations, yield drops to 8 - 9 centners/ha.

Monodominant associations form in the third stage of pasture degradation: on solonetzic soils, the prostrate summer cypress (Kochia prostrata); on calcareous chernozems, desert alyssum

(Alyssum desertorum); and on sandstone weathering products, sandy ceratocarpus (Ceratocarpus arenarius). These associations have a poor floristic composition (10 - 15 species including 7 - 8 synanthropic species) and a low yield (2 - 3 centners/ha).

Changes in the floristic composition of steppe communities during degradation may be followed in series D (Table 5), namely changes in a petrophytic forb-scratched fescue-Lessing's feather grass steppe: quasinatural associations, pink-scratched fescue-hairy feather grass; stage II, Austrian wormwood-scratched fescue; and stage III sandy ceratocarpus (Ceratocarpus arenarius) associations. As is evident, the composition of the grass stand gradually deteriorates with degradation (38 species in the quasinatural association and 10 species in degradarion stage III).

Conclusion

It was found that the floristic composition, structure, productivity, as well as the proportional involvement of synanthropic species in the composition of the aboveground phytomass of meadow and steppe plant communities change appreciable during pasture degradation. Monitoring of vegetation must be based on convenient and reliable methods for assessment of the condition of plant communities and the level of their anthropogenic degradation. Such methods are still insufficiently developed. HADAČ (1978) used the indicator of the proportional involvement of ruderal species in the flora of a region of Czechoslowakia to estimate the level of human impact on the natural plant cover. Our studies showed that the criterion of the proportional involvement of synanthropic species in the composition of plant communities, especially grassland communities, can be successufully employed to evaluate the degree of their degradation. At first we used the criterion of abundance according to the Drude scale (modified by ALEKHIN).

However, the Drude scale for assessment of abundance is insufficiently precise, and its use does not eliminate the subjectivity of estimates. In continuing our studies we attempted to find more objective criteria enabling an assessment of the level of degradation of grassland communities in order to improve the methodology. In addition to the number and abundance of synanthropic species, we used the indicator of their proportional involvement in the composition of the aboveground phytomass. Samples for estimating productivity were taken not only with respect to agrobotanical groups but synanthropic species were specially distinguished.

The results obtained show that the assessment of the level of pasture degradation of meadow and steppe communities and the assignment of these communities to one or another stage is facilitated by indicators of the proportional involvement of synanthropic species in their composition; a) the total number of synanthropic species; b) the percentage phytomass produced by synanthropic species with respect to the total aboveground phytomass.

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