Restoration of woodland belts and sustainable development of agroecosystems of steppe zone of the Orenburg oblast (Russia)

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Abstract. Orenburg oblast is situated in the steppe zone. The climate is continental, characterized by a large amplitude of fluctuations in both summer and winter air temperatures, and insufficient precipitation. Due to such low climate potential, the development of agricultural production in the region needs constant improvement (increasing soil fertility, erosion control, planting sustainable crops). Therefore, optimization of agricultural production in order to restore the productive potential of land is one of the most actual problems in the region. Orenburg oblast due to its geographical location is characterized by dry winds, which not only dry up the soil, but also sharply reduce its fertility, effect on the water balance, and reduce yield. Therefore, the creation of forest protection treestands in this case is a priority method that contributes to the preservation of soil fertility in the region and, consequently, to the increased rate of agricultural production. In this article, we consider some species of plants belonging to the genera Sorbus L., Crataegus L., Aronia Pers., Syringa L., which have a number of positive ecological and biological characteristics, compared to plants that are widely used in forest protection plantations in the region today (Betula pendula Roth., Pinus sylvestris L., etc.). Using plants that have significant advantages in creating protective forests, it becomes possible to solve the problem of sustainable development of the land fund, and, consequently, to increase the rate of agricultural production. This will allow regulating land use processes not only at the regional level, but also at the state level.

1. Introduction
Agroecosystems are subsidized ecosystems. Their sustainable functioning, expressed in yield, is ensured by the flow of substances and energy from humans in different forms – tillage, irrigation, fertilization, etc. For humans, the most difficult is to influence the environment of agrocenoses, the climatic conditions in which they develop and form a crop [1].

For agroecoses of the steppe zone, the most important anthropogenic factor affecting their habitat is artificial forest plantations – protective woodland belts located along roads or separating agroecoses from each other. In the first case, the main function of forest plantations is to reduce dust, delay the receipt of combustion products of motor fuel in agroecosystems. In the second case, shelterbelts are a tool for regulating and optimizing the environment of agroecosystems.

2. Results and Discussion
Shelterbelts are the artificial complexes which are a part of an ecological framework of many regions, in particular steppe, being objects, historically alien to a landscape, but necessary for its ecological
optimization in the conditions of intensive economic activity (protective shelterbelts and green zones of settlements) [2].

The degree of influence on the surrounding areas and the effectiveness of woodland belts largely depends on their design, which is determined by the openwork or wind permeability [3].

A complete assessment of the effectiveness of woodland belts of different designs is possible at the basis of a comprehensive study of their impact on the yield of adjacent fields, their microclimate in different climatic conditions, taking into account the economic side of the issue [4].

The positive impact of shelterbelts as a component of the landscape is their versatile influence on the environment. They serve as a means of stabilizing the ecological situation in the agricultural landscapes of the arid zone, improving the hydrothermal regime, gas exchange, water-physical properties and soil fertility, reducing insolation and improving the microclimatic conditions of agricultural territories. Belts weaken the wind force by 20–40 %; increase humidity by 3–6 %; reduce the depth of soil freezing by 15–50 %, reduce the intensity of snowmelt by 2–2.5 times, half the effective evaporation of moisture. The power of the snow cover in the plume on the windward side of different shelterbelts varies quite significantly. So, E. G. Paramonov and A. A. Obidin indicate that the snow cover of a 2-row elm belt is 22 cm, while that of pine is 39 cm (+77.3 %). This is due to the fact that in the pine tree stand, the lower branches do not die from the lack of solar energy, and the belt becomes windproof in its lower part, which significantly reduces the wind speed. On the leeward side it results in much longer and higher plumes of the snow cover [5].

Woodland belts are one of the most powerful and long-term means of changing the agroecological properties of the soil. Numerous studies show a positive effect of shelterbelts on the accumulation of organic matter, preservation and accumulation of soil humus. At the same time, a number of studies show the negative impact of planted forests on deep soil waters.

The forest landscape is an important organizing force that determines species interactions in communities. In artificial plantations, species completeness of ecosystem is determined primarily by anthropogenically created stands and undergrowth and spontaneously arising other components – living ground cover, entomofauna, mesofauna, avifauna, mycobiota, etc [6, 7].

