The historical and present-day forest amelioration in the Northern Pre-Caspian Region

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Abstract. The sandy lands of the Northern Caspian Sea region are a vulnerable natural landscape. Intensification of anthropogenic pressure leads to the soil cover degradation. The first mass plantations in the Caspian lowland began in the mid-19th century. However, due to the lack of knowledge about the reclamation conditions the results were unsatisfactory. Progress was made only at the end of the 19th century. In some parts of the sands (Tugai-Khuduk) individual trees have survived up to the present day. The work of forest-meliorators in the Soviet period fixed more than 200 thousand hectares of sands in the region, and also to create more than 50 thousand hectares of deflation-resistant shrub pastures. Forest is an azonal form of vegetation for this area. Based on the data obtained on water consumption by trees and shrubs, we gave an assessment of grazing protective forest strips, tree “umbrellas”, farm and reclamation forage plantations, conservation forest bioregions, boundary forest strips and sand-fortified plantations. They perform various functions. Unvegetated sands have the ability to store a freshwater lens that is no longer fed at the overgrown areas due to evaporation and transpiration costs. One hectare of open sands in the Caspian Sea can accumulate 1000-1500 m\textsuperscript{3} of water per year. The whole complex of forest-reclamation plantations on pastures in Astrakhan region occupies an area of 151 thousand hectares. Financially supported reforestation programs should be adopted at regional and possibly federal level, due to the importance of planting in many spheres of life in the area.

1. Introduction
There are more than 5 million hectares of sandy land in the Northern Caspian Sea region, including Kazakhstan. This is the most vulnerable natural landscape. Its destruction is caused by many factors. Overgrazing, ploughing, construction works lead to degradation of soil and vegetation cover and cause appearance of movable barkhan sands. The effect of anthropogenic pressure is sharply intensified during climatic anomalies associated with increased wind activity and reduced precipitation. Four periods of anthropogenic impact activation in the arid zone are quite clearly distinguished:

1. Early pastoral phase, first millennium BC;
2. The heyday of the Golden Horde Khanate (1200-1400 AD);
3. The rise of economic activity in the late 19th and early 20th centuries;
4. Intensification of pasture use, ploughing of virgin soils, development of transport means, construction works in the 1950s and 1980s.

As a rule, periods of intensive human activity coincided with xerothermal periods, so their combined action caused catastrophic destruction of sandy soils. The strongest deflation burst occurred at the end of the 19th century. In the Caspian Sea the annual increase in the area of mobile sands
amounted to 40 thousand ha. On the Don, cossack villages: Veshenskaya, Nizhnkundruchenskaya, Oblivskaya, etc., were filled up by sand. The “Ukrainian Sahara” appeared on the Lower Dnepr [1]. During the last anthropogenic pressure (1960s-80s) a European desert emerged on the Black Earth in Kalmykia and Dagestan and great efforts were required from foresters and forest meliorators to curb this unprecedented natural phenomenon.

The first mass planting in the Caspian Lowlands began in the mid-19 th century. The government allocated funds for greening these settlements and roadside planting to improve the life of the Kalmyk people. The results were poor. Trustee of Astrakhan province K.N. Kostenkov wrote: “From 1846 till 1861 130000 gold roubles were spent for forestation in Kalmykia. The results are negligible. There are a little bit more than 10 hectares remain. Obviously, the forests can exist only in the places where there is inflow of water and where the soil is freed from the influence of salts. Considering the reasons for the failure of this, very useful in principle case, it is impossible not to be convinced that everything was based on ignorance of steppe and climatic conditions, both of the people who made such a grand plan of afforestation and, later, of the executors of this plan” [2].

In 1890, however, the Forest Department returned to the Pre-Caspian. The Naryn Forestry was established on an area of more than 127000 hectares. Planting of pine and deciduous species began on the Ryn-sands in the northern part of the Pre-Caspian area. Still the preserved isolated forests of *Pinus sylvestris*, *Pinus nigra*, *Robinia*, *Elaeagnus commutata* and other species create a unique appearance of the sandy desert. They increase the anti-deflation sustainability of the area, increase the ecological capacity and the desert monotony attractiveness, provide timber and rich harvests of mushrooms [3].

