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STRUCTURAL ORGANIZATION OF ECOSYSTEMS AND PATTERNS OF THEIR DISTRIBUTION

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NATURAL STEPPE ECOSYSTEMS AND WHAT THEY TRULY ARE[1]

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Steppe ecosystems have suffered through major transformations, caused by long-term cattle grazing and ubiquitous land plowing, and now they lack life-supporting functions. Preservation and restoration of ecosystems the way they naturally are have become our main goals. It may seem that cease or restriction of grazing and plowing should make the natural condition of steppes restore. However, it is still unclear how much the natural ecosystems differ from the anthropogenically transformed ones, and what their functionality mechanics truly are. The types of animals' impact that have formed in the nature without any connection to human's activities (such as wild ungulates grazing, soil digging by steppe fossorials) are similar to such anthropogenic factors as cattle grazing and land plowing, to a certain extent. Grazing in steppe natural zones has always been a natural factor, playing its required role in ecosystems. In the natural conditions the activities similar to plowing are the mechanical soil processing carried out by numerous large and small animals living in the ground. All these types of vegetation and soil transformation are not a random phenomenon, but a regular one, and it spreads throughout the entire steppe zone, inhabited by animals. This phenomenon is similar to the anthropogenic impact in itself. Nature protection measures, aiming to restore natural ecosystems, must take into account the necessity to preserve these natural dynamic processes. Without these processes, the specific features of steppe ecosystems functionality inevitably disappear, followed by negative aftermaths and nature degradation.

Keywords: natural ecosystems preservation, anthropogenic and natural forms of functioning, land plowing, land digging caused by animals, cattle grazing, wild mammals grazing, natural ecosystems degradation.

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Preservation of natural ecosystems is one of the priority tasks of the modern human society. Humans' life, as well as the life of every living creature on the planet Earth, depends on environment and plays a major role in its formation and functioning (Photo 1, 2). It is considered that all agricultural activities and various forms of nature usage have a negative effect on the environment, causing its degradation and replacing natural ecosystems with artificial ones. The latter do not have the required life-supporting functions and can lead humanity to a "social-economic catastrophe" in the nearest future (Zalikhanov et al., 2006). The call for wise limitation of nature usage or even its partial exclusion becomes more and more frequent. There are also some propositions for a principal change of the nature usage strategy by a directed preservation of life-supporting functions and introduction of technologies which imitate natural processes into agriculture (Pavlov et al., 2007). The requests for necessary preservation and restoration of ecosystems in their original condition become popular. However, it is still unclear what exactly should be called natural ecosystems, what they really are, how much they differ from the artificial ones, and what their functionality mechanics truly are. We will try to clarify this problem by the example of steppe ecosystems which have suffered major transformations for many millennia, caused

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by humans' agricultural activities.

Photo 1. "...the steppe grows white with dense needle grasses, and green it does grow with soft silken grasses" (Koltsov, 1839). This is how we imagine an intact natural steppe.

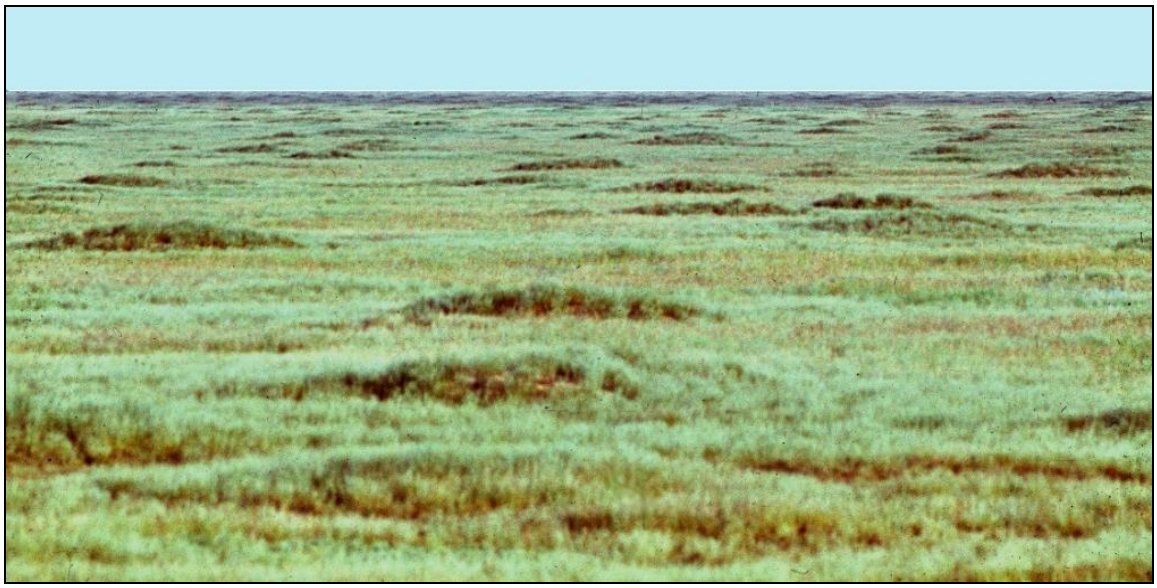

Photo 2. "…the ground squirrels' hillocks, uniform in their shape and composition, appear in a vast amount, covering areas of dozens and even hundreds of square versts, and form steppe into a very specific patchy and lumpy shape. … ground squirrels play quite a big geological role..." (Mushketov, 1895). And this is how the steppe actually is.

Are the Grasses or Trees More Common for Steppe Zone?

The modern conception of a steppe ecosystem is a natural complex of living and inert components, formed in the arid climate at the absolute dominance of herbaceous plants with shrubs, semi-shrubs and steppe bushes. The dominance of herbs is a necessary attribute of steppe ecosystem. It is known that steppe formations appeared more than a million years ago, while their modern look was formed in the Pleistocene interglacial period, in the prehistoric era (Velichko et al., 2011). However, the existence of grassy steppes as independent indigenous natural formations has been questioned for many years. At the turn of the XIX century there was a popular idea that steppe territories were originally covered with forests, and therefore their modern look with scarce, in a common sense, herbaceous vegetation is a secondary phenomenon, result of humans' destructive activities (Avdeev, 1964; Razumovskii, 1981). In the end of the XIX century and in the next one there was another idea that steppe plants were slowly supplanted by forests, however, now the process is being constrained by humans (Korzhinskii, 1888). The actual display of such concepts can be seen in humans' intention to afforest the existing steppe territories, aiming to replace the scarce vegetation with rich woody (forest) plants and hoping to restore the original natural cover. This is evident in the modern plans to afforest hundreds of thousands hectares in the steppe territories.

