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Chapter 2

PASTURES IN THE ZONE OF TEMPERATE CLIMATE: TRENDS FOR DEVELOPMENT, DYNAMICS, ECOLOGICAL FUNDAMENTALS OF RATIONAL USE

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ABSTRACT

The peculiarities of historical phases of steppe ecosystems transformation influenced by grazing pressure have been analysed, estimations of well-directed modification of organic carbon and biogeochemical flows in the system "vegetation – soil" have been received. Characteristic periods of chronological organization of bioclimatic processes have been determined on the basis of analysis of observational series of annual and interannual variations in meteorological parameters and steppe pastures productivity.

The results of investigations of plant formations for natural pastures located in different ecological conditions are presented. Vegetation variety of meadow and calciphilous steppes on sample areas and pastures has been studied. Data on useful, harmful, rare species of plants, influence of species diversity of formations on the fertility of slopes have been received and connections between the number of species and main elements of soil fertility have been determined.

Methods of ecological restoration of steppe pastures on Chernozems and on slopes nearby deposition of carbonate strata have been described. The species which have the best environment transforming qualities have been revealed. In the rhizosphere of these plants the processes of parent material destruction and soil formation are occurring strongly, as a result slopes can be used for meadow formation and further utilization.

The fact is that the legume component is less stable when pastures are being established on the basis of gramineae-legumes mixes. This problem becomes more acute on eroded alkaline soils. There are results on studies of the dynamics of productivity and stability of legumes (*Fabaceae*) in the composition of mixes for cultivated pastures on the areas divided by ravines. Original data on seasonal dynamics of overground phytomass gramineae-legumes mixed crops for cultivated pastures distinguished by one legume component have been analysed. Bioenergetic effectiveness of mixed crops on the basis of various species of legumes is shown.

INTRODUCTION

In the Holocene history of steppes (the past 10–13 thousand years) a consistent series of plant formation modifications were determined by both natural rhythms and changes in economic modes. An analysis of different conditions of steppe vegetation evolution determined by nature and man’s impact and total estimation of productional process in historico-ecological periods are of great interest. By means of annual production from natural grasslands’ dependence on climatic parameters, one can reconstruct the basic stages of steppe vegetation evolution determined by nature and anthropogenic impact in the zone of temperate climate.

Demutation processes begin when grazing pressure is reduced, that is progressive pastoral succession which is the most common kind of secondary autogenic succession of grass ecosystems (Skarpe, 1992; Zhang, 1992). According to structure and species composition, changing demutation belongs to progressive autogenic succession; it carries out with enrichment of species composition and complication of plant community organization (Trophimov, 2001).

The estimation of the most common extant plant communities in pastures within gully plantings is of great interest in the view of their biological productivity in changing climate conditions.

The comprehension of natural grasslands adaptation to the influence of ecological factors allows us to control their structure and productivity (Bennet, 1985; Dover, Hopkins, Manning, 1986).

In the East European Plain, the forest-steppe zone stretches greatly from the north to the south because of moderate continental climate and broken relief. It is the main soil-vegetable zone in the southern part of the East European Plain; it covers a vast territory, which is more than the steppe zone area (Fig. 1). There are two steppe subzones in the forest-steppe zone. Northern subzone of meadow (northern) steppes is characterized by its southern variant that is herb-grass. On the test area the second subzone of herb-bunchgrass steppe (in the south) is characterized by northern variant of southern steppes, that is herb–sheep’s fescue–feather grass steppe.

In Ukraine, the steppe zone stretches from the Danube lower reach to spurs of the Central Russian Upland (more than 1000 km), more than 100 km wide in the west and 300–450 km wide in the east. It covers the vastest area (40% of Ukraine territory) in comparison with other natural zones. As arable lands dominate in the steppe zone (61–67% of territory) the proportion of natural grasslands area (pastures and hayfields) varies from 12% in the north to 10% in the south. The proportion of pastures in the total area of natural grasslands is 92% within the northern subzone of the steppe zone (on the rest area there are hayfields in high-water beds and terraces). In the southern steppe, the proportion of pastures reaches 96%.

An analysis of land transformations of the last 10 000 years in the south of the East European Plain (the forest-steppe zone in Russia and the steppe zone in Ukraine) have been carried out on the basis of archaeological and spore-pollen data; and the transformations of the last two centuries in Kherson province and Kherson uezd (region) have been analyzed according to statistics.

That part of the East European steppes (1802–1917) belonged to Kherson province, an administrative territory in southern Ukraine (between the late 18 century and early 20 century) that stretched from the river Dniester (in the west) to the Dnieper (in the east) and from northern coastlines of the Black Sea to 300 km north. The total area of the province was 71.935 km^2. Kherson uezd (region) was one of six uezds (regions) of Kherson province and its area was 19.25 km^2.

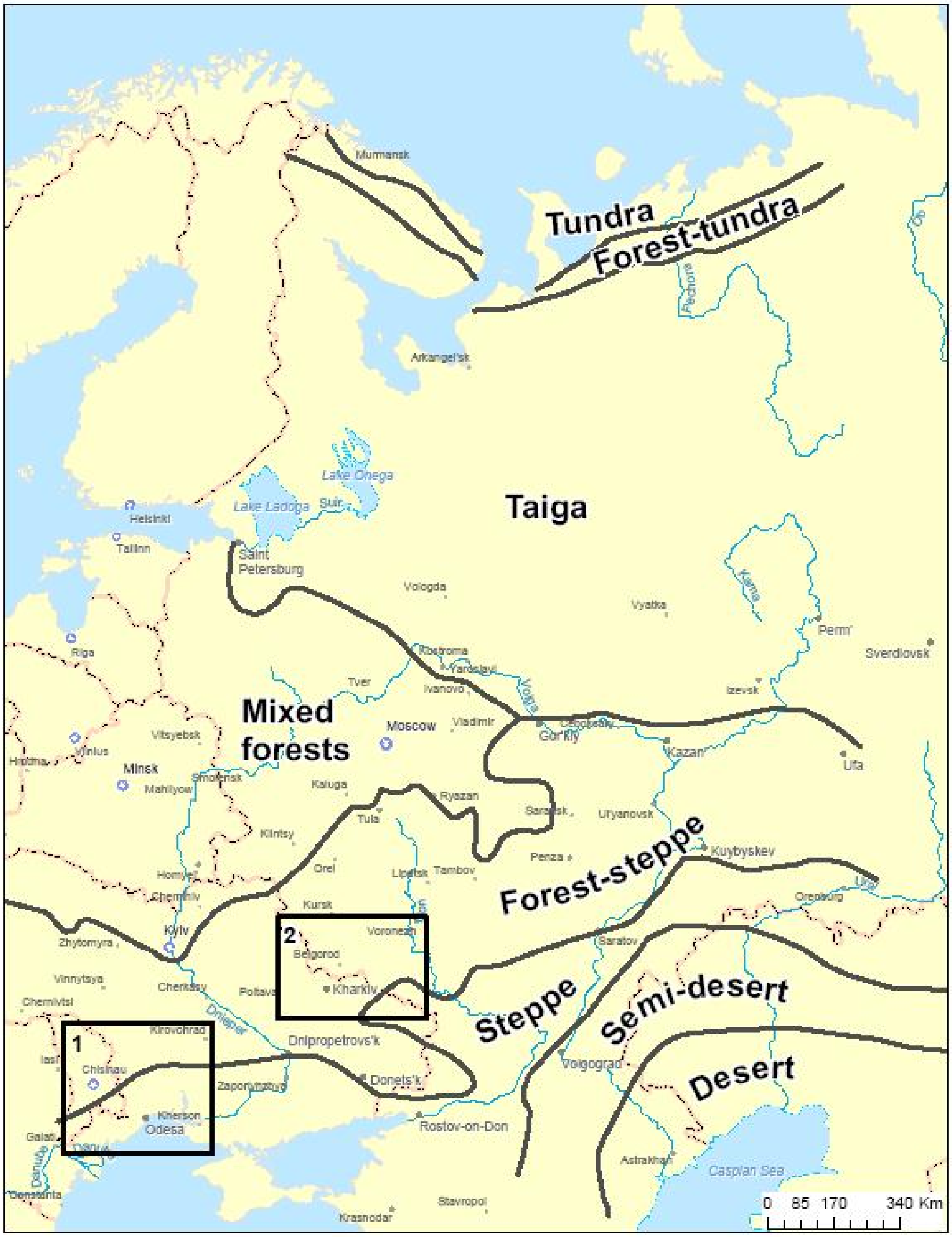


Figure 1. Study subjects on the territory of the East European Plain: 1. The territory of former Kherson Province, Ukraine; 2. Belgorod Region, Russia.

THE CHANGING OF ORIGINAL AND PHASIC COMMUNITIES IN THE STEPPE ZONE

In the south of East European Plain there were bunchgrass steppes at the Dryas–Preboreal transition (approximately 10300 years ago). This fact confirms that extant indigenous nucleus *in situ* (in the period of Pleistocene cooling) of the steppe vegetation was the basis of Holocene steppes formation.

The Preboreal and Boreal (10 000-8000 years ago) were characterized by the formation of landscape zonal structure in the East European Plain. Those days decreased proportion of goosefoot, wormwood, halophyte and increased dominance of grasses and mixed herbage distinguished the steppe zone according to spore-pollen complexes. Wild animals (auroch, tarpan, saiga and others) influenced on vegetation development. In the second half of Holocene the characteristic of the steppes stretched from the river Danube to the Dnieper, according to archeological data, was the influence of hunting on population number of wild animals. The result was a considerable reduction of dominance of open species of biotopes (tarpan, saiga) due to increase of population level of semi closed and closed biotopes in theriocenosis.

In the Atlantic period of the Holocene (8000-5000 years ago) climatic conditions of steppe zone were characterized by temperature decline and moistening increase. Under maximum temperature (6200 – 5500 years ago) in present northern and southern steppe subzones the proportion of mixed herbage and composite family (aster family) increased, grasses dominance was lost, meadow steppes were formed. According to changes in the Holocene annual average temperature and climatic chronology there was identified climatic conditions for transition form meadow mesophytic to xerophitic vegetation at the turn of 5350-5250 years ago. The next period, the neoglaciation was marked by temperature decline and increase of climate instability. There was a determined tendency of natural evolution of steppe ecosystems under those conditions. The tendency defined the consistence of steppe ecosystems which is appropriate to environment conditions. Dinesman (1984) made a clear statement concerning virgin steppes described by geobotanist; they are anthropogenic digression variant of steppes which had more mesophytic aspects in the middle Holocene. This fact also concerns the protection plot of the sheep's fescue–feather grass steppes in Askania-Nova where plain vegetation got zonal thick bunchgrass basis during eighty years' absence of grazing and hay harvesting, but not pyrogenic factor (Vedenkov, 1979).

