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Trees and Shrubs as Landscape Structure Elements of the Western Kazakhstan

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Abstract

The purpose of this article is to analyze the environment of the Western Kazakhstan desert and steppe biota in order to select tree and shrub species with good prospects for a large-scale succession in the desert. We have analyzed the tree and shrub species available in the Western Kazakhstan in order to identify a group of species suitable for desert lands. The specific feature of our subject matter is that the problem of desert advancing is imposed by the problem of global warming and increasing of the level of carbon dioxide in the atmosphere. We have considered the current status of forest fund and assessed the agro-forestry potential of the West Kazakhstan Region. The article identifies the main stages of silvicultural activity. Forest ecosystems performing a variety of environmental functions are important elements in the landscape structure in arid regions. The role of their creation, regulation and support is particularly important in the light of climate and social changes. The key attributes of plantation often involve drying processes, brashy wood, pests and diseases, unauthorized logging, changing species, invasion of aggressive species and aesthetic unattractiveness.

Keywords: landscape, woody vegetation, forest division, ravine forest, land and forest reclamation, arid region, West Kazakhstan Region

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INTRODUCTION

Now is a rather unique moment, when the long-term observations allow us to conclude that the previous climatological models, predicting global warming caused by the increase in the carbon dioxide in the atmosphere, should be clarified. In recent years, there have been more evidence that the increase in carbon dioxide in the atmosphere and the resulting increase in temperatures have led to the so-called *widespread greening* – extending area of vegetation (Anagnostou et al. 2016).

European climatologists of the Joint Research Center (JRC) headed by Giovanni Forzieri have studied the satellite images and discovered an unusual relationship between the planet greening, triggered by global warming, and the change in the average temperatures in arid and moderate areas. In the moderate area, greening leads to the temperature growth acceleration, as expected. Another conclusion, however, was unexpected: vegetation spread in arid areas inhibits the further warming there (Forzieri et al. 2017).

This paper establishes that the leaf area index (LAI) – the ratio of leaf surface over the land surface – is higher on the 25-50% of land covered by vegetation (data vary depending on the satellite, since images were taken at different times). On the contrary, this figure drops on less than 4% of territory. In fact, these drops coincide with deforestation areas. In 2016, they made a model of the greening process to understand what factors are responsible for planet greening. Some of the parameters were amplified or weakened in order to assess how this affects the increase or decrease in process intensity. The model takes into account the main impacts of human activity. As a result, they have found out that 70% of the fixed LAI growth is caused by an increase in the carbon dioxide in the atmosphere. As this parameter was leaved out, we ended with a reduction in simulated greening by 70%. The mechanism of this effect was twofold. Firstly, carbon dioxide is the main building material of plants, since organic molecules are built from it during the photosynthesis. Secondly, its excess reduces the plant's need for water. To get carbon dioxide from the air, plants open the stomata. The more CO2 they get, the less is their need in stomata (Boer et al. 2011).

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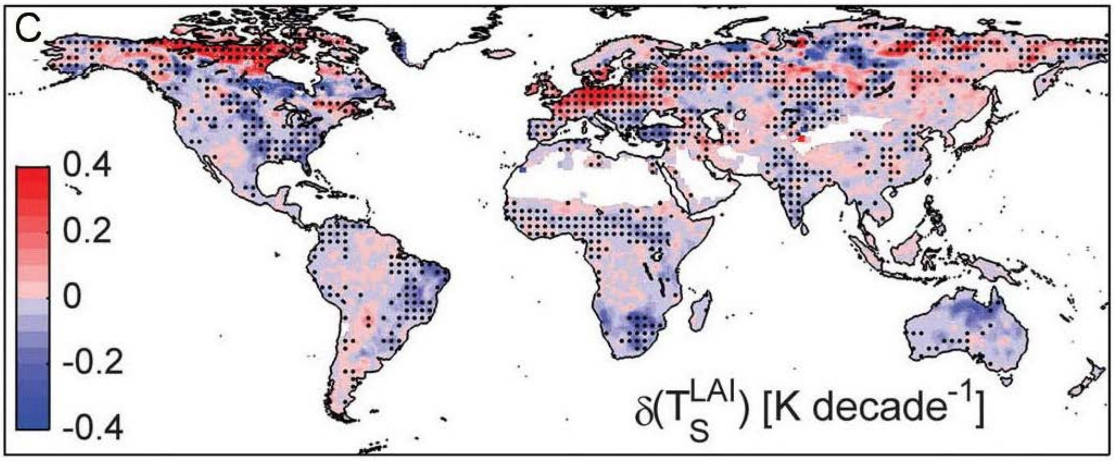