We have to admit that humanity still does not have a clear understanding of which vegetation type is more common for the steppes, the scarce herbs or seemingly more rich forest plants. In the late XIX century all existing conceptions were analyzed and proved them unconvincing, so the problem is still unresolved (Bogatov, 1899). Obviously, the search for truth requires an understanding of the relative vitality of woody (forest) and herbaceous (meadow, steppe) plants in the arid climate[2], the main limiting factor of which is water availability for plants. It has been long known that the natural vegetation communities use the available food resources regardless of their species composition. Moreover, "the plants of cenoses use the absorbed energy of photosynthetic active radiation, with more or less similar coefficients of efficiency. According to this, with the optimal availability and analogous conditions, different phytocenoses form more or less similar crops" (Nichiporovich, 1973, p. 36). Apparently, when available soil moisture is scarce, but the water availability is similar, trees and grasses are equally productive and form organic masses, close in their values. However, the similarity ends there. Distribution of organic production between the structural parts of trees and grasses is fundamentally different. Trees accumulate most of the photosynthesis products (40-50%) in their aboveground parts (trunks and branches), thus forming a large amount of woody organic material, specific for the forest ecosystems (table 1). Herbaceous plants accumulate these products mainly in the underground parts, providing themselves with a compensating increase of their underground organic mass and, primarily, roots. Steppe grasses get from 80 to 95% of the total vegetation mass, and woody plants get no more than 25%. As a result, the water availability of the roots significantly increases for the herbaceous plants. Relation between the root mass and living aboveground mass of the mainly photosynthesizing organs (leaves) of the meadow and steppe herbaceous communities is many times higher (4 to 27) than one of the forest communities (lower than 0.6; table 1)

Eventually, water consumption in the herbaceous communities is significantly higher and is proportional to their roots concentration in a soil layer (Sudnitsyn, 1979). It makes grasses win the competition for water when it is scarce, and provides them with dominance over woody plants, therefore, shaping the steppe grass formation. It is clear that during the period of water deficit in the steppe climatic area, herbaceous communities become more viable than the forest ones. Therefore, the herbaceous zonal steppe is indigenous for the climatic conditions of steppe natural zone, it is a natural formation, while the forest communities are extraneous for the automorphic steppe habitats.

[2] The deficit of water in the arid territories results in a negative water balance: water consumption (evaporation) exceeds its intake (sum of precipitation).

The long-term humanity's intention to enrich steppes with artificial afforestation, thus giving them a seemingly natural look by "returning" forests, is not only unjustified, but also impossible.

Table 1. Share of underground mass (roots) in the phytomass of various zonal vegetation types (Abaturov, 2014).

Plant community and its geographical location	Mass of roots (% of the total vegetation mass of phytocenosis)	Relation between the mass of roots and live aboveground mass	Calculated according to the literature sources
Beech forest, Denmark*	17	0.59	Larcher, 1995
Deciduous forest of temperate zones	19	0.23	Jackson et al., 1996
Boreal forest	24	0.32	Jackson et al., 1996
Boreal forest	–	0.39	Mokany et al, 2006
Meadows of forest zone (Zhitomir and Chernigov Regions)	81	4.13	Shalyt, 1950
Meadows of temperate zones	–	4.2	Mokany et al., 2006
Meadows of temperate zones	83	3.7	Jackson et al., 1996
Cold deserts	82	4.5	Jackson et al., 1996
Meadows of forest-steppe zone (Kursk Region)	87	6.70	Shalyt, 1950
Steppe with needle grass and Volga fescue (Kherson Region)	93	13.8	Shalyt, 1950
Steppe with Volga fescue and needle grass (Western Kazakhstan Region)	90	13.3	Kamenetskaya, 1952
Xerophytic dry steppe (Western Kazakhstan Region)	96	21.7	Kamenetskaya, 1952
Deserted steppe (Kherson Region)	96	26.9	Shalyt, 1950

Notes to table 1: * – the calculations were applied to the annual production; the live aboveground mass included only leaves.

We should understand that the enrichment of the steppe territories by afforestation is misleading: production and the total accumulation of organic matter (underground and aboveground) in the herbaceous steppe does not yield to the forest community, the most organic matter of which is presented mainly by the dead wood, but even exceeds it, considering both the aboveground and underground organic mass, including soil humus.

Nevertheless, the natural forest communities are widespread and common for the steppe climatic zone, however we should remember that they are spread only locally, forming separated forest stands and wooded ravines in the spots with extra moisture (relief lows, hollow outlets, river valleys etc.) and are basically the non-zonal natural formations. As the result of high water availability, increased density of leafage and mutual leaves shading, the competition for water becomes the competition for light, and here the trees have an advantage. Their long trunks allow them to lift the canopy (leaves) over the assimilating organs of other plants (herbs, bushes), thus giving them an advantage to use light, which is the main condition for the forming of a close tree stand, i.e. a forest community in those local habitats. In this case the trunks can fully play their functional role, providing the trees with more efficient usage of the limiting factor (light) and dominance in the vegetation cover.

Animal Grazing as a Natural Environment-forming Factor

As follows from what has been said, the natural vegetation cover of the automorphic steppe landscape (i.e. the one that lacks extra soil moisture) is presented with the herbaceous type of vegetation. A classic example of the natural steppe is a mixed-grasses-tussock-cereals steppe, mostly with needle grass (photo 1; Лавренко, 1940). According to some of the existing conceptions, these steppes were common and natural on the Earth during the pre-anthropogenic period, and now it is believed that they have been deeply transformed by the influence of the agricultural human activities, especially the long-term cattle grazing and widespread land plowing, and became very rare or even disappeared from most of the steppe regions. It seems that cease of grazing or its restriction should create the required conditions for the restoration and preservation of that natural steppe tussock-cereals (needle grass) vegetation. But is it really so, could these steppes exist stably ages ago, and can they exist now, if the agricultural activities will be completely stopped?