Specific conditions arise within the ecotonic zones of artificial plantings, as a result of which 20-28% of herbaceous plant species live only within the fringe, not being found either under the canopy of the forest or in the adjacent open spaces [2, 8].

Specific conditions of artificial forest plantations lead to an increase in the diversity of arthropods, primarily due to specialized stenotopic species peculiar to these habitats [9]. Shelterbelts play an important role in the distribution and settlement of birds, acting as a nesting biotope with sufficient construction material for nests [2, 10].

One should dwell on fungi of artificial plantations. In conditions of low forest cover, mushrooms growing in shelterbelts are of significant interest to the local population, despite their likely accumulation of pollutants. In most shelterbelts, the species composition of fungi is very poor and is represented by 2-3 species (representatives of the genera Agaricus, Clitocybe, Lactarius, Russula, Tricholoma); the yield of these species is also low. Much higher species diversity and yield are found in large artificial pine forests. The most abundant species in these stands are Chroogomphus rutilus (Schaff.:Fr.) Miller, Lactarius deliciosus (L.: Fr.) S. F. Gray, Suillus granulatus (L.) Roussel, S. luteus (L.) Roussel.

The value of shelterbelts is particularly high in arid and semi-arid conditions of the steppes of Eurasia. They form a specific microclimate, provide moisture retention and weaken the action of dry winds. In the Orenburg oblast, located in the steppe zone of Russia, afforestation has been paid attention to since the XIX century. Today, plantation forestry is of 920000 hectares (16.3 per cent of the forested area of the territory) [11]; in most areas these plantings include field shelterbelts.

These artificial plantations for a long time successfully performed their functions judging by the relatively stable grain yields in the region. However, most of the shelterbelts were created in the 60-70 years of the twentieth century and at the beginning of the XXI century the destruction of the spatial structure and, consequently, the ecosystem functions of these plantations began. The reason for this is
the loss of old-growth trees, increasing the frequency of wildfires, extreme temperature conditions of
the growing seasons (in particular – the conditions of 2010), outbreaks of insect pests, the spread of
infectious diseases (bacterial cancer-water birch), etc.

Thus, today there is an urgent need to take measures to update the existing system of shelterbelts
within the region. Monitoring of artificial plantations in the region showed the effectiveness of the use
of birch (Betula pendula Roth), pine (Pinus sylvestris L.), pennsylvania ash (Fraxinus pensylvanica
L.) as the main woody plants. It is less effective to use ash-leaved maple (Acer negundo L.), small-
leaved elm (Ulmus pumila L.) in plantings due to short-lived treestands susceptibility to diseases.

In our opinion, the modern restoration of shelterbelts should be based on the use of proven woody
plants in combination with new woody and shrub plants, which will significantly improve the
ecological efficiency of shelterbelts and also increase the aesthetic value of artificial plantations, as an
integral part of the steppe landscape of the Orenburg region.

The floristic composition of trees and shrubs used in the organization of forest plantations for
agricultural landscapes is quite poor, due to the historical experience of regional forestry. As a result
the agricultural ecosystems, being a product of anthropogenic activities, become insufficiently adapted
to the environment, highly vulnerable, with low resistance to anthropogenic loads (technogenic
pollution). Enhancement and stabilization of agricultural territories, restoration of ecological balance
and the creation of highly productive agro-ecosystems could be realized through the improvement of
their landscape, i.e. inclusion of previously unused species in the composition of forest plantations
(including the exotic plants) if they have high adaptive potential for growth in certain climatic
conditions.

Botanical gardens, dendrological parks and other specialized institutions are the main research
centers professionally conducting work on the study of ecological and biological properties of
indigenous plants, as well as introduction tests with subsequent acclimatization of alien plant species.
In Orenburg, this type of research is carried out at the base of the Botanical garden of the Orenburg
State University [12].

Although it is possible to significantly expand the floristic wealth with the help of plant
introduction, the assortment of exotics is not used in forestry effectively. A number of Russian authors
proved the high significance for forestry by individual introducents but they occupy small areas with
their partial participation in treestands. In foreign practice, introducents are used in the creation of
forest plantations more and more often, since most of them have much more significant ecological and
biological properties, thus not inferior, and even qualitatively superior native species.

In each specific place of introduction plants of the same species, depending on the
climatogeographic conditions of their origin, exhibit a different degree of ecological plasticity.