The extreme droughts of 1891-1892 caused an upsurge of deflationary processes in the southern regions of Russia. The government began to establish sand- and ravine-parties, whose task was marking out areas movable sands and fastening them. The work of these parties was carried out in practically all southern provinces of Russia. The scope of the sand fastening work was enormous. In particular, in 1913 the sand fixing work covered 18.2 thousand hectares in the Astrakhan Governorate. The works involved hundreds of people. All the works were carried out by the sand- and ravine-parties in close contact with the local population. Organizational issues, obtaining planting material, selecting people for planting and security issues were discussed.

A large amount of forest planting on the Pre-Caspian sands was carried out after the famous "Nature Transformation Plan" adopted in 1948. In accordance with this plan, the Saratov-Astrakhan state forest belt was planted in the Astrakhan region. On an area of 5 thousand hectares of brown soils *Ulmus parvifolia* was planted. Since the 1960s, the region's forestry farms have been concentrating on sands fastening, where the most tangible results have been obtained. Maximum areas have been sown with *Avena strigosa*. Planting of *Calligonum*, *Tamarix* and *Haloxylon* by MLB-1 machine is used.

Owing to the work of forest reclamation specialists, 200000 ha of movable sands have been fastened in the Northern and North-Western Pre-Caspian and over 50000 ha of deflation-resistant shrub wood pastures have been created. The productivity of these lands reaches 8-12 centners/ha, which is twice as high as the native pastures productivity. New methods of sands fastening depending on relief dissection, aeolian material mass and groundwater occurrence depth have been proposed. It can be confirmed that sands fastening works provide sands fastening within 2-3 years, if it is carried out at a proper level [4].

However, despite the success of sands fastening work, the establishment of high-density forest plantations as a form of sandy land use remains an understudied issue for the Northern Pre-Caspian region. It can be confirmed that of all the thousands of hectares planted over the past 50 years, no more than 200 hectares have survived. The most valuable plots are located in the north of Astrakhan region. As a rule, these plots have root-accessible groundwater or liman irrigation. A century and a half of experience of protective afforestation in the Pre-Caspian, despite the scarcity of practical results, has allowed a fairly comprehensive assessment of the afforestation possibility in this desert zone.
2. Materials and Methods

2.1. Limiting factors

The forest is an azonal vegetation formation for the Northern Pre-Caspian (excluding floodplains). With average annual precipitation in this zone of 250 mm, only half, or 125 mm, which is 1250 m$^3$ of water per 1 ha, can be used for transpiration. An average of 1200 m$^3$ of water is needed for normal vegetation of 1 tonne of tree leaf apparatus. Consequently, the annual precipitation of the Pre-Caspian provides water for only one tonne of leaves. At the same time, a forest phytocoenosis creating a forest environment (reduction in daytime temperatures by 1-2°C, increase in relative air humidity by 2-3%) should have 3-5 t/ha of leaves in dry weight, and 6-8 t/ha in wet weight. Annual precipitation of the Pre-Caspian provides moisture only to scrub-type shrubs. High-density stands require additional water sources of 1500-2500 m$^3$ per hectare. This water can be obtained, as described above, from groundwater, local runoff, irrigation and snow accumulation.