The animal grazing in the steppe natural zones has always been, even before humans' intervention, a natural phenomenon, playing major roles in the ecosystems. In the past these animals were wild herbivorous mammals, now they are replaced with the farm animals. Certainly, the activities types of the wild and farm animals are not equal, but their functions in the ecosystems and their impact on the environment are quite comparable. In the recent past a complex of wild ungulates was common for the steppe, semi-deserted and deserted landscapes. It included such species as onager (*Equus hemionus* Pall.), Przewalski's horse (*E. Przewalskii* Pol.), Bactrian camel (*Camelus bactrianus* L.), saiga (*Saiga tatarica* L.), black-tailed gazelle (*Gazella subgutturosa*), wild sheep (*Ovis* spp.) and others (photo 3-6).

All of them were common and numerous inhabitants of the steppes and tepid deserts. In the 1970s the winter herds of onagers in Kazakhstan semi-deserts had thousands of animals (Sludskiy, 1963). In the middle of the XIX century numerous herds of the Eurasian wild horse (tarpan) were a common sight in the dry steppes and semi-deserts of Greater Caucasus Region and the interfluve of the Volga and Ural rivers (Kirikov, 1983). According to the records of many researchers, in the early XIX century in the prairies of the North America there were 50-80 million of bison (*Bison bison*), 40-100 million of pronghorns (*Antilocarpa americana*), and the total number of the wild ungulates was very close to the modern cattle – 103-118 million instead of 191 million (Watt, 1968). In the protected nature areas of the African savannahs, where the ecosystems were preserved in their original condition, the wild ungulates communities are exceeding the farm ones by the pasture load and their functional significance to ecosystem. The idea that the numbers of wild mammals were very dense in the natural landscapes, is supported by some paleontologists (Vereshchagin, Gromov, 1977). They believe that in the late Pleistocene mammoth steppes the numbers of large ungulates in the herds were very close to the ones that can be seen in the protected African territories nowadays. The scale

and role of the animal grazing in the nature is one of the most important global factors, providing us with the understanding of the formation, functioning and dynamics of the most terrestrial ecosystems, distributed in the steppe and semi-deserted regions of the Earth.

Photo 3. Przewalski's horses and Bactrian camels, grazing together on a steppe ("Zhivaya Priroda Stepi" association, Manych settlement, Rostov Region, April 2016).

Photo 4. Herd of American bison, grazing in a cereal steppe ("Zhivaya Priroda Stepi" association, Manych settlement, Rostov Region, June 2018).

It is considered that grazing is a destroying factor, causing steppes degradation (desertification). However, now it is known that increased animal grazing is not the only one to cause vegetation degradation, because its total exclusion or just a simple restriction are equally fatal to the steppe ecosystems, and are leading to the disturbance of indigenous steppe systems (Abaturov, 2006). The main reason for these disturbances is accumulation of the non-decomposed dead vegetation

mass (litter), the environmental importance of which was described for the first time in the XIX century by I.K. Pachosky (1917) in the steppes of Circum-Pontic Region, and studied in the Central Black Earth Nature Reserve (Kursk Region) by A.M. Semenova-Tyan-Shanskaya (1977). The absence of grazing in the protected nature territories makes the litter mass (steppe "felt") grow up to 10 t/ha, while on the pastures it is always lower or is not present at all (fig. 1). A sturdy and thick litter layer oppresses many plant species, obstructing and slowing down their growth in spring, and excludes their seed regeneration. The tussock cereals are the most vulnerable to this, especially the needle grasses. The absence of seed regeneration leads to plants' aging and weakening, then thinning out, revealing clearly visible bare spots of ground which are covered with litter instead of herbs (photo 7). When litter starts to accumulate, the productivity of vegetation cover significantly drops; at the maximal thickness of litter (91 cwt/ha) the production[3] of the aboveground phytomass (37 cwt/ha), according to our data, was significantly lower than of the nearby pasture vegetation growing at the edge of the nature reserve (53 cwt/ha) with decreased (23 cwt/ha) thickness of litter (photo 7).

Nowadays it is well-known that litter formation causes a decrease of plants and animals' species diversity, makes the steppes overgrow with shrubs and bushes, and has other negative aftermaths which destroy the natural condition and functionality of the steppe ecosystem (Didukh, 2014; Tkachenko, 2014).

Photo 5. A herd of camels, grazing on a steppe fallow land (former arable land; "Zhivaya Priroda Stepi" association, Manych settlement, Rostov Region, July 2015).

In addition, the litter material keeps and excludes from the biological cycle a vast amount of mineral elements the plants feed on, including the available nitrogen (Abaturov, Kulakova, 2010). The material of steppe litter (according to the data for the meadow steppe of the Central Black Earth Nature Reserve) contains from 0.91 to 1.69% of nitrogen and 7.26-10.23% of mineral matter.

[3] Annual increase of aboveground vegetation mass.

Photo 6. Przewalski's horses on a cereal steppe pasture ("Zhivaya Priroda Stepi" association, Manych settlement, Rostov Region, October 2015).