According to the results of long-term observations and studies, we propose to expand the
assortment of plants used to create artificial shelterbelts through the introduction of new species of
woody-shrubby flora belonging to the genera Sorbus L. (Sorbus aucuparia L.), Crataegus L.
(Crataegus sanguinea Pall., Crataegus Arnoldiana Sarg Maxim.), Aronia Pers. (Aronia mitsurunii A.
Skvorts. et. Maitulina), Syringa L. (Syringa vulgaris L., Syringa josikaea J. Jacq. ex Rchb., Syringa
komarovii C. K. Schneider), which passed the introduction tests and are the most promising and stable
for growth in the conditions of continental climate of the Orenburg region.

Sorbus aucuparia and Crataegus sanguinea have a fairly wide distribution in the region but are not
used in the floristic composition of shelterbelts of the Orenburg region. Crataegus Arnoldiana is the
introduced species characterized by a high degree of stability.

Sorbus aucuparia is a tree 4–15 m tall. The shape of the crown is ovate. Leaves are compound
pinnate, consisting of 9–11 serrate leaflets. In the Orenburg oblast, vegetation period of mountain ash
on average lasts for 193 days. The plant belongs to the group of early starters and late finishers in the
growing season (group II on the features of phenological development). The growing season starts in
early April (average phenodata – 9 April). Flowering is observed in the period from May 8 to May 17.
The flowers are assembled in flat corymbose inflorescences. The number of flowers in the
inflorescence varies in the range of 160–200. In a single inflorescence, from 50 to 85 fruits are formed.
Fruits are spherical, bright red or yellowish, 1.0–1.2 cm in diameter [2, 12]. Mountain ash is well propagated by seeds and cuttings. When propagated by seeds, a large percentage of germination is achieved (80%). The species has a wide range of natural distribution: all other the Europe, most of Asia and North Africa.

*Crataegus sanguinea* is a small tree up to 4 m, often growing as a shrub. Spikes are few or absent. The leaves are egg-shaped, dark green. In Orenburg this species vegetates from April (average April 8) to the end of September (average September 20). By the feature of phenological development it belongs to the I group – early beginners and early ending vegetation. Plants of this group are characterized by better winter hardiness. Flowering species observed in the first decade of may, between 9 and 17 May. Fruit ripening takes quite a long time, compared with other types of hawthorn – 40–42 days. Fruits are round, blood-red colored with a diameter of 1.12 cm [4, 7, 12]. Germination of seeds requires pre-treatment. In urban areas the plant is widely used to create hedges. The species is characterized by the European type of geographic range.

*Crataegus Arnoldiana* is a tree with zigzag ascending branches. The maximum height is about 6 m (more often up to 4.5 m). That is a large-fruited species of the family Crataegus. Vegetation observed within 181 days, from mid-April (average phenodata – April 12–13) up to the beginning of October (October 9). The species belongs to the group III of phenological development of the plant – late budding and early ending of the growing season. In the conducted introduction tests on drought resistance, it proved to be the most stable species, showing the best performance. Flowering is observed at the same period that blood-red hawthorn. The fruit ripening period is shorter averaging 15–17 days. The fruits are large with a diameter of 1.76–1.80 cm and an average weight up to 3.63 g. The color of the fruit varies from crimson to red. The species has a high level of seed productivity – up to 11,600 seeds per tree. Seeds needs stratification to germinate. Group of prospects of plant is I. Homeland of Arnold’s hawthorn is the North-Eastern part of the USA.

*Aronia mitshurinii* – shrub with height 1.5–2 meters. An adult plant is may have up to 80 uneven-aged branches. The species is characterized by elliptic form of the leaves – dark green in summer turns to purple color in autumn. The duration of the growing season in the Orenburg oblast is 177 days. The species belongs to the I group by the features of phenological development. Swelling of the kidneys starts quite early at the beginning of April (5–6 April). Flowering is observed in the first decade of may, during 9-10 days. The flowers are collected in corymbose inflorescences; the inflorescence has length an average of 25 to 27 flowers with white petals. Fruit ripening is observed in the period from August 11 to August 23. Fruits are globose, dull, black color, diameter from 9.5 to 1.1 cm. Vegetation ends in late August – early September. Perspective group I. It is considered that the parent form of the species is the North American species *Aronia melanocarpa*. The Michurin’s Aronia was obtained as a result of experimental researches of I. V. Michurin held by him at the experimental nursery in Kozlovska (now Michurinsk) in Tambov oblast.

