Monitoring the state and ecological ameliorative effect of tree and shrub coulisse and row plantings on pastures in the arid conditions of the northern Caspian

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Abstract. The paper summarizes results of long-term observations of the state of roadside tree and shrub plantings of Ulmus parvifolia, Tamarix ramosissima, Calligonum aphyllum and Haloxylon aphyllum in the arid conditions of the Northern Caspian. All said species show high survival on sandy loam soils, are drought-resistant and long-living (40 and more years). Studies have shown ecological and ameliorative effect of plantings on the vegetation cover of adjacent pastures and protection of the route Astrakhan-Volgograd from sand drifts and snowstorms of East and South-East directions.

1. Introduction

On the territory of the arid zone of the country one of the most important tasks in the field of scientific provision of steppe and protective afforestation is the improvement of methods and techniques of arrangement, increase of longevity, environmental, agricultural and utilitarian efficiency of planted forestations [1-9]. The arrangement of forestations in the semi-desert zone is extremely complicated because of soil salinity, insufficient soil and air moisture, high summer temperatures, and other specific unfavorable factors of the arid climate [10-16]. The greater part of the territory of the Astrakhan region is located in the arid zone with unstable and not really usable vegetation cover. Roadside tree and shrub coulisse and row forestations affect wind and hydrological regimes of the area, fulfill ecological function of protecting the highway from storm winds and snowstorms, sand drifts during the warm period, providing at the same time a positive impact on vegetation of desert pastures [17, 18]. The aim of the study is to determine the actual state of tree and shrub coulisse and row forestations for the 40-year period and to assess their ecological and ameliorative impact on pastures of semi-desert.

2. Materials and methods

The research was developed in a coulisse and row forestation planted by a forest reclamation station in 1977 along the Astrakhan-Volgograd highway from the side of semi-desert at an angle of 40-90 ° of...
NE-SE winds ("Kharabalinsky" site). The forestation starts from the northern part of the city of Kharabali, its length is 4 km, width 74 m, area 30 hectares, distance from the road 20-25 m. The protective forestation includes 3 pasture-protective and forage strips (PZKP) and 4 rows of *Ulmus parvifolia*. Planting scheme: PZKP - 7 m (*Ulmus*) – 5 m (*Ulmus*) – 7 m PZKP – 7 m (*Ulmus*) – 5 m (*Ulmus*) – 7 m PZKP. Species composition of PZKP: rooted cuttings of *Tamarix ramosissima*, seedlings of *Calligonum aphyllum* and *Haloxylon aphyllum*. The shrubs were planted with in-row spacing of 1.5 m, spacing of 4 m between rows, and edges of 2 m. The pre-sowing soil cultivation was conducted in autumn of 1976 as an entire plantation plowing to a depth of 40-45 cm. The shelterbelts were planted in spring of 1977 by three forest-planting machines SLCH-1 and a tractor DT-75M. The distance between shelterbelts is 20 m. In autumn of 1977 the soil was cultivated for planting of small-leaved elm seedlings with the tractor K-700 - a partial beardless plantation plowing of the 2-meters rows to a depth of 40-45 cm, and with a subsurface deep tiller cultivator KPG-250.

In spring of 1978, the 4 rows of *Ulmus parvifolia* seedlings with inter-row spacing of 1.5 m were planted in the cultivated rows by the tractor MTZ-75 (Belarus) equipped with forest-planter SLCH-1.

Geomorphologically, the research site is the Late Khvalynsky sea plain, complicated by Baer’s Knolls and aeolian relief forms (ridge, dune semi-fixed sands). The surface is a drainless weakly undulating plain with a slight slope from northwest to southeast with a developed meso- and microlief. Groundwater is confined to the water-bearing complex of the Khvalyno-Khazar sediments with a total capacity of 45-50 m. The thickness of the first water-bearing horizon is 14–17 m. The hydrophilic rocks are small sands, less commonly dust. The depth of groundwater levels varies from 5–10 m in inter-hill depressions, up to 10–15 m on Baer’s Knolls.