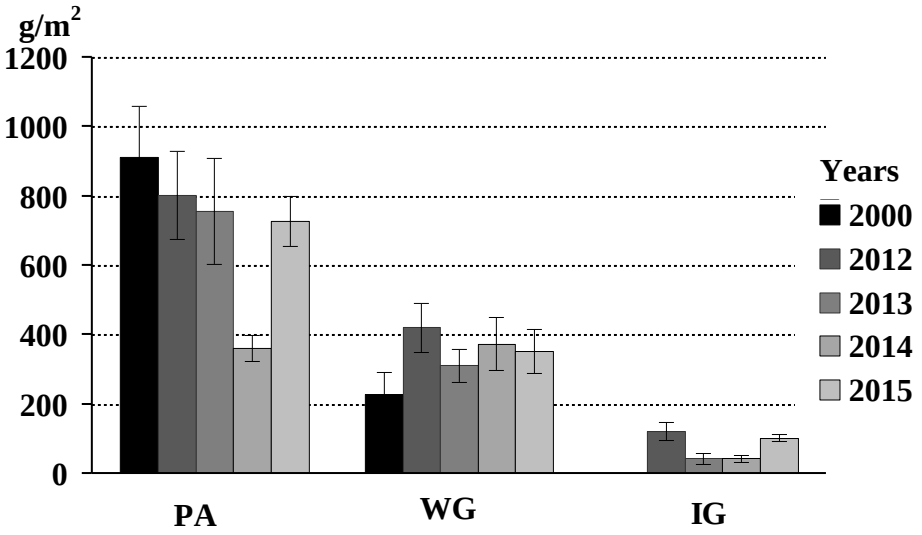

Fig. 1. Mass of steppe litter (g/m^2, dry weight) in the steppe mixed-grasses-cereal communities of the Northern Caspian Region (Dzhanybek). *Legend:* PA – protected area, WG – area with weak grazing level, IG – pasture with intense grazing (Abaturov et al., 2016).

At the constant stock of dead vegetation material (litter), reaching 9000 kg/ha in the protected nature areas (Bystritskaya, Osynchyuk, 1975; Semyonova-Tyan-Shanskaya, 1977), it holds and excludes from the biological cycle about 50-160 kg/ha of nitrogen and 400-500 kg/ha of mineral matter. It seems the values are only an insignificant part of their composition in the root-inhabited soil. In the deserted-steppe (meadow-chestnut and solonetzic) soils of the Northern Caspian Region (Dzhanybek Station of the Russian Academy of Sciences) a layer of 0-30 cm thickness contains 6400-10800 kg/ha of total nitrogen (fig. 2). However, it must be considered that most of this nitrogen is in the humus, non-decomposed root mass, i.e. in a form inaccessible for plants and it is not part of the biological cycle. Meanwhile the content of mobile soluble easily hydrolysable nitrous compounds does not exceed 400-500 kg/ha, and the amount of easily nitrifying and more mobile nitrogen forms, available for plants, is 220-230 kg/ha (fig. 2).

Photo 7. Steppe vegetation state in the area where grazing is prohibited (on the left) and in the near grazing area (on the right; Dzhanybek Station, in 2000).

Considering these exact "useful" forms of nitrogen, the steppe litter conserves and excludes from the plant ration the mass of scarce and easily accessible nitrogen, which value is equal to the value of half the nitrogen contained in the soil (Abaturov, Kulakova, 2010). Undoubtedly, during vegetation period plants draw the maximal amount of these compounds from the soil, accumulating them in the dead vegetation mass, excluding from the biological cycle and causing nitrogen deficiency for plants to feed on. The amount of available nitrogen compounds and other nutrients significantly depletes, the soil fertility drops.

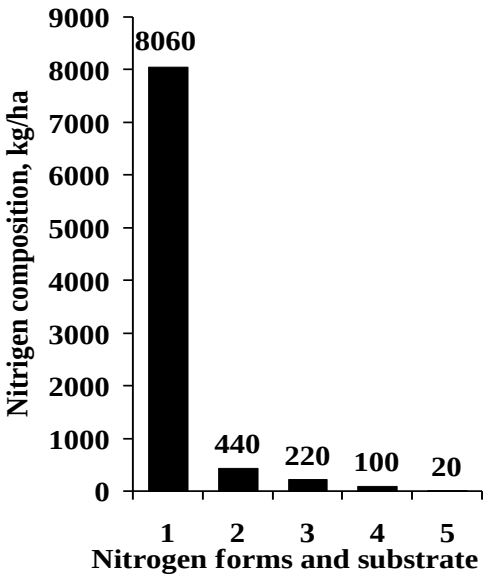

Fig. 2. Stocks of various nitrogen forms in the ground, in the steppe litter and in the aboveground phytomass. *Legend:* 1 – total nitrogen in a layer of 0-30 cm depth in the meadow-chestnut soil, 2 – easily hydrolyzable nitrogen in the same substance, 3 – easily nitrifiable nitrogen in the same substance, 4 – nitrogen in the steppe litter, 5 – nitrogen in the aboveground vegetation mass (Kulakova, 2008).

Under these conditions the activities of phytophages become the most important ones for the ecosystems functioning, especially of the herbivorous mammals. Animals of the steppe pastures eat the most part of the aboveground vegetation mass, process it during digesting and metabolism and then fully return it to the root-inhabited ground, with its mobile (available for plants) nutrients. Most of the utilized organic nitrogen assimilates when digested, and returns to the ground as the products of metabolism (urea, ammonia), where they transform and become available for plants. About 15 kg/ha of nitrogen returns back this way (Abaturov, Kulakova, 2010).

Apparently, accumulation and negative role of steppe litter is a regular phenomenon, common for the steppe ecosystems, where the high enough productivity of herbaceous plants combines with the activity of reducers (ground invertebrates, fungus and microorganisms), decreased due to the arid climate. In these conditions the reducers' roles are played by the herbivorous mammals that restore the balance between synthesis and destruction of vegetation organic matter, thus preventing the dead vegetation mass from accumulation.

We should accentuate that without any

grazing of the herbivorous mammals the steppe litter is not the only one to form in the territory; another type of specific and ecologically important dead vegetation mass is the steppe dry grass. It forms after the plants finished their vegetation and died, but the dry stems stayed attached to the roots (photo 8).

In the steppe ecosystems steppe dry grass has a special ecological meaning. Those steppe plants, especially the cereals, that finished their vegetation to the midsummer, then accumulated in large amounts due to the absence of animal grazing and formed a layer of dry flammable litter, are a source of constant steppe fires, which are very common for steppes where the grazing animals are scarce or absent. It became especially noticeable in the European and Asian steppes in the past decades, after cattle herds and grazing were reduced. The latter had caused the steppe fires to widely spread in these territories, when fire was regularly covering large areas of the mixed-grasses-tussock-cereals steppes of Russia and Kazakhstan.