All the above species are characterized by an average degree of thermal stability [12], which also indicates the successful acclimatization of plants in the dry steppe zone of Orenburg region. In addition, regular passage of all phases of development, annual flowering, formation of quality seeds are undoubted signs of success adapting to new natural conditions. Paradoxically, the same properties with high severity and the appearance of self-seeding can make these species potential components of biological pollution. However, seeds of these species are characterized by deep rest and for their germination, as a rule, pre-sowing treatment is required, so the appearance of self-seeding in these species is not detected.

Genus *Syringa* L. unites representatives of deciduous ornamental shrubs belonging to the family *Oleaceae* Lindl. *Fraxinus pennsylvanica* Marsh belongs to the same family – a species that is actively used in the creation of shelterbelts for agricultural landscapes and roadside landings near major highways in the urban environment of the Orenburg oblast. As for the representatives of the genus *Syringa* L., no species of this genus were found in the structure of shelterbelts of agricultural areas in the Orenburg oblast, but *S. vulgaris* L. is the species widely used in landscaping of urban areas.

*Syringa vulgaris* is a multi-stemmed deciduous shrub with a height from 2 to 8 meters. The natural
area of distribution – the Balkans, the Carpathians. Species is widespread in the Orenburg oblast. Leaf blades are heart-shaped. It is used as a decorative shrub in gardening of streets, parks, squares, house adjoining territories. In the conditions of Orenburg, vegetation period is 194 days. The species belongs to the I group of prospects by the features of phenological development. The growing season starts on average on April 6 and ends in early October. Blooms from early May, an average of 18 days. Color of flowers from white to various shades of purple. The fruits ripen in mid-September. Panicles with seeds can be collected until December. Seeds belong to the I class for purity and germination. Soil germination is 41 %. Seeds require pre-sowing stratification to increase germination. Actively propagated by root suckers. It has a fairly high drought resistance and winter hardiness. In winter, it does not freeze. It is not demanding as for the soil composition and application of mineral fertilizers.

*Syringa josikaea* is a multi-stem deciduous shrub from 2 up to 5 meters high. The natural area of distribution: endemic to the Carpathians. Leaf blades are elliptical in shape. Can be found as a decorative bush in gardening of parks, squares, private house adjoining territories at the Orenburg region. In the climatogeographic conditions of the Orenburg oblast the vegetation period of this species is 184 days (group of prospects of introduction – I). The growing season begins on average on April 10 and ends in the first decade of October. Blooms from May 20 to June 10. Highly decorative. Full ripening is in September. Seeds for purity and germination belong to the II class. Soil germination of seeds is 50 %. Seeds need pre-sowing stratification to get out of the state of rest. The undergrowth does not form. It has good drought resistance and winter hardiness. It freezes only in severe winters with high values of the minimum air temperature and the lack of sufficient height of snow cover [12].

*Syringa komarowii* is a multi-stemmed deciduous shrub from 1.5 to 6 meters tall. The natural distribution area is China. The shape of the leaf blades is mainly oblong-ovate. In climatogeographical conditions of the Orenburg oblast it is an true introducent. It is found only in the collections of specialized institutions (arboretum of Orenburg State Agrarian University, Botanical Garden of Orenburg State University). The period of vegetative development in the Orenburg oblast is 186 days. It belongs to the I group of prospects for introduction. Vegetation begins with bud swelling on average on April 11, leaf fall – in mid-October. Blooms from May 22 to June 11. According to the degree of decorative perspective it is highly promising. Fruits ripen in the second decade of September. Pre-seed stratification is necessary for seed germination. Seeds by purity and germination belong to the III class. Soil germination of seeds is 54 %. Does not form overgrowth. It is quite drought-resistant and winter-hardy. It can freeze in snowy and windy winters, but it restores the habit well after damage caused by low temperatures.

3. Conclusion

All the above-described plant species belonging to different genera can be evaluated as quite promising, introductively stable plants at the conditions of the Orenburg region. Thus, these species can be recommended for introduction into the floral composition of forest, dendromeliorative, protective and landscaping plantings for Orenburg oblast and adjacent regions.

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