The second factor limiting the success of afforestation is soil salinity. The typical Pre-Caspian brown desert soils aeration zone structure is characterised by leaching of the upper 100-120 cm and salinity of the lower horizons. The root system of tree species in this case spreads only in the upper horizons, and they in some years dry out completely and crops die. The rhizosphere, within the biological capacity of the tree, can also be restricted by a root-permeable screen. These can be saline soils, tertiary quartz sands, “chocolate” clays, rock formations. For arid conditions, the VNIALMI researchers proposed the following classification of forest site conditions by the depth of root-permeable screens or by the thickness of the rhizosphere [5]: the screen at a depth of 1 m—areas are non-forestable, with a screen depth of 1-2 m—conditionally forestable areas. Shrubbery can grow here with appropriate reclamation measures (deep ploughing, snow retention). With a rhizosphere depth of up to 3 m, the forest site conditions are considered satisfactory, but it is not possible to grow high-sized stands under these conditions. Quite satisfactory conditions are formed when the aeration zone thickness is more than 4 m. In such cases, even with minimal precipitation, areas of low-growth forest can exist under Pre-Caspian conditions. An example of this is the Tugai Khuduk tract in Kharabalinsky district, where until recently there were plantations of *Morus, Robinia pseudoacacia, Gleditsia* and other species are planted 100 years ago. On the right bank of the river Volga – in the Dovalgen tract, there is a grove of *Elaeagnus commutata*, a group of trees of *Morus* and *Robinia pseudoacacia*, also up to 100 years old. On brown soils, underlain by saline soils, all previously established plantings died at the age of 10-15 years. Only *Haloxylon* trees grow, but they also die out at the age of 20-30 years without natural regeneration, and *Tamarix* trees are presented on the shores of saline lakes [6].

To summarise the afforestation experience in the Pre-Caspian, the following main points can be reasonably made: afforestation with the use of tree species is possible in conditions of deeply salt-washed soils. These can be sandy soils that have undergone a long barchans stage, or depressions where surface runoff water has washed out the aeration zone. On non-saline soils in the presence of additional water sources of 1500-2500 m$^3$/ha reproductive plantations of tree species *Populus, Robinia, Ulmus, Gleditsia*, etc.) can be grown. On non-saline soils, in the presence of water supply only through atmospheric precipitation, forest plantations in the form of low-growing thickets – scrubs can be grown.

These fundamental positions allow for a prospective evaluation of different types of reforestation plantations on pasture land in the Northern Pre-Caspian [7].

2.2. The forms of forest reclamation

Pasture-protective forest strips. This type of linear plantation, planted every 150-250 m, is a rational means of improving animal grazing during the unfavourable days of late autumn and spring. It is particularly important to protect animals during the calving period. A system of forest strips is placed near wintering grounds on soils washed of salts by 2-3 m. The strips of this type are of dense construction in order to retain snow and improve the water supply to the stands. Pasture protection forest
strips are placed on 8-10% of the pasture area. Summer pastures are left open for better ventilation of the area.

Tree “umbrellas”. Successfully used in the summer near watering holes to improve animal resting. They are placed on low, non-saline areas. The agronomic technique of growing umbrellas has been developed. The greatest difficulty is the protection of the umbrella planting from overgrazing. It is necessary to have 2-3 umbrellas per 1000 ha or one large flock.

On-farm protection plantations. In the Pre-Caspian and in particular in Kalmykia, Dagestan and Astrakhan region there is an "spontaneous" pastoralism. Public livestock farming in mass has ceased to exist, and private livestock farming is not legally defined. Previously there were no fixed points on the summer pastures. It was obligatory for a nomadic shepherd to have camels and an arba. Every week the shepherd moved to a new place. A long stay was only in winter, when the ground was wet or frozen. This prevented pastures from breaking. In the mid-20th century, permanent farms and points began to be built, which led to the mass destruction of sandy land. The year-round keeping of both public and private livestock invariably leads to the destruction of light soils.

As a consequence, barchan sands form around shepherds' camps, farms and even settlements within a radius of 1-2 km. They can only be accessed by cross-country vehicles, and in windy weather people close their windows and doors to escape the sandy dust. In the 1980s, the village of Smushkovo was backfilled. Smushkovo, the central farmstead of the Polynnoye state farm, 4 farms of the Aksaray state farm, etc. were filled up. Many points were abandoned and the sands were overgrown. But now farmers appeared again, the number of livestock has increased and the secondary breakdown of pastures has already begun. If grazing is oriented towards fixed points (which is most likely, without a protective tree and shrub ring (belt) they will be sandbagged. Two examples can be given where a shrub belt provides a tolerable, if not comfortable, living environment. For example, a small village near Krasny Yar on the left bank of the Buzan is protected by Tamarix plantations, which, despite the overgrowing, protect the sand from being blown over and preserve the possibility of access to the village. There is also a stable shepherd's point in the Prideltovsky woodland among the Calligonum. The width of the shrub belt around the shepherd's point on the farm should be 200-400 m. At this distance, cattle going out to graze are dispersed and do not produce a destructive effect on the soil cover. Without a shrub belt, stationary operation of shepherds' points, brigades, farms on the sandy lands of the Pre-Caspian is not possible.