The pasture influence affects vegetation as well as soil properties. It is well known that in the arid ecosystems on the bare spots between the plants a layer (crust) of lichen, algae and moss develops. It has a negative effect on the water-physical properties of the environment, and changes the soil moisture regime, significantly decreasing its water permeability (photo 9; Gunin, 1990; Belnap, 2008). Formation and efficiency of this crust depend on grazing intensity. In the dry steppes of the Northern Caspian Region (Dzhanybek Station) the share of ground surface, covered with such crust of cyanobacteria (*Nostoc* spp.), lichens (*Calopla caraesaeneni*, *Endopyrenium desertorum*) and moss (*Tortula desertorum*), was noticeably dropping from 97% without grazing to 37% on the pasture. Meanwhile, soil permeability on the pastures unlike the territories without grazing was growing 5 timed as the result of the ground cover destruction caused by the hooves of the grazing animals (table 2). In this case, grazing of herbivorous mammals, farm animals included, becomes an important element of the steppe ecosystem functioning.

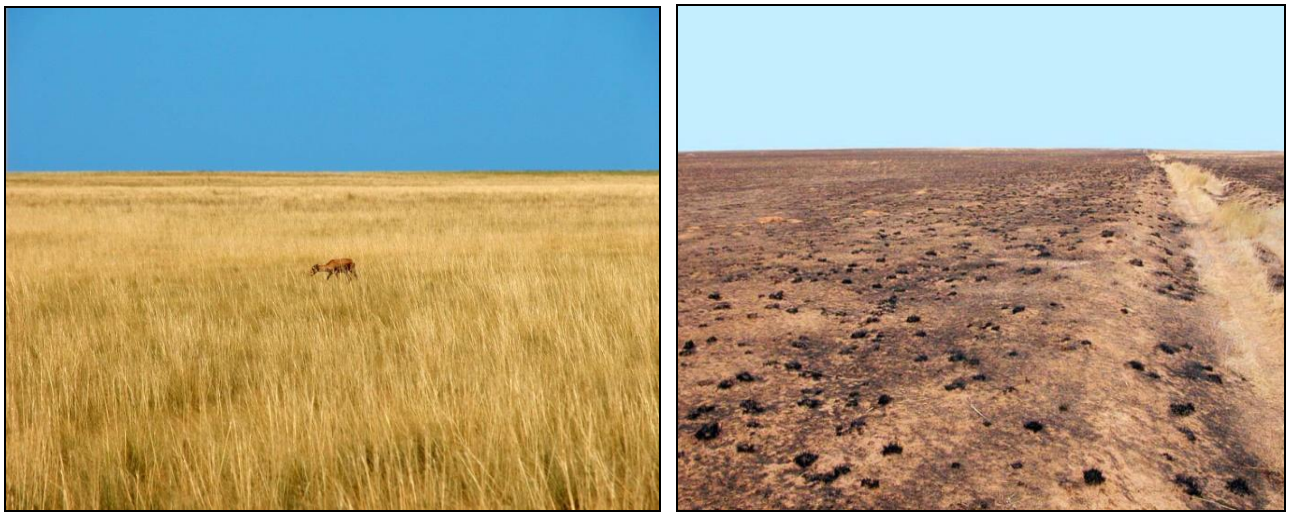

Photo 8. Steppe during the dry summer period, with cereal plants that already finished their vegetation and turned into steppe dry grass (on the left), under the same conditions but after a steppe fire (on the right; Kalmykia, July 2007).

These examples are an evidence of the important functional role of grazing animals that control many ecological processes in the steppe ecosystem, therefore becoming the significant factor of the natural functioning of the steppe ecosystem. They prove that animal grazing (including the farm ones) has a very specific role in the natural functioning and preservation of the steppe ecosystem. It makes the steppe territories, affected by the grazing of the wild and, to a certain extent, farm

animals, be referred to as the natural, stably functioning steppe ecosystems. And vice versa, without the grazing animals the forming ecosystems should be considered disturbed and having no specific features of functioning and appearance, typical for the steppes.

Photo 9. Ground surface in the nature reserve without cattle grazing (on the left), with a crust of lichens (*Caloplaca raesaeneni*, *Endopyrenium desertorum*), moss (*Tortula desertorum*) and algae (*Nostoc* spp.), and in the nearest pasture for livestock (on the right).

Table 2. Changes of soil permeability on the saliniferous solonetz, affected by cattle grazing, Dzhanybek, in 1984 (Abaturov, 1991).

Index	Nature reserve	Pasture with moderate grazing	Pasture with intense grazing
Permeability coefficient, mm/minute	0.055±0.001	0.054±0.004	0.240±0.019
Total amount of water, absorbed in 260 minutes, mm	82.4±6.47	75.9±9.48	109.8±7.50

Mechanical Disturbance of Steppe Soils is a Natural Process

Land plowing is the most important anthropogenic factor, destructive for the steppe ecosystems. However, even in the natural environment the processes similar to plowing are quite common, unavoidable and widely performed by the vast amount of large and small fossorial animals, when they process the soil mechanically. Specific soil-forming processes start in the areas, disturbed by these activities, and as the result the complicated steppe ecosystems acquire some specific features. For example, the ongoing long-term (thousands of years) activities of the ground squirrels (*Spermophilus pygmaeus*) that widely inhabit the steppe significantly change its look (photo 10). They dig up holes, forming little hills on the ground surface, and the hills form a typical "squirrel-genic" landscape, which is common for the wide steppe territories.

The mole vole (*Ellobius talpinus*) is another very common animal, the activities of which are widely spread in the steppes. It feeds on the roots of steppe plants and lives in the ground. The way it processes soil is similar by its form and scale to the anthropogenic land plowing of the steppe lands (photo 11). People noticed the mole vole's activities many years ago. The mole vole

(“digger”) “digs the ground very intensely and leaves the piles of ground on the surface, and from afar it looks like it’s been freshly plowed...; the piles stand so close to each other that often for ten steps around there isn’t enough space to place a foot. This little animal doesn’t threaten the human’s agriculture very much, on the contrary, while loosening the soil, it makes the ground “fluffy”, as the gardeners call it, and makes it more fertile; at least, I happened to notice that in the areas where the diggers had been living for a long time, the hayfields improved and the meadowsweet and pea-tree began to grow” (Zarudniy, 1897). After these animals deplete the available food resources (underground plant organs), they move to another undisturbed place. Then, the abandoned, exhausted and dug territory turns into a typical steppe fallow with annual plants (photo 11).