The water-bearing horizon is supplied by precipitations – up to 200 mm yearly. According to the degree of mineralization, groundwater is saline (8-10 g/l) and prevailing very saline one (10-22 g/l).

The soils are brown in a complex with half-grown sands and the participation of solonets up to 25 % or more. The main genetic characteristics of brown semi-desert soils are determined by the specificity of the conditions of their formation, in particular, by the arid climate and low productivity of vegetation. A small amount of precipitations and high temperatures determine the short duration of the processes of formation and development of humic substances. Low humus content and low thickness of humus horizons are characteristic features of brown semi-desert soils [19]. Winds of all directions are registered throughout the year, but east and south-east winds prevail. Storm winds are often registered at a speed of 20-24 m/s. This results in sand-drift of roads during warm seasons and in snow-drift in winter.

### 3. Results and discussions

The survival and safety of *Ulmus parvifolia* seedlings in the first year of growth were at least 80-70 %. The average survival in the PZKP planting of 1977 was 60-70 %. The atmospheric precipitations contributed to plants survival and conservation, since in the year of 1978 the amount of precipitations exceeded the average long-term values in 1.7-1.8 times (more than 250 mm of precipitations for the period from April to August), soil moistening along the profile reached 2 m. Inventory of crops in 1978 confirms the favourable conditions of the said year which provided high survival and safety of the studied shrub species by all types of soil cultivation. The soils under the plantings are brown sandy, typical of the Astrakhan semi-desert zone. Exploratory observations of 2013–2017 showed that the current state of the coulisse and row plantings was unsatisfactory, being the result of mismanagement of the 90s and early 2000s, that was the cessation of planting care, the systematic grazing of plantings by cattle (cows, sheep, goats, horses, and camels), *Haloxylon aphyllum* break down, poaching damage of valuable pasture grasses (*Kochia*, *Camphorosma*, and other species).

There was a gradual violation of the integrity of the structure of the multi-layer phytocenosis (Table 1). By the age of 40, the state of most of the species studied has deteriorated primarily due to soil compaction and grazing of cattle (especially goats). The average yearly nominal growth of shrubs in height is 3-4 cm.
Table 1. Taxation indicators of shrubs of 40 years of age in the pasture protective and ameliorative forage shelterbelt

| Woody species          | Baer’s Knolls | Inter-Knoll depression |
|------------------------|---------------|------------------------|
|                        | conserv %     | height, m               | diameter, cm | increase in height, cm | crown diameter, m | conserv %     | height, m               | diameter, cm | increase in height, cm | crown diameter, m |
| *Haloxylon aphyllum*   | 32            | 1.8                    | 13           | 3.7                    | 1.2               | 35           | 2.0                    | 15           | 4.3                    | 1.3               |
| *Tamarix ramosissima*  | 64            | 1.5                    | 7            | 2.9                    | 1.9               | 56           | 1.3                    | 5            | 2.3                    | 1.8               |

*height was measured only in healthy shrubs; in the numerator are indicators of 2013, in denominator - indicators of 2017.

*Ulmus parvifolia* fell by 98 % on the Baer’s Knolls, as a result of systematic grazing and lack of available soil moisture, the *Ulmus* planting was optimal 1000 pcs/ha. In 2013, the conservation of *U. parvifolia* was 5 %, the mean height 1.2 m, the mean diameter of the trunk 5-6 cm. The conservation of *U. parvifolia* in inter-knoll depression reached 18-25 %, mean height 11.9-2.0 m, mean diameter of the trunk at a height of 1.3 m 10-11 cm, the width of the crown of trees 1.9-2.2 m. In recent years, *Calligonum aphyllum* began to fall out, although the moisture supply of crops is higher than in an open pasture. This is confirmed by snow surveys made during the winter periods of 2013-2017. In the shelterbelt after the storm winds, the snow accumulation was 3-5 times higher than on open pastures: the snow cover was 15-35 cm, and 5-10 cm on the control site. It provided additional 200-250 m³ of moisture per 1 ha of plantings when the mean compactness of snow of 0-15, 0-20.