Fig. 1. Changes in the local average temperature as a result of shifts in the integral leaf surface for 1982-2011. Black dots are areas where the fluctuations of the above parameters have a high statistical significance (Forzieri et al., 2017)

Climatologists from the JRC and the Ghent University (Belgium) have decided to find out what was the previous, actual impact of greening on the global warming in 1982-2011. They took the satellite images made during that period (Global Inventory Modeling and Mapping Studies dataset), compared the LAI changes in different regions of the world, and thus, clarified the assessments that their colleagues made a year earlier.

The image data were put behind the model describing the surface receipt of solar radiation and its subsequent loss after comparing the LAI changes that were recorded in different regions of the planet. The heat receipt was calculated as the sum of the long-wave solar radiation and short-wave radiation, absorbed by the Earth's surface (Rα). Losses include the infrared radiation that goes into space (LWout), sensed (non-isothermal) heat (H) and latent (isothermal) heat (LE model). Latent heat is the heat absorbed or released by the thermodynamic system without changing the temperature in this system, for example – when water evaporates. The heat balance was calculated, according to LWout ≅ Rα — LE — H. The LE was calculated from the plant respiration data. The Global Land Evaporation Amsterdam Model Version 2b was applied to calculate the volume of water evaporated from plants under various conditions. The data, calculated according to the above scheme, were compared with the actual recorded temperature in order to find out how the zero greening would change the temperatures in different regions. As the greening factor was leaved out and the model did not reproduce the recorded temperatures, we could assume that the LAI growth was caused either by warming, or by cooling. In areas, where the average annual temperature exceeded 290K (16.85 °C, the hot area), the latent heat losses have played an unexpectedly significant role in the regional heat balance (LE model). According to our calculations, increased vegetation, tracked by the LAI, has led to an increase in the amount of water evaporated from plants into the atmosphere. Thus, the surface has lost an unusually large amount of latent heat. This has led to a significant regional cooling in a hot climate, most significantly in areas with least precipitation, for example – Australia and South Africa.

The calculated cooling effect was observed in areas covered with 60% of all vegetation. Although the greening could not compensate for global warming, it reduced the growth of average annual temperatures by 14%, most significantly in some parts of the planet. In South Africa, eastern South America and Australia, greening has been lowering the average annual temperature by 0.4 K every decade during the 1982-2011. The moderate rainfall in these areas could be probably the trigger here. According to the calculations made by different researchers, the less is the precipitation, the more significant is the share of latent heat (released from evaporation) in the heat balance of a specified area. Researchers note that the heating effect of the greening process turned out to be much stronger (by 5 times) in cold years than in ordinary ones (areas, where the average annual temperature is less than 280 K). In hot areas, the cooling effect is also several times stronger during the warm years. We consider the period to be significantly hot or cold, if the average annual temperatures deviated from the standard by more than 0.5 K. Thus, vegetation has reduced the temperature fluctuations in years when the temperature deviated significantly from the standard. On a planetary scale, these two greening effects – heating and cooling – have almost compensated each other. Their combined effect (vs the non-greening model) lowers the surface temperature of the planet by only 0.007 K per decade. The most important global effect of vegetation advancing is that greening fixes the climate by warming up the surface in cold regions and cooling it in hot regions. Researchers did not focus on the issue of where the evaporated water is coming from in the arid areas in the first place. Based on the observations made over the past 60 years, however, there was established in 2016 that the amount of rainfall is increasing around the world (Donat et al. 2016), since planet warming contributes to the increase in evaporation from the ocean. In the dry areas, this figure grows by 1-2% every decade. Thus, plants use that moisture, which they get from more intensive rains.