Photo 10. Typical landscape of a steppe formed by ground squirrels, created and maintained by the long-term activities of *Spermophilus pygmaeus*.

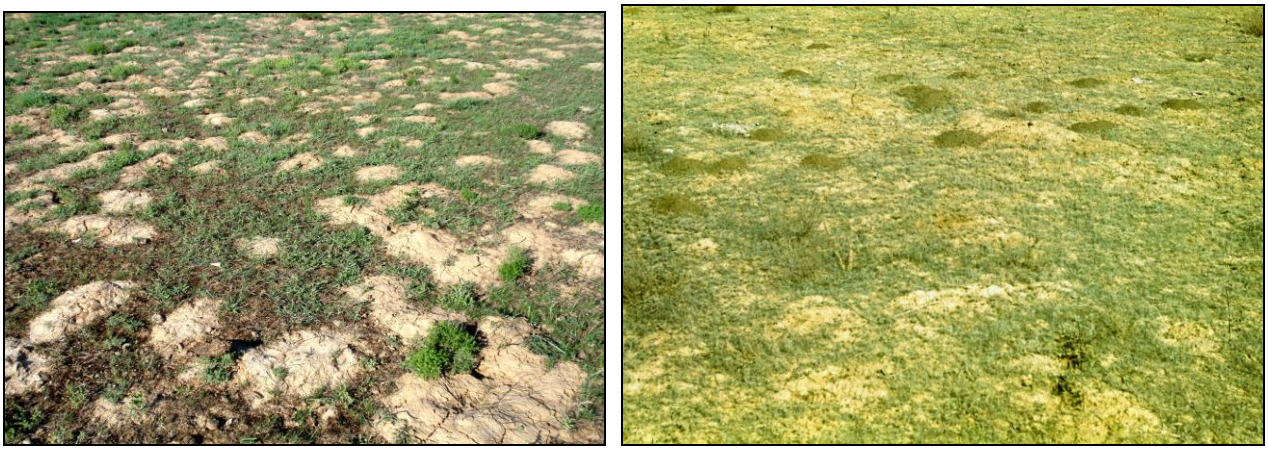

Photo 11. Steppe ground dug by mole voles: a freshly dug spot on the left, an abandoned spot (fallow land) on the right.

The systems of voles’ holes (*Lagurus lagurus*, *Microtus socialis*, *Lasiopodomys brandtii* etc.), the single holes of various species of ground squirrels and other rodents make the upper soil layers loose, the animals pierce the water-impenetrable horizons with their holes and tunnels, turning soil cover sieve-like, thus making its depth easily accessible for precipitation (photo 12; Formosov, 1928;

Abaturov, Zubkova, 1972; Abaturov, 1984; Dmitriyev, 2006). Otherwise, without these holes the precipitation water stagnates on the ground surface, soil becomes silted, and the bared takir-like spots start to form (photo 13). As the result of regular changes or rotation of the habitats used by these animals (or, according to A.N. Formozov's (1928) terminology, of the shifting system of agriculture), the entire steppe surface can be quickly (on a scale of a century) and thoroughly dug.

a)

b)

c)

Photo 12. Holes of *Microtus socialis*: a) in Kalmyk steppe in April 2018, with the wild grasses in the spot of abandoned holes in the background, and new holes in the foreground, b) new inhabited holes in the Northern Caspian Region (Dzhanybek Station, June 2014), c) permanent holes on a pasture of a mixed grass steppe in the Manych River valley (Manych settlement, Rostov Region, April 2016).

The aftermaths of this zoogenic soil transformation are mostly permanent and more influential than the usual anthropogenic plowing, after which the gradual soil recovery begins, returning lands to their original condition. Every year in the dry steppe of the Northern Caspian Region (Dzhanybek Station), when hibernation is over the population of the little ground squirrel (*Spermophilus*

pygmaeus Pall.) comes to the ground surface from its wintering holes and builds hectares covered with separated holes. Each of them is a vertical drain, 5-6 cm in diameter, piercing the ground, including the water-impenetrable solonetzic layer, down to about 1 m, thus opening the access for the melt and rain water to the saline soil depth (photo 14).

Photo 13. Slightly flooded ground surface after the rain (June 2012) without rodents' holes (on the left), and a bare patch with silted soil in a flooded area (on the right; October 2012).

Photo 14. A vertical spring hole of *Spermophilus pygmaeus* (its spring exit after hibernation) on the saliniferous solonetz (a vertical ground drain about 100 cm deep (Dzhanybek Station, May 2008).

In the spring after the snow has melted away solonetzic saline soils of the Northern Caspian Region steppes can be moisturized along these holes down to 1.5 m depth, while usually (without the holes) water cannot penetrate deeper than to 40-50 cm (fig. 3). The changing pattern of the moisturizing of the dug up soils causes severe transformations of their morphology, structure, composition, chemical and physical properties. The saline regime and solonetzic characteristics of these soils change very quickly, followed by the soils significantly thickening, sinking and forming depressions (fig. 4). This process is permanent and causes formation of kettles with chestnut soils and

steppe mixed-grasses-cereals vegetation and bushes. Then a microrelief forms with kettles and complex soil-vegetation cover, which makes the formed steppe look patchy (photo 15, 16).