On the virgin plot near the Bug estuary (the south of Ukraine) the productivity of feather grass *(Stipeta capillata)* was estimated. The productivity is more typical for local groupings of the zonal aspect in the sheep's fescue–feather grass steppes. Feather grasses (*Stipa pennata*) reach maximum phytomass earlier (between late April and June), than *S. capillata* does, but in this period it is only 52% of phytomass *Stipeta capillata* in August. According to average data of the period between 1981 and 1992 (Lisetskii, 1992) the sheep's fescue–feather grass associations of local aspect retrospectively correlated with the late Atlantic phase of the Holocene could give an annual amount (12000 kg/ha) of the plant substance, that is equal to the humus formation rate 2000-2500 kg/ha per year. Taking into consideration the decay rate of separate structural particles and the proportion of main organogen elements (Ca, K, P), it is calculated that root necromass (in the 0–20 cm soil layer) of the feather grass is a source of these ash constituents (58 and 131 kg/ha), and *Festuca valesiaca* (sheep's fescue)

38 and 66 kg/ha, respectively. As a result, the soil with feather grass gets organogen elements 1.8 fold more than with sheep's fescue. Thus, feather grass is more valuable in humus formation. This fact is confirmed by researchers who determined that the humus proportion in the 0-30 cm soil layer with feather grass is 1.7 fold more than with sheep's fescue.

In the forest-steppe and northern steppe the first palynological signs of productive arable-and- cattle-raising economy (pollen of cultivated grasses, segetal vegetation) are found in the late Atlantic phase related to climatic optimum: 5500-5200 years ago. Arable-and- cattle-breeding tribes of Neolithic Gumelniţa culture on the Black Sea basin territory are known near the Danube in Ukraine. According to data by Subbotin L.V. (1983) cattle was dominant in gumelniţa tribes (36% of farm animals), but the number of small cattle (mainly sheep) differs not much, and beside that the horses ratio was higher (9%) in comparison with earlier epoch.

The nature management experience of the late Tripolye culture was similar to Gumelniţa culture. Cattle-breeding of that period had the steppe aspect; there was not only adjoining the farm pastoral form near the river-valley but also outrun. Faunistic data of settlements suggest the dominance of small cattle (68%), cattle (18%) and horses (14%). The finds of wild animals bones in the settlements make it clear that the objects for hunting were the representatives of the open steppes (tur, saiga, Asiatic wild ass) and valleys (red deer, wild boar).

Important natural and anthropogenic changes occurred during the transition from the early to the middle subboreal phase (over 4200 years ago). Subboreal thermal maximum, equal to the Bronze Age (it lasted 1000 years), predetermined the prevalence of dry climate. Cooling and siccation of climate (manifested mostly between 4200 and 3700 years ago) determined xeromorphic characteristics of herbaceous cover in steppes. The grazing pressure and steppe vegetation fire became significant factors for evolution.

Feather grasses *Stipeta capillata* and *Stipa pennata* disappear under the grazing influence, anthroporesistant digressive formation of sheep's fescue dominated. It occurs because tussock failure of feather grass reaches 50% and sheep's fescue – 5% at phytomass detachment (Tanphilyev, 1939). It is recorded that in sheep's fescue–feather grass and sheep's fescue associations some indices decreased. Phytomass productivity reduced to 14000-15000 kg/ha, organic matter reserve (aboveground mortmass) to 1300-4600 kf/ha, rate of annual humus formation to 1400-1900 kg/ha, the amount of main organogen elements to 100 kg/ha. Special examination of steppe fires influence on the vegetation performed rapid postfire recovery and intensive bearing of sheep's fescue (Shalyt, Kalmykova, 1935). The structural particles of aboveground mass reach their starting value in 2 years after the fire in sheep's fescue–feather grass associations of the Black Sea basin (Lisetskii, 1987). Changes of vegetation cover are determined by pyrogenic factors with natural reiteration. These changes make for the graminoid proportion increasing of the steppe phytocenosis. Coenotic value of sod grasses especially increases. The amount of legumes reduces; this fact is rather significant for description of changing of biochemical conditions for humus formation. In the judgment of Whittaker (1975) low biomass of graminifolious plants is the result of short living period of aboveground plant parts adapted to fires. It is performed that under sheep's fescue–feather grass associations the portion of mortmass (detritus) in the 0–20 cm soil layer varies from 27 to 32 % of underground phytomass but it increases to 45% after fire. Consequently pyrogenic factor favors humus formation process in the soil. However, the absence of dead plants and litter on the plot destroyed by fire are favorable for intensive transformation and mineralization of latest necromass.

As it was presented earlier (Lisetskii, 1998) that environment potential summarized by radiation balance and annual precipitation in expenditure of energy (Q) by Volobuev formula (1974) was higher in the period between 3500 and 3000 years ago, and between 3000 and 1700 years ago it was lower than present-day values which characterize steppe zone conditions by data of the instrumental period. The past 3500 years were more favorable for steppe ecosystems than the whole of the Holocene history of development. The value Q was estimated at 950 mj/ m^2 per year in comparison with averaged value for the past 10 000 years - 665 mj/ m^2 per year.

The Bronze Age in the north-west of the Black Sea basin (between 25 – 9 century ago BC) is defined by distinct dominance of cattle-breeding tribes (especially before emergence of the settled population of sabotinov type – between 14 and 13 centuries BC). The comparison of spore-pollen spectra in the humus horizon of the middle Holocene buried soil (under “suslikovina” – small hills as a result of burrowing activity of ground squirrels in their habitat) and the present day soil on the absolute reserved territory in Askania-Nova (Dinesman, 1977) showed that the middle Holocene pollen complex was characterized by high portion of Compositae and mixed herbage, lower portion of grasses and goosefoot family and the part of wormwood was similar to the modern-day one.

Relative moderation of grazing pressure in this historic and ecological period is explained by the fact that cattle were predominant domestic animals in the occupation layer of the Late Bronze Age. It is notable that on settled areas in the period between 13 and 12 centuries BC (the present territory of Moldova) bone remains of tarpan were not found in contrast to Asiatic wild ass. Apparently, in the Late Bronze Age not numerous (5-15 animals) tarpan flocks coexisted with the flocks of domestic animals only on the territory between the Bug and Dnieper rivers.

In the Early Iron Age the role of small cattle increased greatly (firstly it concerns sheep) in the cattle-breeding in the north of the Black Sea basin. As a result, the cattle-breeding of settled tribes had some nomadic characteristics. Internal causes for steppe ecosystems formation lost their leading role due to cattle-breading development beginning from the 1st century BC by Dinesman (Paleoclimate…, 1989). Teyetsman admitted that the first examinations of the vegetation of Askania-Nova revealed (Alyokhin, 1986) that the wormwood portion of Austrian in zonal groupings was estimated at 6% of the total phytomass. The digressions (fig. 2) characterized by the presence of 12 and more species on the plot (25 x 25 cm) have little proportion of wormwood in phytomass in the steppes near the Black Sea basin (the ratio of species on the plot 1 m^2 and 25 x 25 cm in separate color aspects was estimated at 2.00-2.67). *Artemisia austriaca* forms the wormwood steppe in conditions of overstocking. This steppe becomes degraded only due to sheep grazing. Overstocking (grazing, toloki - pounded lands) next to building zones developed qualitatively new phase of vegetation influence on soil formation having completed the series of digressive successions. The role of wormwood necromass in biochemical flows of the steppe ecosystems increased according to wormwood concentration. It is connected with two reasons: chemism distinctions and higher rate (1.4-1.8 fold) of wormwood phytomass transformation in comparison with other edificators of evolution changes. Green phytomass and Austrian wormwood roots differ in the amount of organogen elements (Ca, K, P) not much. This amount is estimated to 41-49 % of the total ash level, which is 2 and 3.4 fold more than sheep's fescue and feather grass, relatively. Aboveground phytomass of Austrian wormwood and Crimean wormwood is more enriched in nitrogen than grasses phytomass. The result is the value of elements of potential (humus, total nitrogen) and effective (active forms of phosphorus and potassium) soil fertility under wormwood plants is higher than in the soil under sheep's fescue (Lisetskii, 1992).

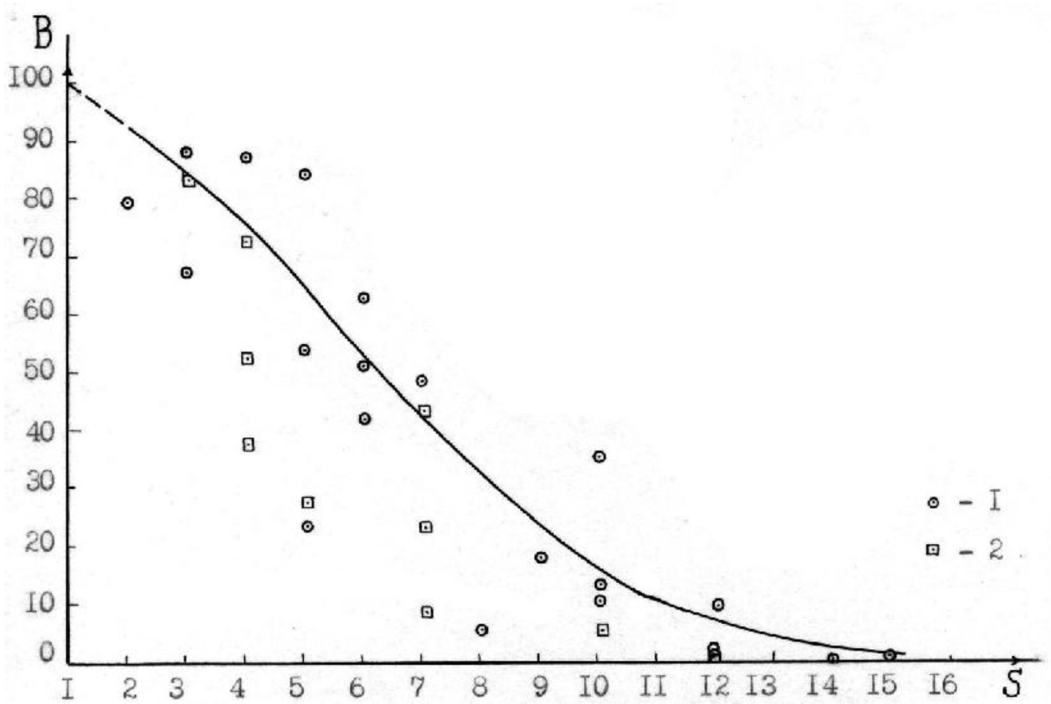


Figure 2. The dependence of Austrian wormwood (1) and Crimean wormwood (2) concentration in aboveground phytomass (B, %) on the amount of species(S).

$$B = 100 \cdot e^{-0.0015 \cdot S^{2.1}}.$$

According to our field examination, based on sheep's fescue sowing on the sample plots with the soil chosen under associations of different proportion of wormwood, sheep's fescue productivity relative to edafotop with its total dominance (100%) averaged between 1989 and 1992: for wormwood-sheep's fescue association (the wormwood portion – 32% of phytomass) – 130, for wormwood association – 145 % (table 1).

Table 1. Conditions and results of field microplot trial

Parameters	Associations		
	sheep's fescue	wormwood-sheep's fescue	Wormwood

Associations phytomass, g/m^2	38.56	50.56*	60.00
Chemical parameters of soils in plots:			
Humus, %	3.21	2.82	3.64
Nitrogen gross, %	0.204	0.198	0.224
C:N	9.1	8.2	9.4
pH	6.85	6.86	6.85
Absorbed bases, mEq /100 g:			
Ca2+	19.2	19.2	17.2
Mg2+	4.8	4.6	4.4
Na+	0.43	0.43	0.43
Water extract , %:			
Dry residues	0.034	0.060	0.066
Ca2+	0.005	0.006	0.005
Mg2+	0.001	0.001	0.001
Na++K+	0.002	0.003	0.006
HCO3-	0.015	0.018	0.018
Cl-	0.005	0.007	0.009
sheep’s fescue phytomass in the experiment**, g/0.004 m^2:			
August 27, 1988	0.64	0.33	0.79
May 27, 1989	0.71	1.42	1.31
October 29, 1989	0.21	0.89	0.68
May 23, 1990	1.32	1.94	1.78
June 20, 1991	9.64	8.77	13.00
May 29, 1992	8.43	6.92	10.48
Relative productivity of sheep’s fescue in the experiment (1989-1992), %	100	130	145

*Wormwood mass is included – 16 g/m^2.