Summarizing: now is a favorable time to intensify the struggle against the deserts. Although the phenomena contributing to this struggle (the increase in the carbon dioxide in the atmosphere and the related warming) are considered as negative ones, they contribute to greening (through the increased precipitation and CO2 content, and through another stomatal behavior (less moisture loss)).

Recent data (Zhu et al. 2016) have revealed that the LAI and precipitation rate are increasing everywhere, including the desert areas.

As the moment has come, there should be a strategy-based land recovery plan made. All the above material indicates that regions, previously considered as unsuitable for tree and shrub vegetation, will be capable of maintaining the increasing number of plants in years ahead. Moreover, there will be a positive feedback – plants with high LAI will contribute to a local decrease in temperature. The tree and shrub vegetation will further contribute to the formation of a favorable microclimate through shading and moisture retention (water is absorbed by a developed root system from the soil and/or retained snow retention). Based on the above, we can form the opinion that the process of reclaiming desert lands should be prompted.

Our contribution is that we analyzed the environment on the border between areas of natural and anthropogenic afforestation, and thus, selected some tree and shrub species that will add to successful desert reclamation.

Our research object – natural communities of Western Kazakhstan – is of great importance as an example of extremely varied and diverse locality of relic and isolated biocenoses.

In the following research sections, we will do a retrospective review of desert-steppe biota native to Western Kazakhstan.

The introduced methodology can be applied against desert advancing in other desert areas, and as a guide to harvesting seeds of drought tolerant plants growing in Western Kazakhstan, given that they have some undeniable competitive advantages like richness, complete exploration info on them and continental climate tolerance.

International academic community gives a top priority to the problem of forest plantations and their role in combating desertification. The idea is promoted through international projects like the UNDP (Integrated Drylands Development Program), the International Center for Arid and Semi-Arid Land Studies Drynet, and the DESIRE Project of the Sixth Framework Program for Research and Technological Development of the European Union. The latter, inter alia, notes that well-managed forests have a strong capacity and a strategy for conserving soil and water resources in arid regions (Li and Yang 2014, Riley 1995, Tschinkel 1987). Mongolian scientists describe methods for degraded pasture restoration in semi-desert zones of Mongolia, specifically those that are applied in forest shelter belt formation and fencing (Tsognamsrai and Dugarjav 2016). In semi-arid and arid regions of China, introducing shrubs into degraded steppes is considered one of the keys to restore vegetation and reduce desertification (Zongrui et al. 2017).

MATERIALS AND METHODS

In 2015-2017, our expedition team studied the territory of the WKR in order to determine the status of remaining natural and anthropogenic forest stands.

Aside from the on-site research activity, we analyzed literary sources, topographic and other maps, and space images, obtained with the Landsat 5 TM at 30 m resolution in 2012 (**Fig. 2**). We have used the following maps taken from the National Atlas of the Republic of Kazakhstan: landscape map 1: 5000 000 (Veselova and Geldieva 2010), soil map 1: 5000 000 (Erokhina et al. 2010), forest fund map 1: 5000 000 (Bibekin and Seidalin 2010), forest-forming plantation area map 1: 10 000 000 (Bibekin and Seidalin 2010).

In studying, we have used the navigation and cartographic instruments, as well as the software

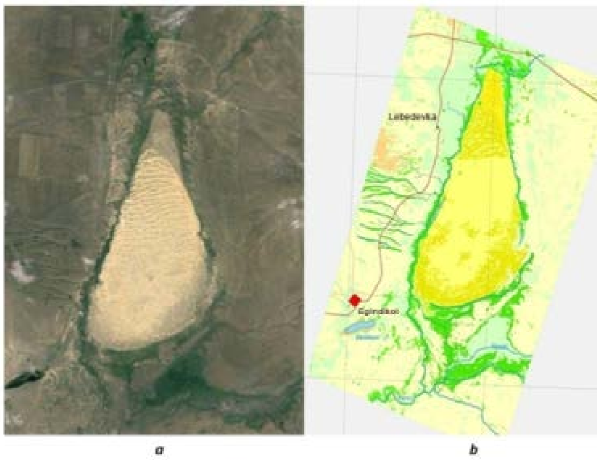

Fig. 2. Distribution of birch-aspen forests on the Akkum sandy massif: *a* – space image (Landsat 5 TM, 30 m resolution, 2012), *b*– map chartdrawn on the basis of a space image