Ameliorative fodder plantations. This type of plantation is established on violated pastures with depleted herbage. In the 70-80s of the last century, the leskhozes of the Astrakhan region carried out large-scale planting of reclamation and fodder plantations. Krascheninnikovia was used for the most part. This shrub proved to be a very successful ameliorant. The plant was easy to grow with minimal tillage. The seeds were dispersed by the wind and gave good sprouts. Today, from Nariman to Nikolskoye village, the botanical composition of pastures contains Krascheninnikovia as a result of ameliorative planting by leskhozes. Experience shows that pasture improvement and creation of ameliorative fodder plantations can be carried out in the form of one-row planting of Krascheninnikovia in 50 m intervals by MLU-1 forest planting machines with turf pullers. It is advisable to sow fodder grasses (Kochia, Agropyron) along the planting furrow and expecting for the natural seeding of adjacent areas [7].

Nature conservation forest bioregions. Their main purpose is to preserve the biosphere reserve of desert lands and provide protection for animals and birds during the winter period. This type of plantation has not yet received an official status, but most of the formerly preserved crops have a protective function. Tugai-Khuduk, Dovalgen, and Chernenkoe tract are invariably visited by birds and steppe animals throughout the year. Rare species of insects and plants are also preserved there. During migrations, flocks of birds stay overnight in these plantations, and local feathered predators make nests. During bad weather, domestic animals also visit these oases, finding shelter from the wind and foraging for safety. Such plantations are often referred to as calmed. They are small, up to 1-2 ha. They are located in areas with root-accessible fresh groundwater. Usually they are an ancient freshwater lenses, formed under barchan sands, which were open for a long time (many decades).
Conservation forest bioregions include berry shrubs and *Elaeagnus*, several of tree species, which provides a nesting sites choice. It can be considered optimal to have 2-3 conservation forest biosphere reserves per 1000 ha of grassland [7].

Rube (boundary) forest strips. This is a new type of forest planting on pastures. Their purpose is to mark the boundaries of land users, improve grazing conditions and ameliorate the adjacent space. These are 2-3-row forest strips created along land-use boundaries using the most resistant shrubs. This is due to the fact that the boundaries run through different soils and the boundary needs to be sufficiently stable everywhere. *Krascheninnikovia*, *Tamarix*, *Calligonum*, *Halimodendron*, *Amorpha*, *Elaeagnus* are the most suitable species. These species are the most resistant to overgrazing.

Sand fastening plantations. Work on sand fastening in the Pre-Caspian, which began at the end of the 19th century, has undergone significant changes. In that period, the most widely used methods included free sowing of *Avena strigosa*, mechanical protection and planting of *Salix caspica* and *Salix acutifolia*. In the second half of the last century, a mechanised method of fastening by MLB-1 machines was developed. In this case, large plants of 1.5-2.0 m in height are planted in spring on barchan sands to a depth of 60 cm. The planting depth allows the seedlings to be protected from blowing out, while the high above-ground part reduces leaf slashing by sand. In the 2nd or 3rd year, sand transport stops, grasses emerge and woodlands are formed. Mechanical and chemical protection methods are not currently used. Forestry farms widely use free sowing of *Avena strigosa*. However, this method is successful once every 8-10 years. An extremely complicated shallow to medium hilly terrain is formed on the fastened area. However, such areas are readily visited by domestic animals in winter. In general, movable sands fastening methods have been developed for different types of movable sands and can be carried out according to the funding and mechanisation of forestry [7].

It is necessary to pay attention on the property of ungrown, open sands to accumulate fresh groundwater at the expense of atmospheric precipitation. Investigations of VNIALMI and other organisations have shown that ungrown sands allow 50-60% of annual atmospheric precipitation to pass to groundwater by filtration, which results in the formation of a freshwater lens. The local population makes wells (khuduk) among barkhan sands and draws fresh water for household needs. If the open sands are overgrown, the precipitation water is entirely used for physical evaporation and transpiration and the freshwater lens is no longer fed.