** Cultivated sheep’s fescue in special field trial (from August 27, 1987 to May 29, 1992) was used as a phytometer of edaphic conditions.

However, it’s unlikely that sheep’s fescue and other grasses replace wormwood habitat in natural conditions. Wormwood *(Artemisia austriaca)* having high level of allelopathic potential overtops the growth and development of the species which are involved in its synusia (Grodzinskiy, 1965). Thus, more favorable soil conditions formed with wormwood necromass are directed towards expansion of their species. We believe that continuous grazing pressure causing the breaking point of phytocenosis is only a trigger (starting point) for virtually permanent process of steppe desertification. The use of analytical methods proves it by the fact that the amount of exchange calcium in soil absorbent complex decreases under the wormwood plants, the amount of chlorine and sodium in water extract increases; it is recorded the considerable increasing of the limiting sulfur portion in phytomass which is fixed for free-salined habitats. Xerophytisation of vegetation layer under the influence of excessive grazing leads to the development of the series of halomesophytes during the transition from wormwood plants pasture to grazing (*Atriplex, Polygonum* and others) (Pachoskiy, 1917).

The peculiarities of the Early Iron Age in northern Black Sea basin are connected with the neighborhood of nomadic and seminomadic farming of the Scythians and the Sarmatians and the agricultural regions of Greek poleis located near the sea and estuaries. Archaeological data make it clear that in steppe Scythia and Olvia there was dynamics of sectoral structure of farming which depended upon the changes of ecological conditions. The Black Sea basin steppes (100 ha), slightly changed by grazing pressure with the forage productivity value 6000 kg/ha (3500-4300 fodder units per year) according to present-day standard of rational density of cattle stock, could provide with forage 90-10 head of cattle and 330 head of sheep. Osteolytic data suggest the optimum ratio of cattle and small cattle (1:3) could be observed in earlier archaic period of development of rural region of Olvia (Zhuravlyev, 1987). Increased grazing pressure could lead to the formation of soils with humus portion 25-28% (in the 0–20 cm soil layer) less than root associations. Moreover soil salinity and consistency strengthened due to biotic accumulation, unproductive moisture loss increased, degree of geochemical cycle control in biomass and soil horizon was determined (Lisetskii, 2008).

Reduced productivity in the steppe ecosystems with continuous grazing pressure determined the necessity of adjustment for the flock structure. It is recorded that the productivity of plant associations is 1300 – 3700 kg/ha or 800-2200 fodder units per year. The formation of these plant associations reflects the transition to digression changes. It is notable that during the Classical and Hellenistic periods of Olvia development increased cattle ratio was balanced by reduced small cattle ratio. Increased cattle ratio was caused by farming needs (Zhuravlyev, 1987). The period of the 5^{th} century BC is the turning-point in evolution of socionatural relations and the transition to a new strategy of nature management in Olvia farming region. In this period the use of principles of distinct regulation and equal territorial anthropogenic pressure replaced elemental development of economic system. This scenario is observed in the last phase of the Scythian economic history (the period between 3 century B.C. and 3 century AD) when under the influence of Greek settlers sectoral structure of farming was harmonized with agricultural districts in the Crimea and along the lower Dnieper river being formed.

The steppes near the Black Sea basin were characterized by similar landscape ecological situation because of the dominance of cultural and economic type, nomadic cattle-breeding, from the fifth century to the eighteenth century. Grazing became the leading factor of the evolution of vegetation layer in the steppes under the same anthropogenic influence of the tribes which changed one another (Huns, Pechenegs, Cuman, Nogais, and Crimean Tatars). Steppe mat burning down , especially during the wars, had material effect on improving of pastures. Wild ungulates ((tarpan, saiga, roes) dominated in the steppe ecosystem formation.

The steppes were used for cattle grazing in the 17th century, there were wild ungulates, but they were not numerous to change steppes into tramped pasture (Kirikov, 1983).

Natural plant groupings disappeared rapidly because of increased area of arable lands since late 18th century when all allotments of lands of Novorossia were confirmed. For example, in Kherson uezd (region) the area of natural grasslands reduced quickly (pastures, virgin lands, fewer portions of hayfields) for 130 years (figure 3). By the 1860s the areas of arable lands and natural grasslands were equal on the territory of Kherson uezd (region).

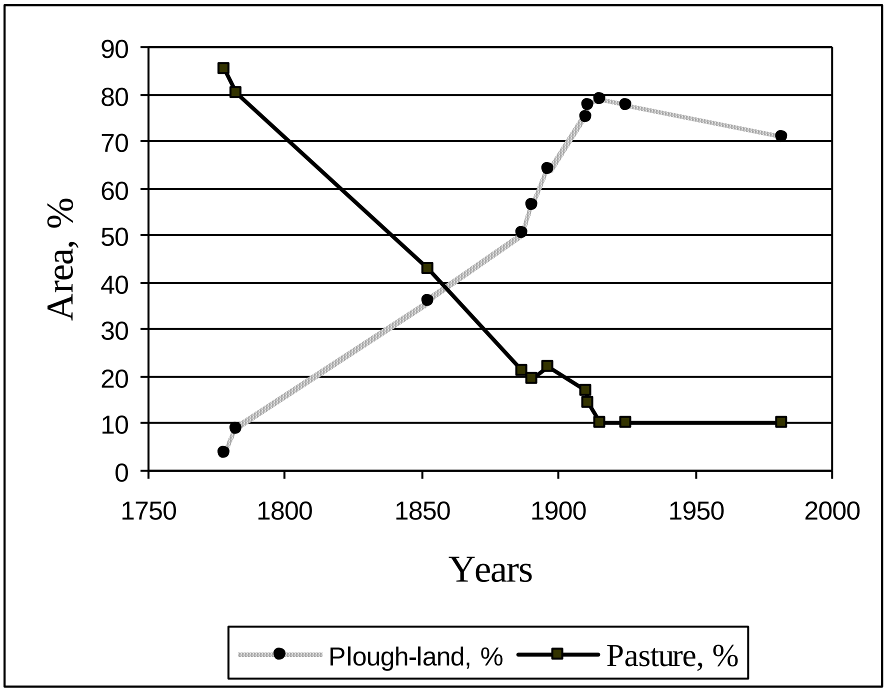


Fig. 3. Dynamics of area proportions of arable land and natural grasslands on the territory of Kherson uezd (region).

Cattle-breading (breading of sheep, oxen, and other domestic animals) predominated over agriculture until the 1930s. Ploughing up maximum value was observed in the period between 1830 and 1850 (from 10-30% to 75%).

Cattle pressure per 100 hectares of lands having existed by the middle of the 19th century in Kherson province (table 2) was typical for other territories of southern Russia (Tavricheskaya and Eketerinoslavskaya provinces, Bessarabskaya region, Don Army Lands). The development of sheep breeding had specific features. Arable lands and hayfields in Kherson province accounting for 19% of its total area, and accommodated 23% of the total sheep stock (and 33% of the fine-wool sheep stock) in southern Russia (12.2 million head).

Table 2. The cattle-breading development in Kherson province in the middle of the 19th century

Year	Head per 100 ha of arable lands and hayfields

	Horses	Cattle	Sheep	Fine-wool sheep
1856	3	9	14	18
1864	2	11	10	47

By the late 19th century due to ploughing up in Kherson province pastures area reduced from 80 (in the beginning of the century) to 20 % (table 3), 1.41 x 10^6 ha.

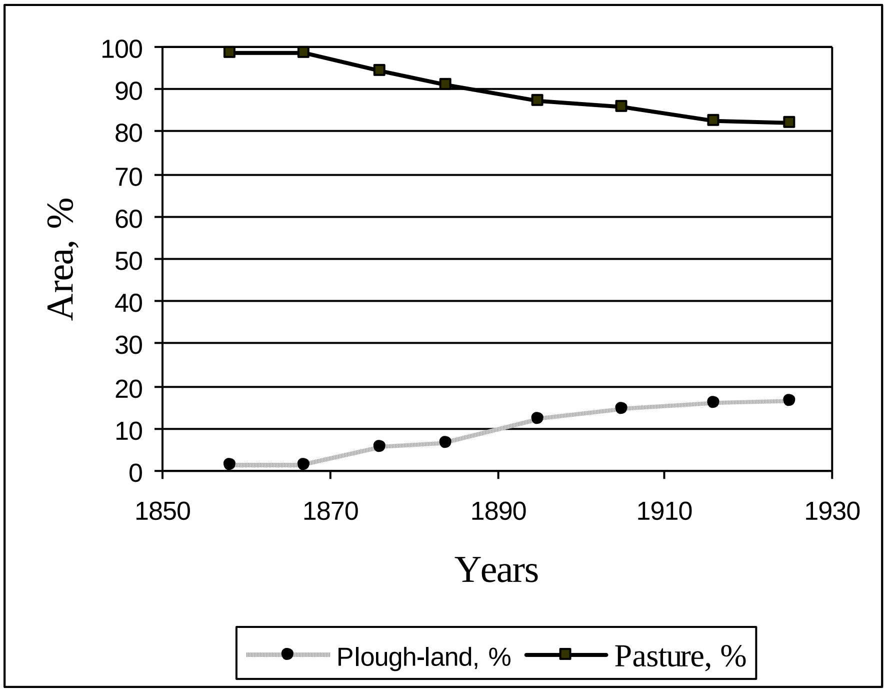
Table 3. Lands allocation in farmlands of Kherson province (Statistical-Economic Review …, 1897)

Farmlands	Territories*						
	1	2	3	4	5	6	7
Plowed land	59	47	57	65	62	64	59
Pastures	20	29	18	15	18	22	20
Hayfields	12	14	10	8	9	4	9
Virgin land	-	2	7	1	1	3	3

* 1- Aleksandriysky uezd; 2 – Ananyevsky uezd; 3 - Elizavetrdsky uezd; 4 - Odeskii yuezd; 5 – Tiraspolsky uezd; 6 – Khersonsky uezd; 7- Kherson province.

In the 19th century some large sheep farms were formed in dry steppe (annual precipitation – 375 mm). Thus, in the biosphere reserve “Askania Nova” it was decreased only 16 % of steppe pastures due to increasing arable lands at the pasture periphery (fig. 4)

Nowadays on the territory of the biosphere reserve “Askania Nova” named after F. Falts-Fein virgin steppe (11000 ha), the largest lot of guarded land in Europe, was kept.



Used data by Kovarsky, 1930.

Fig.4. The correlation between the amount of arable lands and steppe pastures on conditions that farming is extensive in cattle-breeding (e.g. “Askania Nova”).