applications. The obtained space images were processed and bound with the ArcGIS 9.3 program. Thus, we have drawn maps of major forest ecosystems using space images (**Fig. 2**). In cataloguing the woody vegetation, we have used the Garmin eTrex Vista HCX (Taiwan) receiver to determine the field locality. There were determined the rock composition, stem diameter at root collar, crown height and diameter, stand density and area's status after fire and logging.

The forest fund was analyzed using the forest fund accounting data. Temporary sample plots were laid according to the industry standard 56-69-83 (1984). The forest stand structures, their openness in various parts of vertical profile were determined by eye according to the M.A. Dudorev's recommendations (1984) on the forest belt structure. Their age was determined with the Haglof borer (Sweden). Tree's height was determined with a Nikon Forestry Pro laser rangefinder (Japan). Tree's diameter was measured with a tree calliper. We have taken into account the main provisions and principles of methods widely used in silvicultural research and in studying the natural regeneration (Anuchin 1982, Sukachev and Zonn 1961).

RESULTS

Current Situation with Forests in the WKR

The total area of state forest fund did not change significantly over the recent years (215.5 thousand hectares – 01.01.2013, 215.5 thousand hectares – 01.01.2014, 215, 3 thousand hectares – 01.01.2015). The area covered by forests – 100.8 thousand hectares (47%) – has decreased by 2.1 thousand hectares due to forest fires (in 01.01. .2013 – 102.9 thousand hectares, in 01.01.2014 – 103.0 thousand hectares, in 01.01.2015 – 102.9 thousand hectares). In 01.01.2016,regional forest fund was represented by lowland forests, including forest belts along river banks, lakes, reservoirs, channels and other water bodies – 92007 hectares, where a poplar (*P.alba, nigra*) grows.(42345 ha). The share of the latter territoryis41.9%.There are also field-protecting forests (67341 hectares), ravine forests (23639 ha), protective forest belts along public roadways (14440 hectares), state protective forest belts(9857 hectares),municipal forests (7039 hectares), green zones of settlements and medical institutions (2383 hectares). In the region, there are 615 hectares of coniferous species, namely – on the territory of Urdinsk state institution of forest and wildlife protection (123 hectares), on the territory of Yanvartsevsk state.

Natural Woody Vegetation

Depending on the site, forest vegetation of the WKR is represented by the following groups: floodplain forests, separated forest stands of the sand massif and the liman lowering, ravine forests (Akhmedenov 2016, Ivanov 1960, Nikitin 1986, Petrenko et al. 2001).

The floodplain forests include an aspen forest full with brambleberries (in the Zhaiyk and Kuagash river-valleys) and a birch grove with horsetail cover (in the floodplain of the Kuagash River). Separate forest stands of the sand massif include a birch grove with a fern cover (in the Karaagash, Karatal, Kandykty areas), a birch grove with a sedge cover and an aspen forest with the same cover type (in the Karaagasharea), an aspen forest covered with mixed herbs(in the "Petrovskiyepeski" area). Separate forest stands of the liman lowering include an aspen forest with the sedge cover (near the Zhemshin village), an aspen forest covered with mixed herbs and sedges (in the Abyshsay ravine and in the Belagasharea). The ravine forests include an aspen forest covered with mixed herbs and shrubs(the slopes of the Bolshaya Ichka, the Tsygan and the Aktau mountains), an aspen forest and a birch grove both covered with mixed herbs and an weak arctic sedge (in the Segizsay, Kainzhar, Emenzhararea) (Ivanov 1960, Nikitin 1986, Petrenko 1971, Petrenko et al. 2001).