Despite the deterioration of their state and the decrease in the conservation of the species studied, trees and shrubs continue to enrich arid pastures with valuable fodder components, increase the productivity of grasses and the capacity of lands. The positive effect of forestations in arid conditions on the growth of pasture grasses is also registered at a distance of 50-70 m from the shelterbelt. The hay yield of natural grasses in this zone is higher by 0.17–0.30 t/ha than in the open semi-desert (Table 2).

Table 2. Ecological and ameliorative effect of tree and shrub coulisse-and-row plantings on the yield of pasture grasses

| Options          | Air-dry weight, t/ha |
|------------------|----------------------|
|                  | 2013 year | 2017 year |
|                  | May      | August    | May      | August    |
|                  | total    | grazed    | total    | grazed    |
| Sheltered pasture| 0.47     | 0.28      | 0.40     | 0.16      | 0.75     | 0.34     | 0.71     | 0.28      |
| Open pasture     | 0.30     | 0.12      | 0.20     | 0.08      | 0.50     | 0.27     | 0.41     | 0.27      |

Observations over a number of years, studies on the rational use of natural forage lands have shown that coulisse-and-row plantings are an oasis of additional feedstuff. The eatable supply of pasture shrubs during the growing season, depending on the seasons of the year, provides a significant part. This is noted in studies [20, 21].
Sheep in spring willingly eat cereals (Poa bulbosa, Anisantha tectorum, Agropyron pectiniforme, etc.), motley grass (Alyssum turkestanicum, Ceratocephalus arenarius), leban (Kochia prostrata), and in the autumn sagebrush (Artemisia) and Siberian elm (Ulmus parvifolia) eaten by 80-90 %. In summer when droughty period calligonum (Calligonum aphyllum) and juicy shoots of black saxaul (Haloxylon aphyllum) are eaten up.

According to the Kharabalinskaya veterinary bacteriological laboratory, the nutritive value of young shoots of Haloxylon and one-year branches of U. parvifolia is not inferior to the main fodder plants of the Northern Caspian Artemisia, Kochia prostrata, Alhagi pseudalhagi, and contain in the spring-summer period: Haloxylon aphyllum 21.8-22.8 mg/kg of carotene and 85.8-57.6 g/kg of crude protein; Ulmus parvifolia 29.3-24.3 mg/kg of carotene and 58.0-91.5 g/kg of crude protein. When severe droughts Haloxylon is eaten for 65 %. In relatively favourable (average) years according to climatic standards, when the soil is wetted by 1 meter in springtime, pasture yields are satisfactory, therefore the edibility of Haloxylon is low due to the presence of alkaloids in its shoots. Haloxylon tolerates the arid conditions of the southern semi-desert. The main reason for its dying is breaking off shrubs by cattle. Therefore, in the 40-year-old planting, only Tamarix ramosissima, which is poorly grazed, is in satisfactory state. In extremely dry years it suffers from pests and diseases, as well as from fires in summer. High grazing of shrubs is associated with an almost complete absence of ephemera in spring and perennial grasses in summer, which burn down in dry spring and hot summer.

4. Conclusions
On the basis of the developed research the longevity, resistance, and necessity in arrangement of tree- and shrub plantings of Ulmus parvifolia, Tamarix ramosissima, Calligonum aphyllum and Haloxylon aphyllum in the arid conditions is shown. All said species have shown high survival on sandy loam soils and drought-resistance. Tree-and-shrub ameliorative fodder shelterbelt is itself a source of feedstuff in late summer and autumn. Research developed in 2013 - 2017 showed that when simulating the grazing of the remaining crops in the planting of 60 % of the growth of the current year (except for Tamarix ramosissima) and when planting of 2 thous. plants/ha, the stock of dry fodder mass in the age of 40 equals 0.4-0.5 kg/ha.

Consequently, the roadside multilayer tree-and-shrub coulisse-row plantings both protect the road from snow blizzards and sand-drifts and enrich desertificated pastures with valuable forage shrubs and herbs, conserve the integrity and multi-layer structure of plant communities, increase forage capacity of semi-desert. It is necessary to develop a system of agrotechnical measures and measures for managing shelterbelts, as well as to carry out their reconstruction by planting young seedlings and transplants in appropriate sites.

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