By the end of the 19th century it was attained time equality of arable lands with natural phytocenosis,and by 1915 practical limit of ploughing up was set. Also the localization of natural vegetation in unsuitable for ploughing lands was reduced in 10 %. By the beginning of XX in Kherson province land developing by ground landlords and peasants reached 78.2/79.2 % correspondingly. Such extend of land ploughing was at high level: “among all other provinces of Russian Empire, ploughing in Kherson one takes the first rank” (Russia, 1910, V. 14, P. 263). According to summary data from table 1.4 great decreasing of hayfield areas and pasture lands (on the assumption of increasing of arable land ratio) took place in the period of 1887-1914 from 47.0 % to 12.5 %. Thus, from the end of the 19th century the maintenance of pasturable cattle breeding became impossible. From 1897 till 1912 the livestock of fine-wool sheep decreased in 70 %, other cattle – in 5-9 %. The value of grazing pressure counting on natural forage lands was changed from 0.19 conventional head per hectare in the middle of the 19th century till 1.00-1.26 head per hectare in the first decade of the 20th century (see table 4).

Table 4. The dynamics of farmland areas and grazing pressure in Kherson province in the period between the 18th and 20th centuries

Years	Land types, %			Grazing pressure, conventional head/hectare
	virgin lands	pastures	hayfields	
1774		83		-

1796	72					-
1846			36.4			-
1850-1852			11.2		38.3	0.19
1856	-		-		-	0.17
1864	-		-		-	0.29
1872			36.0			-
1881	-		45.1			-
1887		32.3			14.7	-
1890	3.8			20.8	11.3	0.38
1894	2.1			21.7	10.4	0.41
1896	3.0			20.0	9.7	-
1900		24.7			7.1	0.50
1905		20.0			7.3	-
1910		15.3			4.5	1.00
1911		13.6			3.8	1.26
1914		9.2			3.3	-
1915	-			10.0	4.1	-
1921	-			6.4	4.4	-
1925	-			19.5	5.9	0.86
1989*	0.7			10.0	0.6	-

* Modern data from 63 administrative regions within former Kherson province.

On the whole in Kherson province in the period of 1886-1900 (each subperiod – 5 years) hay-producing power on uplands was from 1000 to 1200 kg/h (Statistical Information..., 1902). According to generalized data in Kherson province virgin lands (usually used as hayfields by May, and as pastures in the years of low productivity) had average crop-producing power – 1000 (450-2550) kg/h, and under favorable conditions – 3750 kg/h. In the west sector of Black Sea steppe zone and area between Dniester and Bug rivers (Odessa uyezd), in the end of the 19th century hay-producing power in steppes depended on weather conditions: from 600 to 1800 kg/h, that is in average – 1200 kg/h (Materials ..., 1883). All these data reveal that annual bioproductivity of aboveground layer averages 1700 kg of dry mass per hectare with maximum value till 4000 kg/h, at that bioproductivity was calculated according to the correction for moisture of air-dry hay (16 %) and persisted ratio of phytomass below shear line.

Thus, at the turn of the 20th century natural herbaceous vegetation, mainly under influence of hay harvesting, provided only 36 % of aboveground layer productivity of aboriginal zone communities. As a result of requisitioning some operational vegetation output (65-75 %), average value of neogenic humus is 1.7 t/ha.

Zone growth, forming prospective coverage of soil surface within the bounds of 60-90 %, was the effective regulator of erosive soil loss in preagricultural period, as it was set equilibrium of wash up and pedogenesis rates for the range of prospective coverage from 50 till 75 % (Lang, McCaffrey, 1984).

The analysis of nature management forms connected with plant substance alienation in zonal phytocenosis allows to correct productivity changes caused by anthropogenic factor in different historical and ecological periods. It gave the possibility to describe numerically syngenetic evolution of steppe ecosystems during Holocene:

$$F_t = 2 \cdot t^{0.13} + A_0 + \sum_{k=1}^{7} A_k \cdot \sin(k^2 + f_k),$$

where F_t – vegetation output ridden on nature and anthropogenesis, t/h per year; t -dates from the absolute time scale, years; τ – time readings; A_k и f_k – amplitude and phase of fluctuation k: A_0 = 1.02, A_1 = 1.95, A_2 = 0.80, A_3 = 1.33, A_4 = 0.47, A_5 = 0.38, A_6 = 0.18, A_7 = 0.09; f_1 = -3.03, f_2 = 1.57, f_3 = -1.62, f_4 = -0.74, f_5 = -0.26, f_6 = 0.48, f_7 = 0.89 (Lisetskii, 1996).

Thus, the estimator of vegetation output changes ridden on nature and anthropogenesis for last 10 thousand years can be reconstructed sufficiently by means of calculated method through energy consumption.

SPECIES AND NATURAL PASTURES PRODUCTIVITY IN FOREST - STEPPE ZONE

Examinations of natural pastures in forest-steppe zone were carried out on the territory of Belgorod region (one of five regions in Central Black Earth zone, Russian Federation).Natural pastures average 18.66% (3995.46 km^2) from all farm lands. At present time availing natural grasslands of ravine-gully complex can only partly provide cattle stock by full and cheap fodder.

In previous years during intensive agriculture development abnormal cattle grazing contributed considerable degradation of natural communities on slopes: species was simplified, ruderal component was increased, herbaceous layer productivity was reduced a lot.

At present cattle stock was greatly reduced. Thus in comparison with 1985-1986 by 2000 the cattle abundance in Central Black Earth region (167.7 thousand km^2) was diminished on average 59.8 %, in particular smalls-93.4%. In Belgorod region smalls were reduced on 51.3%-sheep, and 94.7%-goats, in Kursk region 63.3% and 94%, in Voronezh region 57.1% and 92.3% accordingly. It contributed the reduction of anthropogenic pressure on nature communities.

Persisted unique steppe communities on small areas of gully-ravine complexes can be considered not only as pastures, but as reserves for scarce herbs conservation, entomological preserves, provider of pollinators for agriculture crops, areas for recreation. They can become the important part of steady development of agriculture production, carrying social function.

We laid some statsionars (polygons of permanent monitoring) in several nature-territorial complexes, in different kinds of biotopes. Full geobotanic examination was made.

Examination results made it clear that communities had different species saturation, above - and underground mass. On the study areas alpha diversity (species quantity per meter^2) depends on two main factors: the level of anthropogenic pressure and the area's size (table 5). The less pronounced pasture degression and more statsionar area are, the more polytypic genera are.

Plant diversities study in statsionar № 1 made it clear that average crop-producing power of aboveground mass was varied from 437 to 589 g/m^2, but underground mass – from (layer 0-15 cm) – 1121-2284 g/m^2 .

In species of pasture phytome it was emitted 8 life-forms which correspond to meadow-steppe phytocenosis. There are more herbaceous plants; they average 95.26 % from general number of species quantity. The most numerous plant group is permanent grasses – 79.47 %. The number of species index of communities under study varied from 14 to 32 species per meter^2 .

Comparison of aboveground phytomass of communities with different dominants reveals that the average in all study areas was maximum in *Caraganeto (frutexai) – Bromopsiseta (inermisi) – herbosum* communities and reached 789 g/m^2, minimum in *Stipeteto (pennati) – Festuceta (valesiaci) – herbosum* (385 g/m^2).

Harmful and poisonous plants for cattle [*Echinops ritro* L., *Chelidonium majus* L., *Vincetoxicum rossicum* (Kleop.) Barbar., *Saponaria officinalis* L., *Echium vulgare* L., *Carduus acanthoides* L, *Chamaecytisus ruthenicus* (Fisch. ex Woiosz.) Klaskova] average about 8 % from general species. It can be considered a high index. However, in this case, we can speak only about potential infestation danger as the part of harmful species is in significant in the general communities’ phytomass.

Average productivity of above- and underground phytomass in this statsionar is rather lower in comparison with another statsionars situated in dewier conditions. Great relief ruggedness of the area also influences negative on phytomass productivity.

Main species of communities typical for zonal feather-herb grass steppes were presented in another statsionar (№2).

The area peculiarity is that against a background of pasture and mowing exploitation its vegetaion is represented fully by persisted feather-herb grass communities with rich flora (197 species of highest tracheal plants) and the great part of stocked rare species which are in Red data book of Russia (this book includes rare plants and animals to be protected). On average 32 species grow per 1м^2. Study area can be a model of rational usage of natural communities in agrolandscapes (Degtyar’, Chernyavskikh, 2004, 2006).

The results of communities productivity count made it clear that the greatest above- and underground phytomass is formed by *Caraganeto (frutexai) – herbosum* communities of *Caraganeta frutexae* formation accordingly 896, 3948 g/m^2 air-dry substance. It is explained by considerable proportion of bushes.

Plants communities of statsionar № 3 are typical for ravine-gully complex. Among herbaceous communities the greatest above- and underground phytomass was formed in *Paeonieto (tenuifolii) – herbosum* community and amounts accordingly 729, 3588 g/m^2. The least phytomass in *Salvieto (nutans) – herbosum* is accordingly 528, 2299 g/m^2. 187 species of highest tracheal plants grow in them.

Plants communities of statsionars № 4 (the total area is above 1000 ha) were used strongly for cattle grazing. Plants communities of pastures were exposed to strong exploitation by a man.

Grasses in cut varies from 18.2 to 36.5 % by mass of air-dry substance, legumes – from 9.5 to 18.0 %, all the rest is mixed herbage. The portion of weed, harmfull and poisonous species in dry mass of herbaseous layer varies from 12 to 23 %.

Species saturation of communities varies from 18 to 24 forms per meter^2. Average size of aboveground phytomass in the statsionar is 686 g/m^2 of air-dry substance and varies from 631 to 708 g/m^2 (it depends on a tract). The maximum yield of aboveground mass was supplied by communities with great part of *Medicago falcate* L.

Statsionar № 5 is of interest as crucial model area situated in the dewier conditions. Plant communities of this territory are represented by meadow and northern steppes. Maximum phytomass is formed by communities with predominance of tall-growing grasses, sage and mixed herbage. Cut weight of mixed herbage communities is different and depends on edificator. Communities have high species saturation (26-30 species per $meter^2$), the total amount of vascular plants species is 112.

Estimation of how species variety influences the productivity elements of steppe pastures in ravine-gully complexes was fulfilled by methods of correlated analysis and multiple regression. It was ascertained the tendency when increasing of above- and underground mass correlation depends on increasing of species saturation, that is subject to weak, medium and vigorous correlations (r = 0.409....0.838 in different statsionars). Another tendency is that the increasing of underground mass is up to growing of species saturation of communities (r = 0.411...0.732).

Evaluation of study factors influence: alpha-diversity and beta-diversity (species quantity in a statsionar) on sizes of above- and underground phytomass made it clear that these indexes depend on alpha-diversity (60-93.4 % of total dispersion).

To a greater extent species diversity influences the size of uderground phytomass, and to a lesser extent aboveground phytomass depends on species diversity.

In this connection it is essential to estimate influence of communities with the same dominant on productivity of species saturation in details. Rather often just dominant has strong influence upon community growth and development. Knowing the mechanisms of productivity formation in homotypic natural communities gives the possibility to forecast the behavior of anthropogenic formed phytocenosis. For studying it was chosen communities predominated at different stages of succession: *Stipeteta (pennati), Bromopsiseta (inermisi), Elytrigieta (repensi)* and *Salvieta (nutansi)*. As in the case of regressive models, the increasing of aboveground mass in feather grass communities is evident under increasing of species saturation to 17-19 forms per $meter^2$, but then it began decreasing when species quantity is growing. At the same time stable decreasing of underground mass and the correlation of above-and underground mass of plants communities takes place when species saturation is increasing.