We will describe one standard stand. There is an aspen grove with an area of 40 ha to the east of the Togayly village (Taskalinsky District of the WKR). It stretches about 2 km long along a barely perceptible liman lowering. The aspen grove forms four stands, stretched from the north-west to the south-east. It is

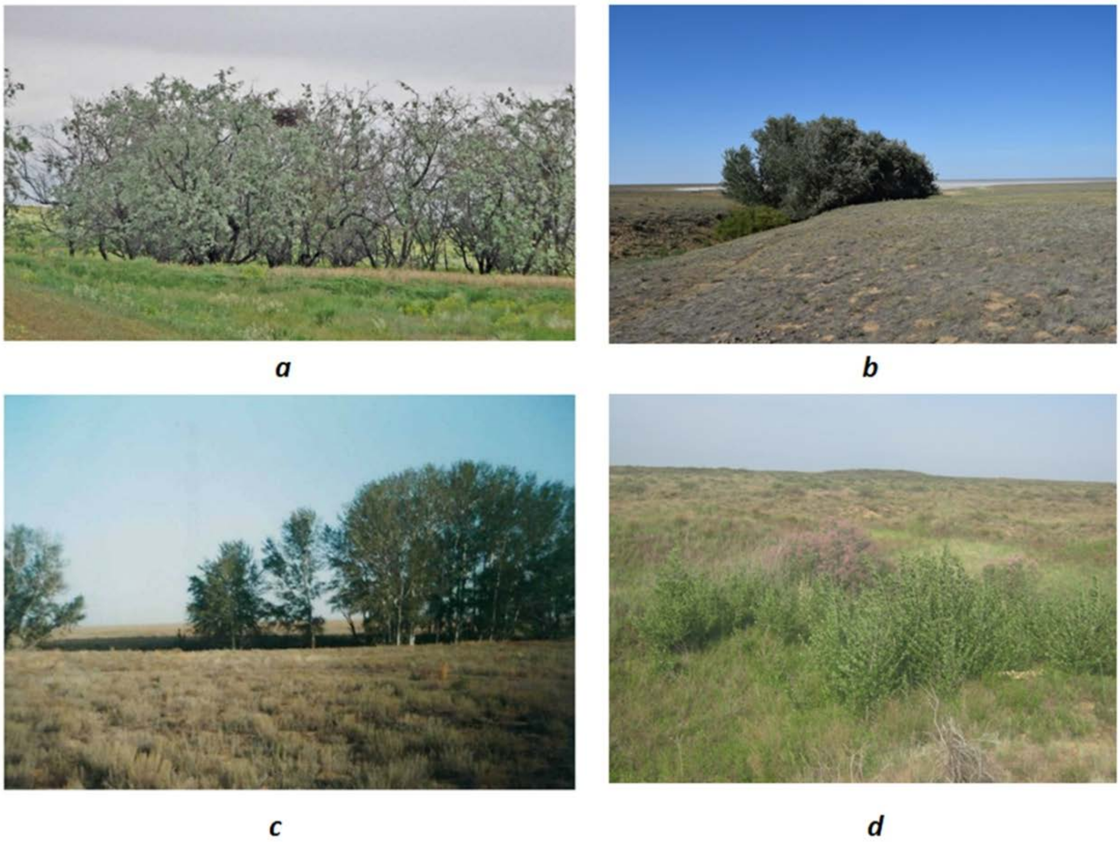

Fig. 3. Woody stands: a – ravine grove with Russian olivesnear the Aralsor Lake, b– ravine oasis with white poplars near the Aralsor Lake, c – ravine oasis with white poplars in the Kyzylzhar area, d –grove with black poplars and tamarisks located in the wind-scoured basin near the Zhetimola winter livestock settlement

represented by a 20-30 years oldcommon aspen (*Populustremula*L.) with an average height of 10 m and a stem's diameter of 11 cm, by ararely-growing white poplar (*Porulusalba* L.) and by a great number of briars (*Rosa canina* L.). There are flat-headed stands with wind-thrown and dead standing trees. In the central lower part of the grove, there are reed thickets. On the clearings, there are quack-grass and licorice meadows. Around the grove, there are quack-grass hayfields. In the understory, there are different shrubs: dog roses, buckthorns, bird cherries and brooms. Here, there are stands with white willows (*Salix alba*), white poplars (*Populus alba*) andRussian olives (*Elaeagnusangustifolia*) (**Fig. 3**).