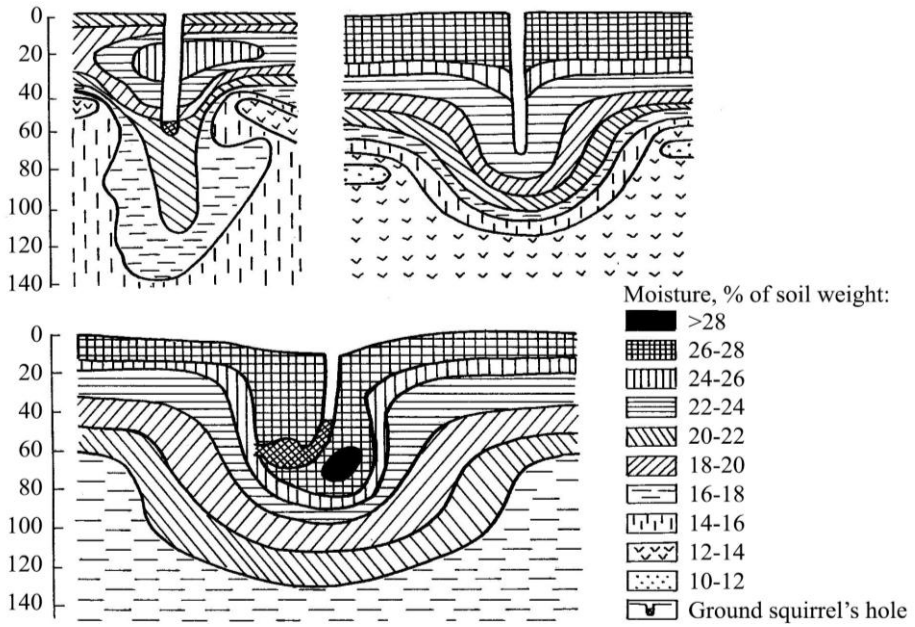

Fig. 3. Soil moisture along the vertical holes of *Spermophilus pygmaeus* (Abaturov, Zubkova, 1972).

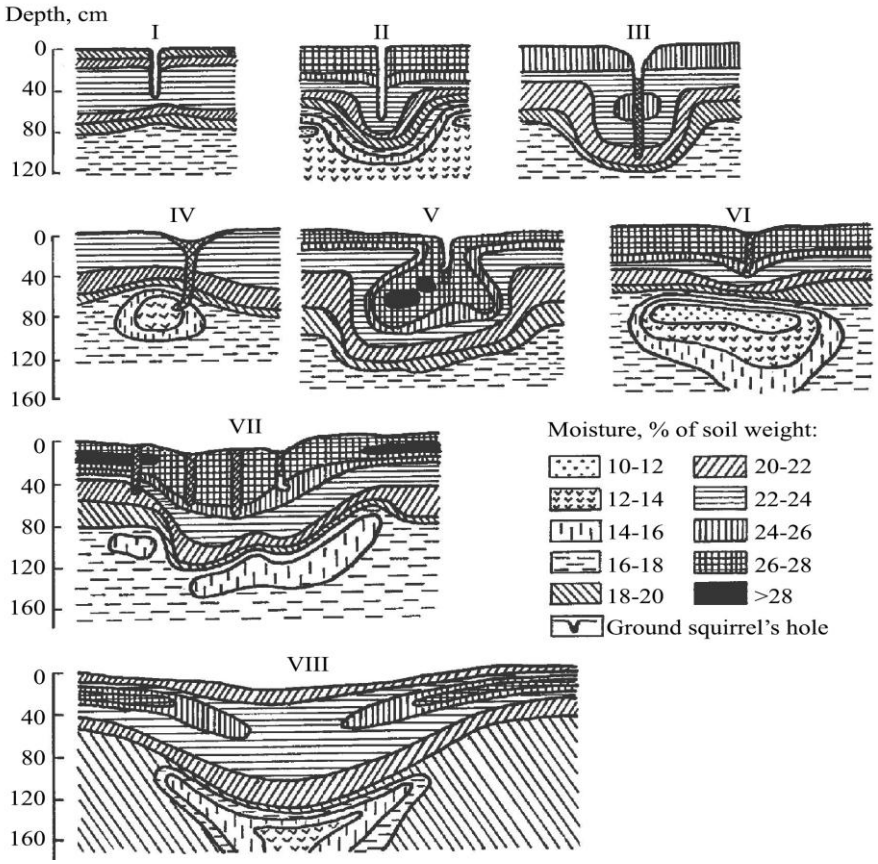

Fig. 4. Stages of a small kettle (VIII) formation with light chestnuts soil under the influence of the vertical holes of *Spermophilus pygmaeus* (Abaturov, Zubkova, 1972).

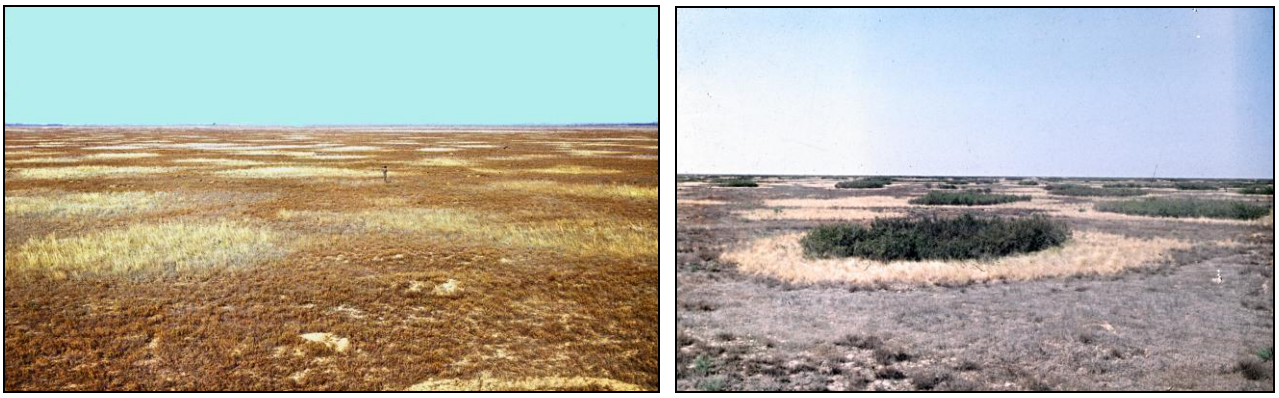

Photo 15. Microrelief with kettles in a steppe of the Northern Caspian Region with tussock cereals (*Stipa* spp., *Festuca valesiaca*) along the kettles, and with black sagebrush (*Artemisia pauciflora*) on the micro-sags (leftward), and bushes (*Spiraea hypericifolia*) along the west kettles (on the right; photo by G.V. Lindeman; Dzhanybek and its neighborhood, September 1970).