Table 5. Phytomass of herb-grass (meadow-steppe) and herb-bunchgrass steppe communities of pastures within gully plantings and their species saturation (average data for 2004-2008)

№ Statsionar	Area of planting, km^2	Communities dominants	SD, specie per $meter^2$	Total species amount	Total sorts amount	Phytomass of air dry substance			Correlation R/F
						F, $г/m^2$	R, $г/м^2$	F+R, $г/м^2$	
1	32	*Stipa, pennata, Salvia nutans, Poa pratensis, Elytrigia repens, Bromopsis inermis*	19	205	98	575	2069	2644	3.5
	3.6	*Bromopsis inermis, Stipa, pennata, Poa pratensis, Caragana, frutexae,*	17	164	68	546	2175	2721	4.0
	20	*Stipa, pennata, Salvia nutans, Poa pratensis, Bromopsis inermis,Calamagrostis erigeios, Cytisus austriacus*	23	166	124	515	1599	2114	3.1
	72	*Stipa, pennata, Bromopsis inermis, Salvia nutans, Festuca sulcata*	17	175	72	570	1916	2487	3.3
	11.1	*Stipa, pennata, Bromopsis inermis, Elytrigia repens, Salvia nutans, Calium verum*	18	163	93	589	2284	2873	3.8
	6	*Bromopsis inermis, Salvia nutans, Stipa, pennata, Medicago falcata, Festuca sulcata*	23	194	135	437	1121	1558	2.6
2	3.2	*Stipa, pennata, Galium verum, Salvia nutans, Bromopsis inermis, Stipa, pennata Salvia*	32	197	129	696	2299	2995	3.2

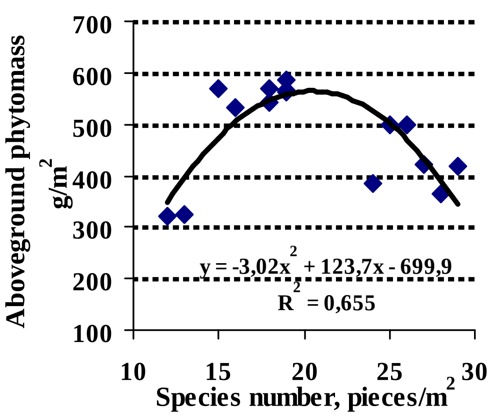
		nutans							
3	1.8	*Bromopsis inermis, Elytrigia repens, Poa pratensis, Trifolium montanum*	14	123	75	370	802	1172	2.1
	3	*Stipa, pennata, Salvia nutans, Bromopsis inermis, Caragana, frutexae*	26	187	121	324	874	1203	2.7
4	3	*Poa pratensis, Agrimonia eupatoria, Salvia nutans, Medicago falcata, Bromopsis inermis, Galium verum, Achillea millefolium*	22	167	83	694	2408	3102	3.6
	6	*Galium verum, Bromopsis inermis, Festuca sulcata, Elytrigia repens, Medicago falcata, Salvia nutans, Agrimonia eupatoria*	22	184	92	708	1744	2466	2.6
	4	*Agrimonia eupatoria, Festuca sulcata, Salvia nutans, Bromopsis inermis*	21	170	78	631	1664	2295	2.9
5	4	*Bromopsis inermis, Salvia nutans, Stipa, pennata, Elytrigia repens, Leucanthemum vulgare*	28	112	85	498	1363	1861	2.9
Average			22	170	96	550	1717	2269	3.1
LSD_{05}			4	19	19	94	443	528	0.4

Notes: SD – species saturation; F –aboveground phytomass ; R –underground phytomass in layer 0-15 cm.

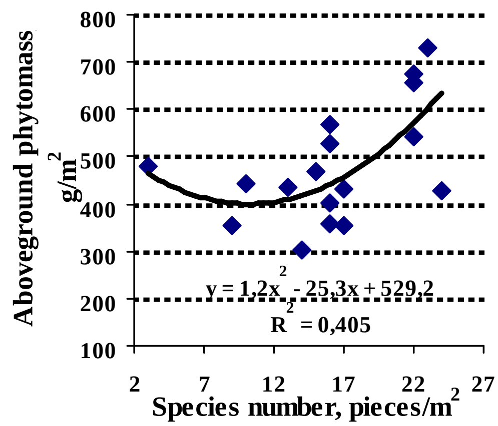
The results of mathematical analysis and building models made it clear that interdependence between species saturation and main data of productivity are described with high confidence by polynomials of the second power (fig. 5).

Domination of *Stipa pennata* L. is typical for climax communities. In this case there is the most stable accumulation of above- and uderground phytomass. Communities aim at monodomination *Stipa* – uderground phytomass is large, fullness of ecological niches in underground sphere is rather high (first of all it is connected with the distribution of resources which are in minimum: usually they are moiature and nitrogen), topsoil aeration, quite the contrary, is low. The great number of dead plant residues is cumulated in underground sphere; availability of feed elements is low, as their basic mass is concentrated in organic matter. The system is an abandoned condition. High density of herbaceous layers is typical for associations *Stipetum (pennata)* with small species quantity. New species intussusception into such community is unlikely.

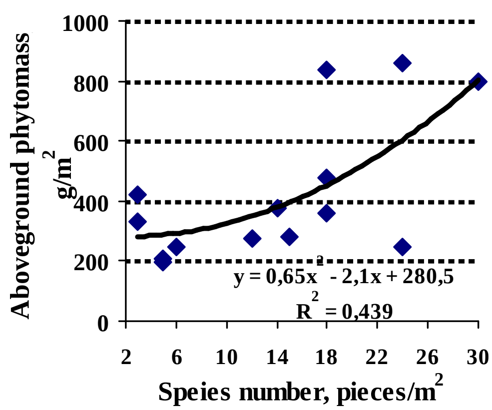
High species saturation is typical only for thinned herbaceous layers. Species saturation increasing happens due to the species having low phytomass, such as ephemers and ephemeroids but they use well spring moisture from soil.



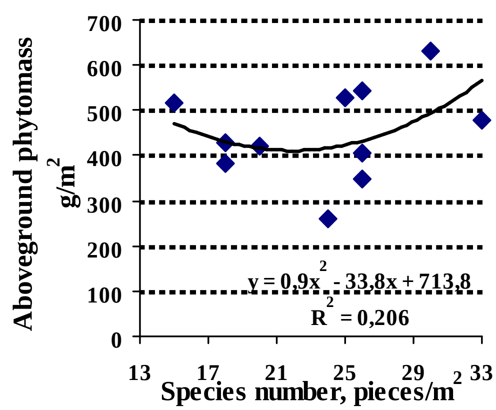
Associations *Stipetum (pennata)*



Associations *Bromopsisetum (inermis)*



Associations *Elytrigietum (repens)*



Associations *Salvietum (nutans)*

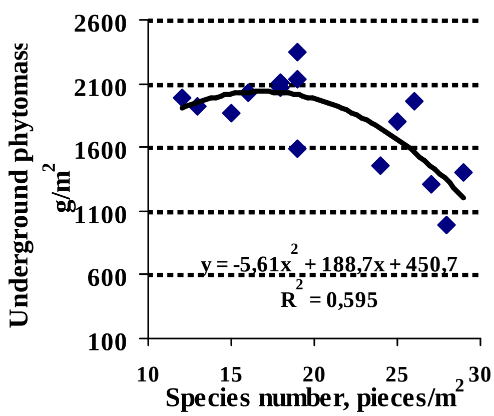
Figure 5. Correlation between species saturation (species per m^2) and aboveground productivity of natural pastures with diferent dominats of plant communities.

Our research made it clear that high species saturation is typical just for southern steppes with pronounced lack of moisture in little used territories. Species saturation increasing influences somehow different on above- and underground productivity of communities which were used as pastures or/and hayfields before.

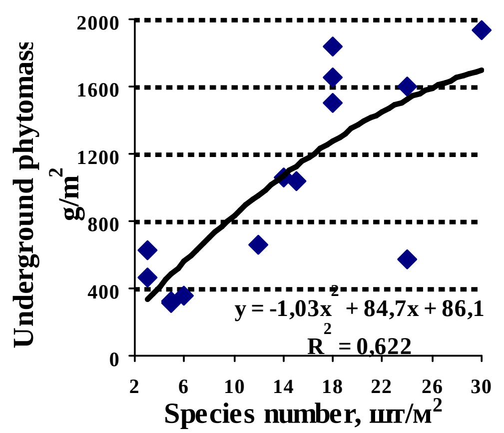
We made the analysis of associations with rhizomatous formers of cenosis (*Bromopsis inermis* Leyss. и *Elytrigia repens* (L.) Nevski), and also with stalky-root ones (*Salvia*) having maximum structural similarity with sown cereals-legumes herbaceous layers. Correlations between species diversity and basic elements of bioproductivity in all these communities are well described by polynomial of the second order, as also in the case with feather grass communities.

However, in this case the tendency is absolutely opposite: species saturation increasing forwardes underground mass rising. Another trend is there is also aboveground mass increasing and correlation between above- and underground mass. Besides it is to the same extent significant for associations *Bromopsisetum (inermis)* and *Elytrigietum (repens)*. This correlation is most evident in communities at the early phases of succession which is propagated on defective soils. In that case introduction even some plant species and small species diversity can sudden enhance first of all underground phytomass and then aboveground one. The correlation of above- and underground mass is a more dynamic quantity and is weakly subject to forecasting.

Increasing of species saturation causes the growth of competition between above- and underground spheres which stimulate the differentiation of ecological niches. Rate of soil infilling with rootages grows. Under these circumstances significant number of labile organic substance as root remains in oil is accumulated and humus formation is forwarded.



Associations *Stipetum (pennata)*



Associations Bromopsisetum (inermis)

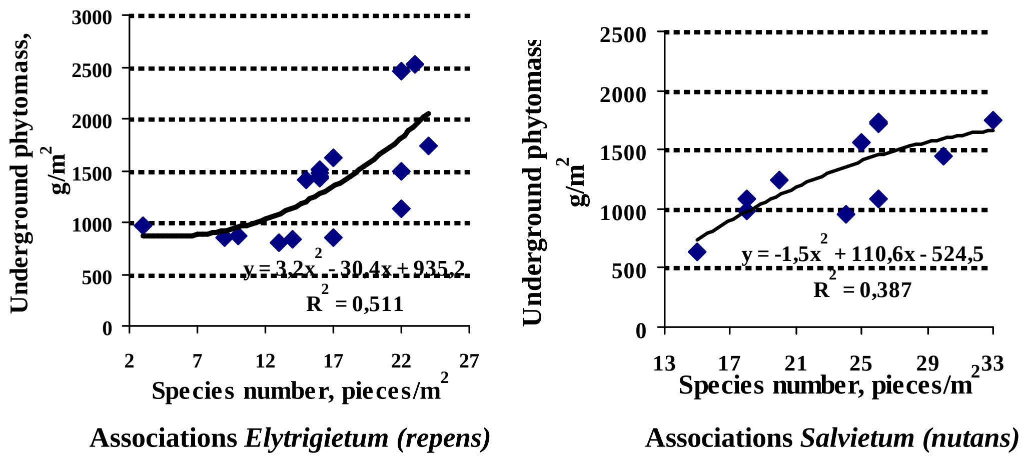


Figure 6 – correlation between species saturation (species per m^2) and underground productivity of natural pastures with diferent dominats of plant communities.