In the treeless desert of the Western Kazakhstan, natural stands with *Rhamnuscathartica*, *Prunusspinosa* and *Loniceratatarica*are the remains of ravine forests that have disappeared over the last centuries (Dinesman 1960). They can be found now only along the water line of a few inland lakes and saline rivers flowing into them. The scrubs are common in the Volga-Ural Sands, consisting mainly of medium-hilly, semi-fixed sands with wind-scoured basins. Woody vegetation of the Ryn Desertis represented by a variety of stands with trees and shrubs, planted in the following combinations: poplars (*Populushybrida*, P. *alba*); Russian olives – poplars – willows (*Salix caspica*and rosemary-leave willow); Russian olives – willows (*Salix caspica* and rosemary-leave willow); alders. Natural poplar and oleaster stands have features of tugai vegetation. There are high-density briers (*Rosa cinnamomea*); trees and bushes can bewinded with clematis (*Clematis orientalis*), and the stand edges are overgrown with rosemary-leave willows. The hills and slopes are covered with single hybrid poplars or by a group of them, as well as with buckthorns (*Rhamnuscathartica*), calligonum (*Calligonumaphyllum*), Kulan-Kuiryuk (*Eremospartonaphyllum*) that can form significant thickets due to root sprouting (**Fig. 4**).

Fig. 4. Shrub representatives in the Volga-Ural Sands: a – Calligonum (Calligonumaphyllum), b– Kulan-Kuiryuk (Eremospartonaphyllum)

Eremosparton is a shrub well adapted to life on mobile sands: covered with sand, it forms additional roots and offspring. Its beans roll over the sand surface. Calligonum reproduces with seeds, coppice shoots and root offspring, perfectly adapted to life on mobile sands. Ball-shaped fruits are rolled by the wind for long distances. Roots are mostly superficial and spread from the bush to a distance of up to 12 m. In the Kazakh and Central Asian deserts, calligonum and eremosparton are planted as the best sandbinders.

In the basins of ashiksites (sandy plain spaces between the hilly sand belts), there can be found hybrid poplars, olives, willows (*Salix caspica* and rosemary-leave willow) and calligonum. In ashik, tamarisks grow in small groups and thickets along the saline basin.

In the wind-scoured basins of the central part of the Volga-Ural Sands, there are willow groves with white poplars (**Fig. 5**).

Groves with white poplars, aspens and willows (*Salix caspica* and rosemary-leave willow) located in 2-3 km to the west from the Shakbay winter livestock settlement; tamarisk groves in 1.5 km to the southwest of the Narik winter livestock settlement; groves with black poplars in the wind-scoured basins near the Zhetimola winter livestock settlement (the southern part of the ZhangalinskySistrict in the West Kazakhstan Region). In deserts, shrub communities are represented mainly by *Tamarixramosissima* and *Calligonumaphillum* (**Fig. 3**). Similar birch-aspen forest plots are represented in the Akkum sandy massif. They grow in the basins of wind-blow sand dunes with a close groundwater occurrence in the floodplain of the Kuagash Riverand ravines attaching the river valleyin the west (**Fig. 5**).

Space image analysis showed a high degree of sand binding by trees and shrubs in the Akkuma sandy massif (**Fig. 2**). The Kandykty Forest with an area of about 5 hectares occupies a large territory at the lowering to the north of Akkuma. There is a Segizsay Stow to the west. It still preserves birch-aspen forests. At the bottom of the Kuagash River, there are birch-aspen belts. At the riverbed, there are willow trees with reed vegetation. In the southern Akkuma, there is a Karatal Stow represented by a fern-like birch forest. This forest occupies 400 hectares, stretches from the northeast to the south-west and is surrounded by herb-grass meadow.

In some cases, one can find trees and shrubs (poplars/Russian olives/willows) along the slopes of certain hills. Nevertheless, they can be found in the wind-scoured basins more often.