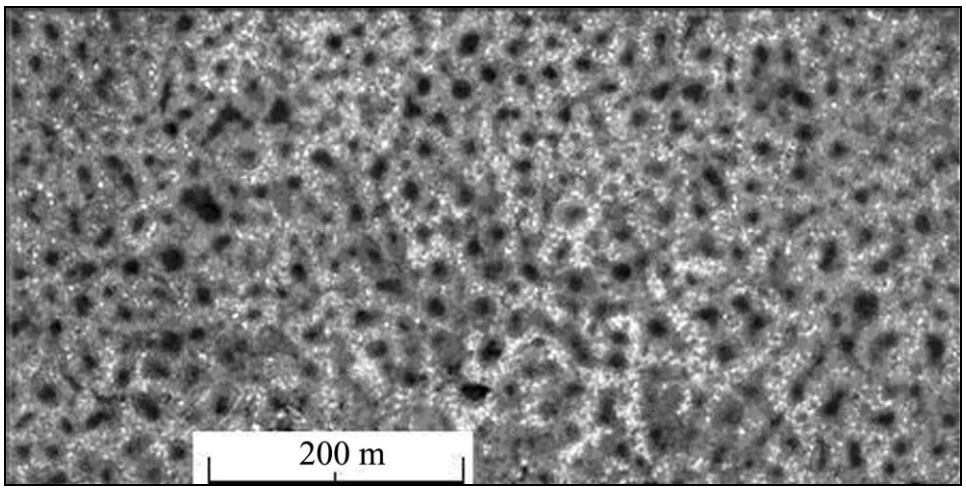

Photo 16. Satellite imagery of a steppe landscape with micro-kettles in the Northern Caspian Depression: the dark spots are the kettles with steppe mixed grass and cereals (N 49° 05', E 46° 11', August 2003).

As the result, the environment becomes diverse. Elements of different nature zones combine there in the same landscape (Milkov, Gvozdetskiy, 1978). There the typical meadow and steppe chestnut and black-earth-like soils in the kettles can be found side by side with the deserted solonetz and solonetzic soils on the micro-kames, while the meadow-steppe mesophilic mixed-grasses-cereals and bushy vegetation alternates with xerophilic mixed grasses communities, halophilic herbs and semi-shrubs.

We can name even more examples of natural transformation of the steppe soils under the influence of mechanical activities of animals; they are various, widespread and well-known, like in Mongolian steppes (Dmitriyev, 2006). They all definitely prove that such forms of soil transformation are not a random phenomenon, but a regular natural process, which covers the entire steppe territory inhabited by animals. Essentially, this phenomenon is the same with the anthropogenic impact. In both cases it can be seen in the mechanical disturbance of soil composition, structure and functions.

The differences can only be noticed when this phenomenon becomes too intense (i.e. constant

plowing) or the transformations become irreversible in the case of some mammals' activities. This is a natural process, and the ecosystems that form under its influence are the natural formations, with no significant differences between them and the anthropogenically created artificial ones. In both cases it is a very important and often highly required phenomenon to provide a stable ecosystem functioning. Certainly, the measures of protection, aiming to restore the natural ecosystems, should take into account the necessity to preserve the processes that provide diversity of such ecosystems and create a specific type of their natural functioning.

Conclusion

Many types of mechanical impact on the terrestrial ecosystems, similar to the anthropogenic ones, such as cattle grazing, land plowing etc., are common for the natural environment as well, without any connection to the humans' activities. They have always been inherent for the steppe ecosystems, the best examples for this are wild ungulates grazing and ground digging by fossorial animals. Wild and farm animals equally play their specific and sometimes very similar roles to form and stabilize the existence of the steppe ecosystems. Their activities in both cases are necessary, to a certain extent, condition for the natural and stable ecosystems functioning, while their absence causes disturbance and degradation. For example, it applies to the efficient role of animals in recycling of an excess of overgrowing vegetation mass, which in its turn provides a balance to the processes of accumulation and destruction of organic matter, created during photosynthesis, a normal functioning of biological cycle in an ecosystem, and a sustainable functioning of its vegetation components. Essentially, they are similar to many anthropogenic types of impact. The difference is only in their scales and intensity of their effect; for example, it can be constant plowing, excessive pasture load due to cattle grazing and common for anthropogenic types of impact, or irreversible changes, caused by many types of wild animals' activities. The exclusion of such activities always has negative aftermaths. For example, a cease or decrease of cattle grazing on the steppe pastures in the last 10 years has become the main reason for the ubiquitous distribution of steppe fires, which constantly affect the steppe territories of Russia and Kazakhstan.

We have to admit that all the true steppe ecosystems have been formed under the impact of these exact mechanisms, mostly natural, and now these steppes are natural formations that have no significant differences from the same ecosystems with anthropogenic origin. The formation mechanisms are the same or very close in both cases. Obviously, those blooming steppes with mixed grasses and cereals, which are considered an example of classical natural ecosystems, undisturbed by human activities, and are expected to form after the agricultural activities were limited or some other protective measures were taken, do not exist in nature, or are very rare and exist for a very short period of time. They were unable to exist stably without the mentioned mechanisms of steppe functioning in the pre-anthropogenic past as well as nowadays. Without the said mechanisms of the human or animals' impact, they become unviable, tend to quickly degrade and disappear after the fires.

The assertions about the necessity to restore forest communities in the steppes, which, as it is stated, are more natural for the steppes than the herbaceous ones, do not take into account the significant differences between the vitality of herbaceous and woody communities during the period of scarce water resources. The underground localization of photosynthesis products for herbs makes their roots mass grow and provides them with the faster and more efficient usage of water. Unlike herbs, in the arid conditions trees spend their photosynthesis products to form a functionally useless trunk mass in the aboveground area. Therefore, grasses in the steppe climate turn to be more competitive than trees, which is the reason for the growth of steppe herbaceous communities as the natural indigenous ones.

Certainly, protective measures, such as steppe afforestation or restriction of agricultural activities, while aiming to restore the natural ecosystems, should take into account the necessity to preserve, to a certain degree, some of the natural and agricultural processes that provide the natural

and stable functioning of the steppe ecosystems. Obviously, the modern attempts to restore the natural ecosystems, transformed by humans, with the help of some protective measures, cease or simple restriction of existing forms of environmental management will mostly be unsuccessful and cause disturbance of the stably functioning steppe ecosystems.

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