Associations with *Bromopsisetum (inermis)* on slopes is typical for more mature plant communities prevailing on more serotinous succession stage, species infilling is already at a high level and they began to compete with each other for resources. Moreover such conditions are favorable for free intussusception of species into communities. High-rate mineralization of labile substance of plant residues forwards infilling process of numbers of accessible forms of feeding elements and becoming additional ecological niches in plant communities.

Salvieto (nutans) – herbosum communities taking sizeable territories are of special interest. These communities have wide biodiversity, bioproductivity and feeding value. They can be considered as climax communities along with feather grass steppes (fig. 6).

Association *Salvieto (nutans) – herbosum* is similar to considered before one *Stipetum (pennata)* according to correlation between species saturation and elements of bioproductivity. But correlation between aboveground phytomass accumulation and species quantity per m^2 has not been determined. There is weak correlation of this index with underground mass. It is connected with intensive competition inside these communities in both aboveground and underground spheres.

DYNAMICS OF PASTURE ECOSYSTEM PRODUCTIVITIES AS RELATED TO CLIMATIC CHANGES

Researches were conducted in Kominternovskii District of Odessa Region (at state farm “Odesskii”), from 1981 to 1995. The representative test area chosen for observations on pasture productivity (46.6 ha) is located 5 km northeast of the city of Odessa and 8 km from the Black Sea coast. This area is characterized by an arid climate (with a precipitation–evaporation ratio of 0.45–0.48) and considerable variation in bioclimatic parameters. According to long-term data, the difference between the total amounts of precipitation in the wettest and driest years is 2.5- to 3-fold in the steppe zone near Odessa weather station and 3.45-fold within the Odessa city limits. Some years may be extremely arid. In 1921, for example, the amount of precipitation was only 192 mm, while evaporation reached 800 mm, with their ratio being 0.24.

The study region is close to a weather station, which allows a more detailed analysis of the relationship between productivity and climate.

The aboveground phytomass of herbaceous plants was estimated in sample plots (25 x 25 cm) in four to six replications, with each sample being dried in a thermostat to determine its absolutely dry weight. The relative error of means for green phytomass ranged from 9 to 13%, it increased to 18% only in grazing period. In the case of dead plants and litter, this error varied more widely, increasing to 20–30% at the peak of grazing pressure.

The study area is in the geobotanical province of xerophytic mixed herb–sheep's fescue–feather grass steppes on dark chestnut soils and southern residually alkaline chernozems. The botanical composition of the herb–grass phytocenosis was rather diverse: the number of flowering plant species found in 1- sq m plot reached 25–34 in May and June, decreasing to 8–19 between July and September. Grasses such as *Festuca valesiaca Gaud., Koeleria cristata (L.) Pers., and Poa bulbosa L.* are chiefly dominant. Vegetation on the bottoms of gullies cutting through the slope included a large proportion of mesophytes: *Alopecurus aequalis Sobol., Elytrigia repens (L.) Nevski, Carex stenophylla Wahl., and Poa angustifolia L.* In some years flowering feather grass *(Stipa capillata L).* in late summer accounted for up to 59% of the total phytomass. Other feather grass species *(S. lessingiana Trin. et Rupr. And S. ucrainica P. Smirn)* occurred mainly on gully slopes, with the amount of green phytomass reaching a peak of 2434 kg/ha (with dead plants, 3614 kg/ha) between late April and June.

In spring (April and May), a considerable role belonged to *Crinitaria villosa* Cass., *Euphorbia seguieriana Neck., Linum perenne L., Medicago lupulina L., Veronica seppacea Kotov, Jurinea mollissima Klok.,* with *Potentilla patula Walsf., Astragalus pubiflorus DC.,* and *Salvia nutans L.* being less widespread. The proportion of wormwood *(Artemisia austriaca)* to the total aboveground phytomass did not exceed 10%. Beginning from the second half of summer, the contribution of wormwood in areas exposed to different grazing pressure increased to 20–90%. The improvement of the phytocenotic role of wormwood identifies the tendency to steppe desertification. The proportion of animal feces in the litter varied from 12.3 to 23.2% (120–340 kg/ha).

Biotopes partly with steppe vegetation located on gully slopes have not only definite economic influence; they are refugium for rare and endangered species. In the study area it is recorded that on ravine slopes cutting gully slopes blackthorns found, which protect *Adonis vernalis L.*, on terrace edge *Iris pumila L.* found.

The pasture functioned continuously for the past 200 years. In the 20th century the study area belonged to Kryzhanovskoy state farmland, the total area was 7825 ha. As reported in general land-surveying plans (in the 1820s) plowed farmland reached 3.7 %, hayfield area was 79.4 % (explicite pastures of that period were not identified). According to statistics (in 1882) the portion of hayfield with pasturage ("tolock" – pounded land) reduced to 33%, hayfields - to 14 % of the total area while arable land increased to 62 %.

Let us consider dynamics of the proportion changes for steppe pastures in land structure and estimation of their productivity on vaster territory for northern Black Sea basin.

The steppe grass stand, both natural and seminatural (transformed to different degrees under the effects of grazing digression and hay harvesting), lost its former economic significance during a short historical period (60 years) from the mid-19th to the early 20th century (Table 1).

In 1864, arable lands and hayfields in Kherson province exceeded 5 x 10^6 ha, accounting for 19% of its total area, and accommodated 23% of the total sheep stock (and 33% of the fine-wool sheep stock) in southern Russia (Tavricheskaya and Eketerinoslavskaya provinces, Bessarabskaya region, Don Army Lands). There were 14 head of ordinary sheep and 18 head of fine-wool sheep per 100 hectares of arable lands and hayfields, in 1856, compared to 14 and 18 head, respectively, in 1864. However, this agricultural practice radically changed already in the 1860s, especially in small farms: livestock breeding was reduced to a minimum, giving way to extensive grain husbandry (Postnikov, 1891).

Depending on weather conditions, virgin lands were used either as hayfields or as pastures. Tolock (pounded land) was called a pasturage located near inhabitants. The yielding capacity of hayfields on virgin lands varied from 450 to 3750 kg/ha. In general, farmers obtained 360 kg of hay per hectare from virgin lands, 520–730 kg/ha from fallows (depending on their age), and 1120 kg/ha from meadows (Economic-Statistical Review … 1891). In 1896, hay yield from virgin lands in some districts of Kherson province reached from 37 to 59 poods (17 kg) per dessiatina (2.7 acres), that is 560–880 kg/ha (Statistical-Economic Review … , 1897). In Odessa district, hay yield from three- to eight-year-old fallows averaged 600 kg/ha in unfavorable years, 1200 kg/ha in ordinary years, and 1800 kg/ha in favorable years (Materials …, 1883); between 1888 and 1890, hayfields yielded 410–600 kg/ha; in 1896, fallows yielded 360– 450 kg/ha.

Pastures and remaining virgin lands in Odessa district (9341 sq km) accounted for only 10.4% of its area by 1910 (Statistical-Economic Review …, 1911).

In Kominternovskii district (1500 sq km) located between the Tiligul and Kuyalnik estuaries pastures and hayfields covered 17% of its total area in the late 1950s. Today, when agricultural development of the region has reached its limit, this proportion is only 9%, or 11% of all farmlands.

Statistical data obtained in the 19th and early 20th centuries can only provide a vague idea of long-term average productivity of grasslands. There are no annual data for pastures and grasslands productivity. However, long-term observations for yielding capacity of main crops are available.

Natural and seminatural grass stands under soil-climatic conditions of the steppe zone yielded up to 900–1200 kg of hay (760–1010 kg of dry phytomass) per hectare without any agrotechnical measures.

Let us consider specific features of the production process in a pasture according to the results of studies in the stationary test area. In the period of more or less regular observations (1981–1990) and, for comparison, in subsequent years with different socioeconomic conditions (1991, 1992, and 1995), 437 measurements of phytomass were made.

Its values in the pregrazing period varied markedly over 13 years, with the coefficient of variation in the maximum value (over 12 years) reaching 39.7%.

A considerable proportion of feather grass in the pasture was recorded in only a few years. In such cases, the maximum yield of green phytomass reached 1800 kg/ha, whereas under usual conditions when sheep’s fescue was dominant this parameter averaged 1500 kg/ha over 12 years.

An annual growth was calculated according to changing capacity of seasonal phytomass of active and latent roots. The activity of roots regeneration was calculated according to Dalman (1968).

The maximum phytomass value reached 1530 kg/ha, the mortmass of aboveground layer (grass plants and litter) averaged 1450 kg/ha, the annual amount of root attrition was estimated at 700 kg/ha, the maximum phytomass value of roots (0-20 cm per m^2) was 5310 kg/ha, the annual values of root secretions reached 0.2 kg/ m^2, over 11 years' observations of the pastures.

By the onset of the grazing period, the herbaceous layer in the pasture consisted of grasses (79%), mixed herbage 15% (including 3% of euphorbia), and legumes (6%). An assessment of grazing pressure over the observation period showed that the pasture area per head of cattle averaged 0.9–1.0 ha, corresponding to medium values of the norm for pastures of the steppe zone.

Long-term green phytomass removal under conditions of moderately intensive grazing, accompanied by fires in some years, resulted in apparent adaptation of the grass stand to this kind of anthropogenic impact. For example, data on the period between the autumn of 1989 to the autumn of 1990 characterize the conditions of postfire recovery of the steppe phytocenosis.

It would be useful to present vertical (layered) structure of the steppe communities to compare economic calculation of pasture productivity (according to statistics) and estimated data for aboveground layer of phytomass in the stationary test area. Vertical structure of a feather grass–mixed herb association (with maximum growth value of feather grass) is characterized by the following proportion of phytomass (0.852 kg/ sqm) on the phytohorizon (cm): 0-0.9 cm (litter) – 36%; 0.9-10.9 – 39; 10.9-30.9 – 18; 30.9-50.9 – 5; 50.9-70.9 – 1; 70.9-90.9 – 1; 90.9-100.9 – 0.1; 100.9-106 – 0.01. The maximum root mass in the 0–20 cm soil layer reached 1488 g/ m^2 within a year, whereas in the 0-10 cm soil layer is 75% of the mass in the 0–20 cm soil layer (Lisetskii, 1987).

In the period of maximum development of grass stand the aboveground phytomass value with the height reaching 0-5 cm (before grazing period) is 26% of the total phytomass in aboveground layer for favorable year conditions. To estimate real productivity of the pasture in different years, the values presented in Table 2 should be reduced by 24–35%, subtracting the phytomass of the lower 5 cm plant parts. In this case, average productivity over the observation period would be 900–1000 kg dry phytomass per hectare or, at standard 16% humidity, 1100– 1200 kg/ha. These values are almost identical to those reported in the 19th and early 20th centuries, which is evidence that our observation period was sufficiently representative.

Steady grazing leads to increasing xerophytization of steppe cenosis, which is manifested in the reduced proportion of feather grass and increasing dominance of sheep's fescue and eventually leads to a general decrease in the productivity of steppes. Consequently, the input of organic matter to the soil with plant residues and the rate of humus reproduction decrease drastically, and prerequisites for soil alkalinization and deflation are created.