3. Results
One hectare of open sands in the Pre-Caspian can store 1000-1500 m$^3$ of water per year. Two to three hectares of open sands can provide fresh water for a shepherd brigade (1000 sheep, 50 cattle and 5 man brigade). Therefore, open sands in the amount of 1% of pastures should be an indispensable attribute of the Pre-Caspian sand pastures. Their overgrowth can reduce the volume of freshwater lenses and worsen the water supply conditions of the pastures [7].

According to our data, the whole complex of forest-reclamation plantations on pastures in Astrakhan region occupies an area of 151 thousand ha (table 1), which is 7.6% of the territory. Moreover, it is higher on sandy pastures – 8.8%, and lower on hard lands – 6.3%. In the list of protective plantations types the areas of boundary plantings and plantings around livestock points on sandy lands have increased. The areas proposed for reclamation and fodder planting have been reduced. Experience has shown that they can be reduced to one row and planted every 50 m. This will allow for the same area of reclaimed land to reduce the planting area by 2-3 times.

4. Conclusion
It should be noted that planting on sandy land can perform interchangeable functions. For example, the best sections of pasture protection forest strips can serve as tree “umbrellas”. Boundary plantations can successfully serve as reclamation and fodder plantations, etc. The reclamation of pastures significantly, by 15-20%, increases their fodder productivity. However, the main purpose of these plantations is to protect soils from deflation, to provide environmental functions in terms of preservation of the desert
bio-fund and to improve the comfort of work and life of the population. Financially backed reforestation programmes should be adopted at the regional and, possibly, at the federal level.

Table 1. Volumes of afforestation work on pastures Astrakhan region, thousand ha.

| Type of protective plantation                      | Planting on sandy areas lands | Planting on hard lands | Total  |
|-----------------------------------------------------|------------------------------|------------------------|--------|
| Grassland protection forest strips                  | 15.0                         | 14.0                   | 29.0   |
| Ameliorative fodder planting                        | 12.0                         | 4.0                    | 16.0   |
| Nature conservation biosphere reserves (calmed)     | 3.5                          | 3.5                    | 7.0    |
| Planting around sheep stations, farms               | 25.0                         | 9.0                    | 34.0   |
| Boundary forest belts                               | 30.0                         | 30.0                   | 60.0   |
| Tree “umbrellas”                                    | 2.5                          | 2.5                    | 5.0    |
| Sand fastening works:                               | 5.0                          | -                      | 5.0    |
| wood planting                                       |                              |                        |        |
| grass sowing                                        | 50.0                         | -                      | 50.0   |
| total forest planting                               | 88.0                         | 63.0                   | 151.0  |
| total grass sowing                                  | 50.0                         | -                      | 50.0   |
| forest cover, %                                     | 8.8                          | 6.3                    | 7.6    |

There is another important issue to pay attention: increasing the productive use of pastures. The dynamics of forage grass growth in the Pre-Caspian is characterised by unevenness. In spring and sometimes in autumn, due to the growth of ephemers and ephemeroïds, pasture productivity increases by 2-3 times. However, the animals do not have enough time to use this growth. By having reserve fodder and reserve livestock, it is possible to increase the loading on pastures for these periods and then reduce the load in summer by transferring some of the animals to reserve feeding. This requires irrigated pastures and fodder production. The area of irrigated pastures for the region’s 2 million ha of rainfed pastures should be equal to 100000 ha with a productivity of 50 centners/ha of fodder units. The Astrakhan region is rich in renewable energy sources (wind, sun) and has fresh water from the Volga River. Volga River and slightly saline waters of the sea coastal zone, and although there are vacant lands. Therefore, arrangement of irrigated land with minimum costs does not present technical difficulties, taking into account the experience of Astrakhan people in the post-war period, when thousands of windmills stood on the banks of canals, lakes and oxbow lakes to irrigate vegetable gardens, orchards and vineyards. We need energetic, business-minded, decent people who see the land they live on as flourishing.

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