Fig. 5. Woody vegetation in the wind-blow sand basins: a –tamarisk-black poplar vegetation in the Volga-Ural Sands, b–birch-aspen vegetation in the Akkum Sands

Anthropogenic Woody Vegetation

In anthropogenic landscape structure, roadside forest belts occupy a dominant position. Most of the roadside plantings that are 60 m in wide involve Siberian elms, created in an ordinary way. The railway tree lines are represented by strip plantings. Siberian elms grow poorly. In general, many abandoned forest stands with a little feeding area have reduced own increment. They also are flat-headed. In addition, Siberian elms were recorded to act invasively in relation to the nearby-growing young plants. It is able to displace the grass vegetation and to urn former fields into dense groves. This process is widespread in the Zelenovsky, Terektinsky and Shyngyrau Districts of the WKR.

In one kilometer south of the Pogodaevo village, there is a Pogodaevsky Forest, with an area of about 30 hectares. On the hill, there are artificial plantings of yellow acacia combined with rare Siberian elms, as well as plantings of natural green ash. On the southern slope, there are single specimens of maple lionfish, Iberian spiraea and golden currant; in the low ravine – of Siberian elm. On the northern and northeastern slopes of the Syrt, cut by ravines, there was yellow acacia planted in the 50-60s. Its canopy became a place for maples, ashes, English and Siberian elms, hawthorns. The stand covering the planted Siberian elms was taxed. Its plantings are irregular, 1/3 part of the stand is drying out and dyeing Tree's average diameter there is 5.6 cm; the average height – 4.2 m; stand density – 0.4.

In the semi-desert zone of the region, roadside forest belts form a grove or a group of small stands (**Fig. 6**). If green plantings grow in the narrow valleys or in the hollow with chestnut-like meadow soils, situation with woody vegetation can be considered as satisfactory or good.

DISCUSSION

Investigated localities provided us with the richest material on the uniqueness of Western Kazakhstan landscapes which being relatively small in area integrate varieties that are both unique and typical for the region. The investigated territory can be called a natural lab, where diverse biocenoses were tested to destruction many times. We can assume that local differences and variety of biocoenoses were formed on the back of area geology. On the one hand, unique localities are local geosystems combining some relict and native landscaping features. On the other hand, high landscape mobility, induced by the salt core taking active part in various natural processes (dissolution of soluble rocks, erosion, show of water), results in the emergence of specific refugia (shelters) for rare ecosystems and biological species. For example, karst terrain of the Inder Lake basin is a shelter for some species like the pit viper (*Gloydius halys*), the Eurasian eagle-owl (*Bubo bubo*), the Great gerbils (*Rhombomys opimus*), etc. This fact can speak for the stability of local biocenoses and their resilience – factors that indirectly indicate the possibility of using local species in combating desertification.