The annual amount of aboveground mortmass in the pasture proved to be lower than in virgin lands: 1390 vs. 2100 kg/ha, respectively.

The annual average amount of dead plants and litter was estimated at 700 kg/ha, whereas the amount of root attrition in the 0–20 cm soil layer reached 5300 kg/ha.

The dependence of productivity on meteorological parameters (Table 5) was analyzed using a continuous time series (1981–1992). Over this period, the annual amount of precipitation averaged 407.5 mm, varying in different years from 246 mm (1983) to 664 mm (1988); the annual average air temperature was 10.2°C. According to long-term data from the

Odessa–Observatory weather station (absolute elevation 42 m) generalized in 1990, the annual average air temperature was 9.9°C and the total amount of precipitation was 446 mm, including 295 mm in the warm period (April–October). Until the past 20 years, normal annual precipitation was estimated at 374 mm. On the whole, it may be concluded that the ten-year period of our field studies adequately reflected characteristic climatic features of the study region.

Table 5. Meteorological conditions during the study period

Year	Annual precipitation, mm	Precipitation in March-November, mm	Annual average temperature, °C	Average temperature in March-November, °C	Q, MJ/m^2 per year	F+M*
1980	616.4	501.9	9.2	12.4	1214.7	-
1981	558.5	393.8	10.7	14.0	1208.7	14.34
1982	327.7	260.4	10.3	13.7	780.4	29.88
1983	246.5	188.9	10.9	14.1	556.0	12.84
1984	484.2	358.8	9.9	13.4	1076.0	10.75
1985	446.6	317.5	8.2	12.2	966.3	12.18
1986	405.6	237.7	10.1	13.9	946.6	8.98
1987	348.6	257.7	8.5	12.2	801.8	20.08
1988	663.6	513.6	9.8	13.2	1290.0	24.86
1989	310.0	292.4	11.5	14.4	745.3	23.20
1990	404.0	371.0	11.6	14.6	973.4	13.20
1991	344.0	-	10.2	-	818.1	18.40
1992	350.0	-	10.3	-	833.2	26.27
Норма	374	290	9.8	13.5	-	17.92

* F+M – the mass of aboveground phytomass (green mass and litter).
Data from the Odessa-Observatory weather station

The centennial dynamics of precipitation are characterized by alternation of dry and moist periods.

The annual amount of precipitation in Odessa between 1894 and 1974 averaged 386 mm, whereas that between 1965 and 1974 reached 471 mm (Zakharzhevskii, 1979). After the especially moist ten – year period (1960-1969), the amount of precipitation slightly decreased and stabilized between 1970 and 1992. However, significant deviations from this trend were recorded. For example, monthly precipitation in June 1984 and July 1988 reached 128 and 142 mm, with the norm being 56 and 39 mm, respectively (Table 5).

By 1991 (i.e., over 109 years), only seven warm winters were recorded in the study region, including those of 1982/1983, 1988/1989, and 1989/1990. In the same period, several winters were unusually warm. A southward displacement of the trajectories of Atlantic cyclones resulted in unusual phenomena such as the rise of daily average air temperature to 10–12°C above the norm in December 1989; the midday temperature reaching 15°C on December 18, 1989 (the highest value over the past 45 years); the average December temperature of 4.6°C (0.2°C in the norm) in 1982; the average February temperature 4.3°C (–

2.0° C in the norm) in 1990; and 18.2 °C recorded in Odessa on February 24, 1990 (the highest temperature over the century).

Climatologists analyzing the data obtained at the Odessa weather station from 1894 to 1990 revealed no definite dependence between the annual average air temperature and annual precipitation. To integrate conditions of heat and moisture supply in a given year, it appears expedient to use the bioenergetic approach proposed by Volobuev (1974). He suggested to appraise effectiveness pedogenesis through function Q – annual quantity of radiation energy consumption on pedogenesis. The function Q together with multiplier of conversion into Si-system is represented as follows

$$Q = 41,868\left[R \cdot e^{-18,8\frac{R^{0,73}}{P}}\right],$$

where Q is evaluated in MJ/(m^2 per year); R – radiation balance, kcal/(cm^2 per year); P – annual precipitation total, mm.

Generalized data on the primary production quantity of basic phytocenosis in zone with moderate climate conditions (these data are determined by appropriated climate conditions, radiation balance, precipitation total) allowed to receive (Lisetskii, 1996) analytical expression of average annual vegetation output depended (according to dry substance mass – F, t/h per year) on energy consumption on pedogenesis Q MJ/(m^2 per year) as follows

$$F = 8.7 \cdot 10^{-8} \cdot Q^{2.69}, \text{¦} \pm t_{05} S_{\text{¦}} = 0.85 \pm 0.13.$$

This dependence evaluates the influence of climate factor equivalent to expenditure of energy on productivity process.

Thereupon, it is interesting to approve this approach for determining how climate conditionality influences on productivity rhythm (time development) within one natural zone, especially steppe one.

It was set negative correlation between aboveground phytomass (green phytomass and litter) in prepasture period from 1981 to 1922 and annual value of radiation energy consumption on pedogenesis (Q).

It would be incorrect to consider that the problem is in finding a direct relationship between pasture productivity and climatic conditions, since specificity of the growing period in a given year manifested itself not only in the total yield of phytomass but also in distinctive features of its regrowth after periodic removal by grazing pressure (within – year grazing period). Hence, years were arranged in series by the criterion of favorability, depending on their production potential, on the basis of data on the maximum values of aboveground green phytomass and dead parts in a feather grass–mixed herb association in the absence of grazing pressure in the 1980s (Lisetskii, 1992, updated).

In the observation period (1981–1989), a correlation was revealed between the *Q* value in the current year and the amount of phytomass in the next year (Spearman's rank correlation coefficient *R*s = 0.50). Similar calculations for the pasture (1981–1992) showed that the aboveground phytomass (including necromass) in the pregrazing period of the next year correlated with annual radiation energy expenditures for soil formation (*Q)* in the current year

(R_S = 0.58, $p < 0.001$), as estimated value t-criterion exceeds critical value Student’s t-distribution in indicated value.

A correction was made only for 1989, which was one of the worst years with respect to bioclimatic conditions: total precipitation was only 310 mm, with 94% falling from March to December. However, the previous year was favorable, with the most abundant moisture supply over the observation period. This combination of factors apparently accounted for the fact that productivity of phytocenosis in 1989 was high both in the virgin plot and in the pasture.

The most favorable conditions for plant growth in 1988 were also accounted for by relatively low summer temperatures, in addition to abundant moistening: the average air temperature between May and September (18.2°C) had the minimum value over those years. The years 1982 and 1983, least favorable in terms of climate, were logically characterized by low productivity. However, correlation analysis revealed no connection between the maximum phytomass value and the annual amount of precipitation during the observation period. A probable explanation for this fact is that a major role belongs to the conditions of moisture accumulation in the autumn–winter period of the previous year. It is also important to take into account the amount of precipitation falling before July: after this hottest month, further increase in the amount of phytomass is observed rarely.

Data on the distribution of precipitation within the year between 1980 and 1990 were used for calculating the sums of precipitation in different periods of two subsequent years: from December to April, from June to May, from July to June, and from August to July. The closest correlation between the maximum phytomass value and the amount of precipitation was revealed for the period from July of the previous year to June of the current year.

Thus, the long-term average productivity (over the past 150 years) of pasture ecosystems adapted to climatic changes in the steppe zone equals 1100–1200 kg/ha, being subject to considerable variation. The parameter more strongly correlating with annual radiation energy expenditures for soil formation (according to Volobuev) is the amount of phytomass in the pregrazing period of the next (rather than current) year. The period in which the amount of phytomass correlates with climatic parameters most closely is the period from July of the previous year to June of the current year.

THE FORMATION OF CULTIVATED PASTURES ON LOW-YIELD ARABLE LAND

As a result of frequent using some territories as arable land, natural pastures in steppe and forest-steppe ecosystems can not supply livestock farming with pasture forage. Moreover at present some natural vegetation areas in staropakhotny regions (regions where lands were cultivated at all times, from of old) are rephugiums which have kept vegetation typical for this zone, rare and precinctive species of plants and animals. It is more efficiently to use many areas as basic territories of ecological system (for example: Pan — European) rather then subject to intensive cultivation.

Forest-steppe on the territory of the Central Russian Upland has high intensity in development of erosion processes and sizeable areas of low-yield arable lands. It is evident from the experience that under such conditions it is necessary not to use intensively some arable lands but to change them into cultivated grass- grazing lands.

To make grass stand on pastures, it is necessary to sow greater species diversity of legumes on grasslands. Great results in studying of herbaceous layers macrobiosis were obtained in some scientific institutions: Williams All-Russian Fodder Crop Research Institute (Russia), experimental station in Rotamsted (G.B.), the university of state Maryland (USA) and others. It was discovered potential for vegetative renewable of longevous agrophytocenosis which were used intensively. It was revealed that, as a result of serial processes, the dominant position in longevous herbaceous layers take rootstock and loose-bunch grasses. Most of research programs were developed for rather dewy and meadow phytocenose zones with acidic and neutral soils.

Peculiar soil group is carbonate chernozems. They have some unfavourable attributes for plant growth and development: alkali reaction from the surface, carbonate excess, weak motility of phosphorous compounds and microelements, strict water schedule.

Late research proves that calcareous soil area is increased in topsoil structure of staropakhotny forest-steppe and steppe regions of Europe. It is connected with erosion processes and more considerable, than in virgin land, gradient of soil liquor tightening to topsoil, induced by intensive physical moisture evaporation (Chendev, 2007).

Under formation of longevous cultivated pastures in ecological conditions of calcareous soils, the problems of legumes stability in mixed grass crop and increasing of their productivity are of special interest.

In the period of 2002-2007 in models of gramineae-legumes pastures herbaceous layers, where main component was legumes, they study six legumes species: *Onobrychis arenaria* (Kit.) Ser., *Lotus corniculatus* L., *Medicago falcata* L., *Trifolium pratense* L., *Medicago varia*., *Trifolium gibridum* L. Legumes component in mixed grass crop consisted of: *Lolium perenne* L. pasture ryegrass (100 pieces/m^2)+*Bromus inermise* (Leys.) Holud (200 pieces/ m^2) + *Festuca pratensis* Huds (200 pieces/m^2).

Soil is typical calcareous eroded weakly chernozem, humus content before the beginning of the experiment – 3.96-4.08 %, pH_c – 7.32-7.34.

Study results made it clear that maximum ratio of legumes (*Trifolium gibridum* L. (71.4 %), *Medicago varia*. (85.6 %), *Lotus corniculatus* L. (82.1 %), *Trifolium pratense* L. (79 %), *Onobrychis arenaria* Ser.(67 %)) in mixed grass crop was in the second year of herbaceous layers existence. Maximum ratio of *Medicago falcata* L. was 43 % in the third year. Later the tendency of cereals ratio increasing was marked. By the sixth year legumes ratio in mixed grass crop together with *Onobrychis arenaria* Ser. was maximum: 28.9 %, with *Lotus corniculatus* L. (27.9 %), and it was minimum together with *Medicago varia*. (11.9 %).

Cenopopulations of being studied species are mainly represented by even-aged examples. *Lotus corniculatus* L has significant renewal of self-seeding, but *Trifolium pratense* L. and *Trifolium gibridum* L. give only solitary coming-up.

As a whole, search revealed the stabilization tendency of ratio of all legumes species in herbaceous layer,beginning with the 4^{th} year of existing at the same level (fig. 6).

In spite of its large ratio in herbaceous layer in comparison with another species, *Onobrychis arenaria* decreases dynamically its own participation relative to the initial status.

It is known that competition is relative. Competitive advantages are always exhibited against definite partners under particular environment conditions. In view of the aforesaid, common populations, according to the competitiveness extent of species, are usually divided into tree basic groups: predominant, indifferent and suppressed plants.

As a result of these interrelations, common legumes species are divided into different groups (in a qualitative sense) on the basis of some competitive aspects.

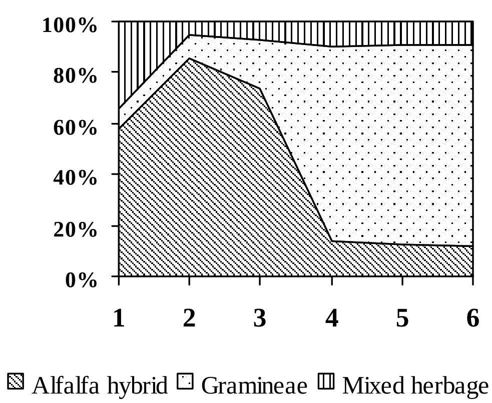
Competitive species can be stabile held in mixed grass crops for rather long period. This fact determines stabilization ratio of legumes after the fourth year of herbaceous layer existence and almost linear nature of its dynamics. It happens under pressure of ecotopic selection and competition between plants.

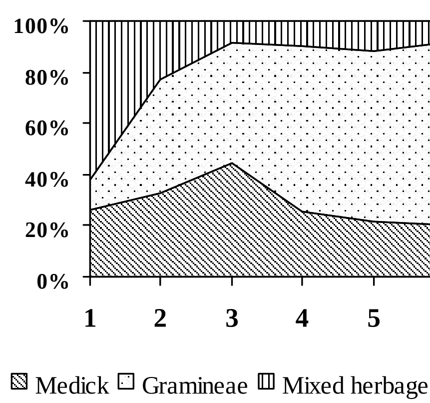
Analysis of legumes seeding done in 2002 revealed that by 2007 the ratio of therophytes or biennials in herbaceous layers *Trifolium pratense* L. was 43-54 %, but *Trifolium gibridum* L. - 58-69 %.

Studying cenopopulation *Lotus corniculatus* L. gave the same results. The ratio of therophytes and biennials in herbaceous layer was 28-32 %. In checked variant (*Medicago varia*), seminal self-reproduction in herbaceous layer was not fixed in seeding of *Medicago falcata* L. and *Onobrychis arenaria* Ser.

It was discovered the medium-strenth positive correlation between seed quantity, getting into soil as a result of self-seeding at the end of vegetation period, and ratio of permanent grasses in crops by the sixth year of existing (r=0.653).

Close correlation was fixed between seed solidity and legumes ratio in pasture herbaceous layer by the sixth year of existing (r =0.853) and rather negative correlation – between projective coverage and quantity of coming-up received from self-seeding in mixed grass crops with *Lotus corniculatus* L. (r =-0.811), with *Trifolium pratense* L. (r = -0.912) and in herbaceous layers of Alsatian clover (*Trifolium hybridum* r =-0.776). There was not such correlation in crops with *Onobrychis arenaria* (Kit.) Ser., *Medicago falcata* L. and *Medicago varia* (r =-0.123....0.231).





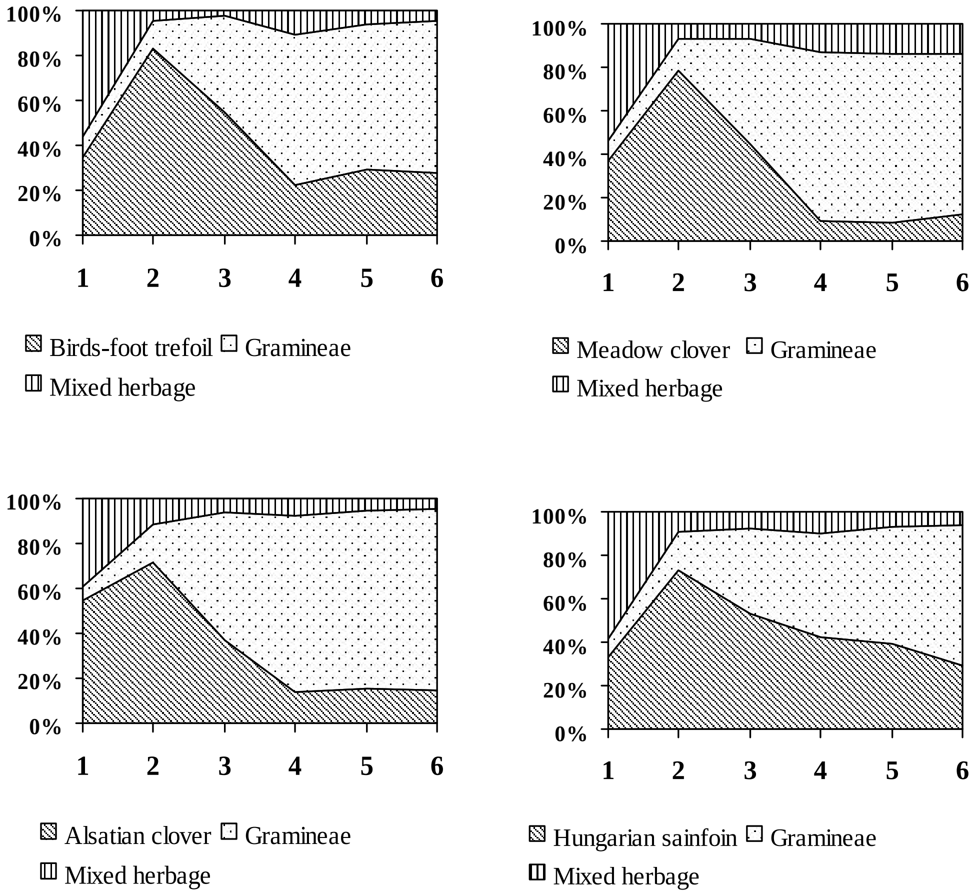


Figure 7 – ratio dynamics of different plant groups in the harvest of absolutely dry substance of gramineae - legumes mixed grass crops on calcareous eroded chernozem which was used six years in the period 2002-2007, %. Notes: 1,2,3,4,5,6 – years of herbaceous layers usage.

In 2002-2007 mixed grass crops with *Onobrychis arenaria u Lotus corniculatus* have the most crop stability (Table 6)

Table 6. Yield of pasture mixed grass crops with different species of legumes on calcareous chernozem, t/ha absolutely dry substance

№	Legume component of mixed grass crops	Year for study						Average
		2002	2003	2004	2005	2006	2007	
1	*Medicago varia*	1.07	4.86	5.90	4.23	2.73	1.86	3.44
2	*Medicago falcata .*	1.04	3.74	4.03	4.29	3.36	2.45	3.15
3	*Lotus corniculatus .*	1.20	5.22	5.90	4.90	3.47	2.67	3.89
4	*Trifolium pratense .*	1.06	5.20	3.57	2.06	1.88	1.63	2.57
5	*Trifolium gibridum .*	1.49	5.07	3.72	2.12	1.07	1.02	2.41
6	*Onobrychis arenaria*	1.09	5.07	6.46	5.05	4.14	3.64	4.24

LSD $_{05}$	0.16	0.59	0.70	0.60	0.36	0.33	

Average for six years, the largest gather of feed units (3329 kg/ha) was provided by mixed grass crops with *Onobrychis arenaria*, the smallest – with *Trifolium pratense* (2242 kg/ha) and *Trifolium gibridum* (2239 kg/ha).

Within the bounds of experience, Hungarian sainfoin crops in mixed grass crops allowed to gather maximum quantity of fat (142 kg/ha), free-nitrogen extract (1895 kg/ha), ash (322 kg/ha) supplying feed unite with digestible protein 128.8 g. As the control, mixed grass crop with Medicago varia yielded these indices to mixed grass crops with *Lotus corniculatus* and *Onobrychis arenaria*.

As a whole, search revealed hard positive correlation between content of easy hydrolyzable nitrogen in soil and gather of digestible protein (r =0.876), between legumes ratio in crops and gather of digestible protein (r =0.776), between crop-producing power of dry substance and legumes ratio in mixed grass crops (r =0.854).

There was positive correlation of medium strength between pH_{KCl} quantity and gather of digestible protein (r =0.546) in mixed grass crops with *Onobrychis arenaria*. Such close correlation was not observed in other plantings (r =-0.246....0.123).

CONCLUSION

The analysis of land management forms connected with plant substance alienation in zonal phytocenosis allows us to correct productivity changes caused by an anthropogenic factor in different historic and ecological periods. This fact permits us to restore plant product changes (for the last 10 000 years) caused by natural and anthropogenic parameters due to calculation method of radiation energy consumption. Thus, the new approach prospects are well founded. According to this approach, the function of time changing in the zonal ecosystem productivity is described mathematically. This function reflects the periodicity of climatic processes and anthropogenic impact.

The long-term average productivity (over the past 150 years) of pasture ecosystems adapted to climatic changes in the steppe zone equals 1100–1200 kg/ha, with the coefficient of variation reaching 40%.

It is determined that the traditional approach in finding a direct relationship between pasture productivity and climatic conditions is unproductive. Specificity of the growing period in a given year manifested itself not only in the total yield of phytomass but also in distinctive features of its regrowth after periodic removal by grazing pressure (within – year grazing period). Years were arranged in a series by the criterion of favorability, depending on their production potential, on the basis of data on the maximum values of aboveground green phytomass and dead parts in an association in the absence of grazing pressure.

The parameter more strongly correlating with annual radiation energy expenditures for soil formation (according to Volobuev) is the amount of phytomass in the pregrazing period of the next (rather than current) year. The period in which the amount of phytomass correlates with climatic parameters most closely is the period from July of the previous year to June of the current year.

It is defined that species diversities value influences productivity of herb-grass and herb-bunchgrass communities of pastures within gully plantings. Alpha diversity is more dominant: the more diversity, the more aboveground phytomass. Beta-diversity has less impact on bioproductivity due to relative uniformity of soil and ecological conditions.

Under formation of cultivated pastures grass stand in calcareous eroded chernozems in forest-steppe longevity is formed by gramineae-legumes mixed grass crops on the bases of *Onobrychis arenaria* and *Lotus corniculatus*. The use (for six years) of mixed grass crops with *Onobrychis arenaria* yields 4510 kg/ha of dry substance, *Lotus corniculatus* – 3910 kg/ha. Under these conditions, crops of *Medicago varia, Trifolium pretense, Trifolium gibridum* can be effective when they are used no more than 3 years. The competitive influence of crop grasses in relation to legumes in calcareous eroded chernozem is higher if the portion of phosphorus and nitrogen amassed in legumes rhizosphere in relation to surrounding soil is more and pH_{KCl} of soil solution is lower. The rhizosphere of *Onobrychis arenaria* is characterized by reduced portion of total nitrogen in comparison with surrounding soil, the absence of differences in phosphorus portion and increased $pH_{KCl.}$ All these facts determine high stability of this planting in mixed grass crops in calcareous chernozem.

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