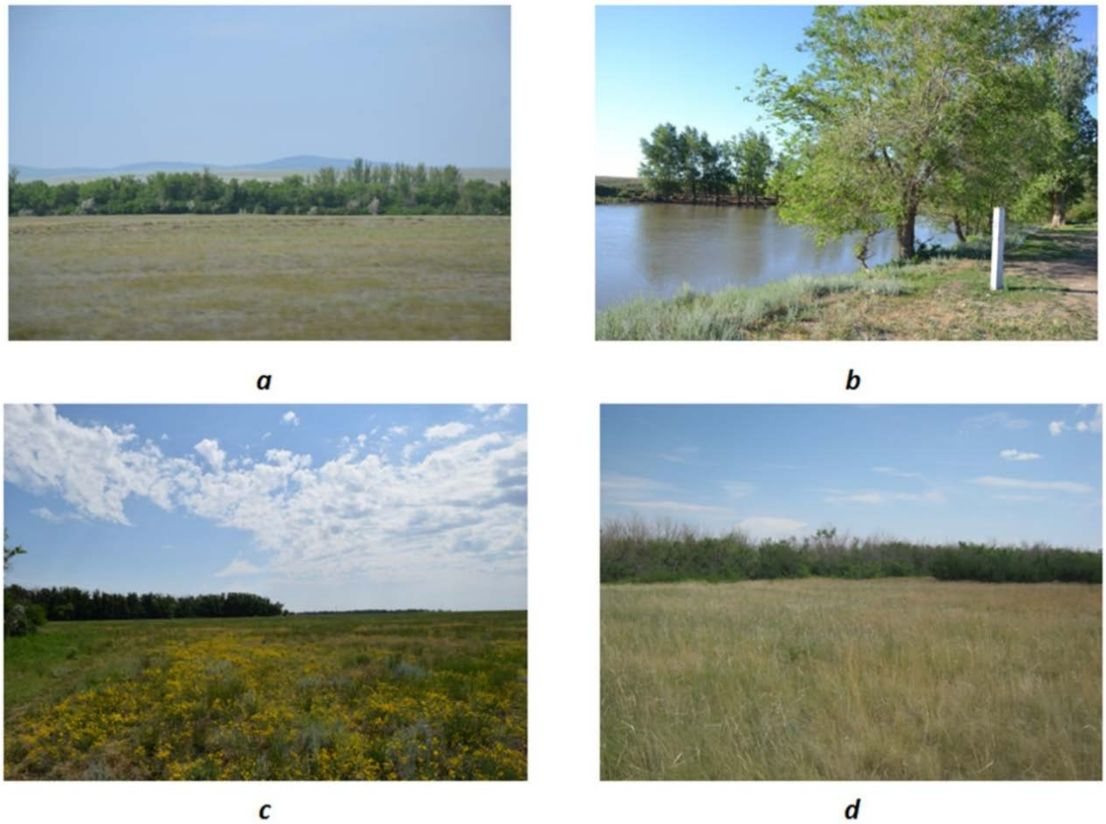

Fig. 6. Anthropogenic green plantations: a – roadside forest belts, Tascalinsky District, WKR, b– canalside forest belts, Zelenovsky District, WKR, c – plantations at the Dzhanybek scientific station, Zhanibek District, WKR, d – Pershinsky Forest Range, Zelenovsky District, WKR

As for the investigated area, each salt dome as an independent tectonic body shapes a unique landscape, so nearby salt dome landscapes belonging to the same physiographic area are often sharply distinguished by features. Disharmonic folding defines the formation pattern of rare and unique isolated terrain features that often include some of the unique ones.

In general, some landscapes of Western Kazakhstan that combine a variety of unique terrains and are rich in rare and relict species of plants and animals can be recommended as candidates for national parks and reserves, where nature itself put up an experiment, giving life to many isolated and unique communities.

CONCLUSIONS

In arid Western Kazakhstan, natural woody vegetation is possible only under azonal soil-hydrological conditions with available fresh groundwater and (or) additional moistening based on snow melt runoff. On solonchaks olonetzes and light chestnut soils with inaccessible groundwater any renewal with the formation of stable forest ecosystems is impossible.

Natural woody vegetation is an integral element of the geosystem in Western Kazakhstan. In landscape structure, the share of this element is insignificant. At the same time, its complexes enhance the aesthetic appeal, stability and diversity of local geosystems.

Further artificial afforestation in the region should be focused on restoring the lost natural communities or their analogues. The number of invasive plants should be minimized, since it is important, at least in general terms, to preserve the original landscape structure. The shrub element restoration will help to increase the number of fresh water reserves in hollows, valleys, sand basins, and to create a favorable environment for plant communities that can be found on the territory of surrounding plains.

The natural model of spontaneous forest community emergence with great species diversity in relief depressions (the case of naturally growing abandoned pond in the Akzhayksky District) makes it possible to take a more reasonable approach towards the process of forest stand creation under such conditions. In abandoned ponds and open-cast mines with periodically excessive moistening, there can form stable natural forest ecosystems similar to Central Asian tugaiin terms of their composition – predominance of willows, oleasters, and poplars (white and black).

The principle of optimal forest improvement lies in creating phyto-reclamation complexes that correspond to the zonal ecosystem with due account for the regional features of landscape complexes.

Durability of studied natural and artificial forest pins indicates a possibility of creating an optimal lowering ecosystems, as well as recommendations on their wide application.

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