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RESEARCH ARTICLE

Field Assessment and Functional Evaluation of Agricultural Shelterbelts in Akmola Region of Kazakhstan

Dani Sarsekova • Gulshat Satybaldiyeva✉

Kazakh National Agrarian Research University, Faculty of Forestry and Land Resources, Department of Forest Resources, Game Management and Fisheries, Almaty/Kazakhstan

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ABSTRACT

Forest shelterbelts are vital components of agricultural landscapes, particularly in steppe regions susceptible to wind erosion and climatic extremes. This study evaluates the current condition and functional status of shelterbelts across four agricultural enterprises in the Akmola region of central Kazakhstan. Field surveys were conducted at the A.I. Baraev Scientific and Production Center of Grain Farming, Yesil-Agro LLP, Kazger LLP, and Rodina LLP. The assessment focused on morphometric characteristics, species composition, sanitary condition, and agro ecological effectiveness. Results indicate widespread degradation due to aging, poor maintenance, and absence of scientifically informed planning. Many shelterbelts have lost their protective and ecological functions, with some areas experiencing up to 80% tree mortality. Contributing factors include lack of regeneration efforts, disruption of hydrological processes, and absence of integrated agroforestry strategies. The study highlights the urgent need for a comprehensive restoration program involving removal of dead trees, replanting with climate-resilient species, regular maintenance, and GIS-based agro ecological planning. Without such interventions, the continued decline of shelterbelts will undermine soil conservation, agricultural productivity, and ecosystem resilience in the region.

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1. Introduction

Despite the extensive documentation of shelterbelt designs, planting techniques, and their ecological benefits, relatively little research has focused on the *long-term performance, degradation processes, and current functional state* of these plantations in Kazakhstan. Most previous studies emphasize their historical establishment and initial effectiveness, yet there is limited empirical data on how shelterbelts have aged, the socio-economic and institutional factors behind their decline, and the effectiveness of restoration strategies under present-day climate change and water scarcity conditions. This gap highlights the need for updated field-based assessments that evaluate both existing and deteriorated shelterbelts in order to inform future policy and management approaches.

The development of protective afforestation in Kazakhstan began in the mid-20th century as part of a major initiative launched by the former Soviet Union. The objective was to establish forest belts to stabilize and increase agricultural productivity in the steppe and forest-steppe zones (Mukanov et al., 2010; Toktasynov et al., 2012). In the early years of the Virgin Lands Campaign, Kazakhstan achieved high crop yields due to the extensive use of agricultural machinery, including

✉ Corresponding author
E-mail address: satybaldieva.gulshat@mail.ru

thousands of tractors and powerful equipment (Mukanov et al., 2010). However, the widespread plowing of virgin lands—combined with flat topography and strong winds—led to devastating dust storms in 1962–1963. These storms disrupted the ecological balance, caused significant soil erosion, and stripped away fertile topsoil, rendering the land less productive and accelerating soil fertility loss (Makhanova et al., 2022).

As land degradation spread, several arable areas were repeatedly withdrawn from cultivation and reassigned to the state forest fund to counteract dust storms. To combat wind erosion and improve crop yields, protective forest belts were established.

Kazakhstan also adopted a soil-conservation farming system that emphasized non-moldboard tillage and retention of crop stubble, a practice developed by Baraev (Sarsekova et al., 2021). Numerous forest reclamation stations were set up to oversee and carry out large-scale afforestation efforts in the steppe regions. The types, designs, planting techniques, and spatial planning standards for these protective plantations are extensively documented in the scientific literature (Amanzholova et al., 2024; Driscoll & de Beurs, 2024; Ruppert et al., 2020; Thevs et al., 2017). These plantations, particularly when used alongside other soil protection strategies, have proven effective in preventing erosion, improving soil moisture, and reducing the impacts of drought, dry winds, and dust storms.

Forest belts significantly contribute to increased crop yields and total grain production, even during years of drought (Cheverdina et al., 2023; Urazov et al., 2025). However, over the past 30 years, efforts to maintain and develop these forest belts in Kazakhstan have declined. As a result, many have deteriorated, dried up, or even caught fire. Given the ongoing climate crisis and growing water scarcity, there is now an urgent need to revise shelterbelt-related economic policies and take action to rehabilitate and restore these protective forests (Huiliang et al., 2022).

Studies indicate that roughly 60% of these plantings have exceeded their functional lifespan, with only remnants of the original belts from the 1960s remaining in many areas. Acknowledging the need for restoration, specialists are actively developing new methods and technologies for creating and enhancing shelterbelts (Jerusalem et al., 2017).

This study seeks to assess the condition of both existing and deteriorated shelterbelts through field surveys, taking into account their lifespan to better understand their current state and the factors contributing to their decline.

2. Materials and Methods

2.1. Study Areas and Their Characteristics

2.1.1. Study area

Field surveys of forest shelterbelts were conducted during the 2023 and 2024 growing seasons (June–August) on four representative farmlands in the Akmola Region, Kazakhstan (Figure 1). These farms were selected because of their different management systems, land-use histories, and shelterbelt conditions. The surveys included shelterbelt mapping, tree species identification, structural assessments, and evaluation of their influence on crop fields:

The Scientific and Production Center of Grain Farming named after A.I. Baraev, located in the village of Nauchny in the Shortandinsky district of Akmola region, was established in 1956 and functions as a leading research institution in northern and central Kazakhstan. The center focuses on the breeding and seed production of 17 varieties of grain, legume, oilseed, and forage crops. The total land area managed by the center is 5,814 hectares, comprising 5,486 hectares of arable land and 328 hectares of pasture. In 2023, the total sown area covered 4,405 hectares, distributed as follows: 2,857 hectares for spring wheat, 131.5 hectares for spring barley, 66 hectares for oats, 352 hectares for cereal crops like buckwheat and millet, 49 hectares for legumes, 115 hectares for oilseeds, 11.5 hectares for annual forage grasses, 268 hectares for newly planted perennial forage grasses, and 555 hectares of perennial forage grasses established in previous years. Additionally, 1 081 hectares were left fallow. The farmland has no natural water bodies such as lakes or ponds and depends entirely on precipitation and snowmelt for soil moisture. Research activities related to forage, grain, and fodder crops are carried out in areas that are protected by shelterbelts. In 2023, crop yields were reported as follows: buckwheat produced 3–3.5 c/hectare, millet 5–6 c/ha, barley 7–13 c/ha, oats 2–8 c/ha, and spring wheat 25–30 c/ha (URL1, 2025).

Yesil-Agro Limited Liability Partnership operates its farmland in the village of Kenesary, located in the Burabay district in the northwest of the Akmola region. The total land area amounts to 87,500 hectares, of which 40,000 hectares are used for crop cultivation. The farm primarily concentrates on growing and producing seeds for grain and legume crops (URL2, 2025).

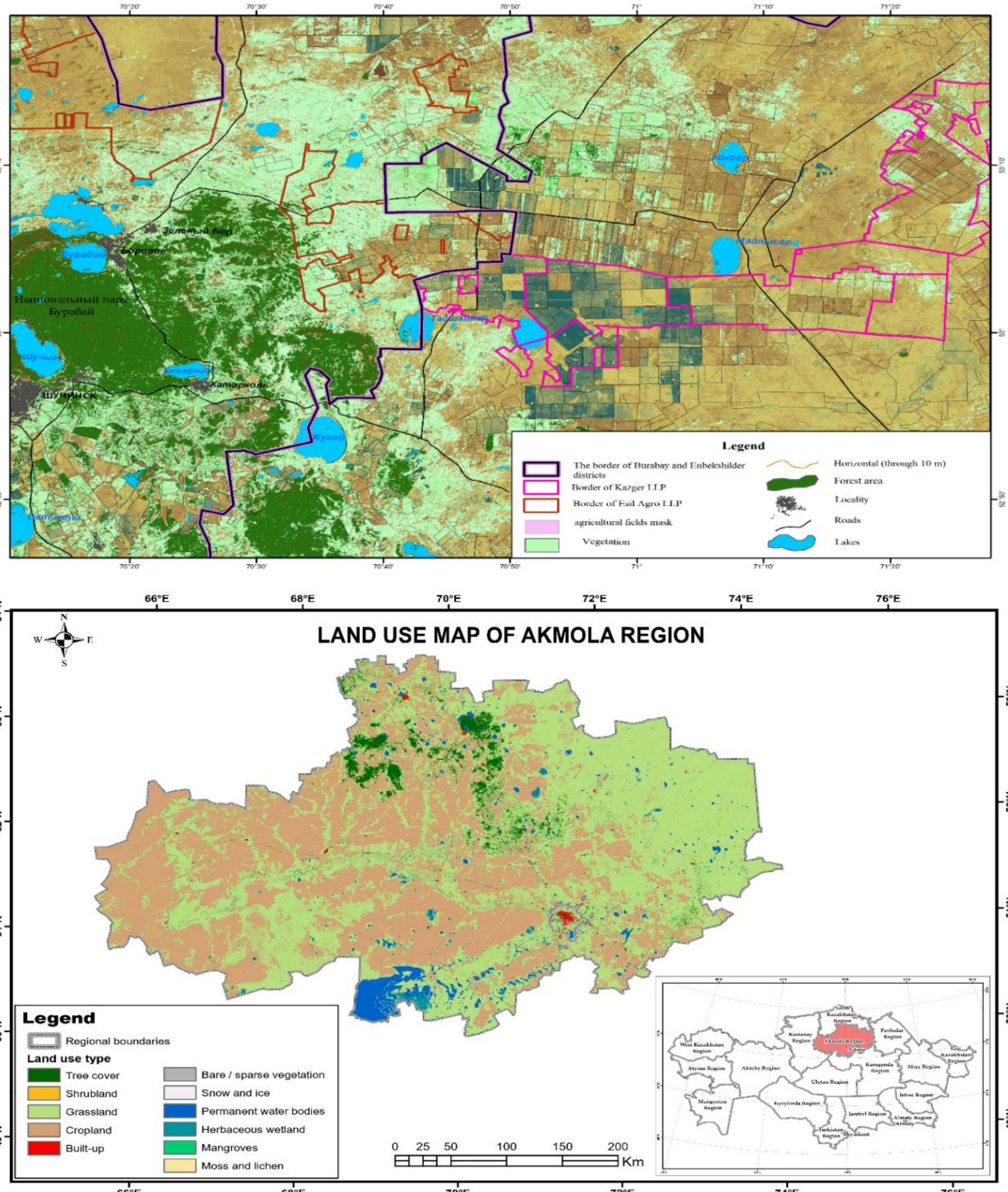

Figure 1. The study area farms and their locations in Akmola region of Kazakhstan.

On the farmland of Kazger Limited Liability Partnership: Kazger LLP, a crop production enterprise founded in 1997, manages farmland located in the Don and Krasnoflotsky rural districts of Enbekshildersky district in northeastern Akmola region. The company operates under long-term land lease agreements for agricultural use, with extensions available through 2051–2056. The total land area amounts to 50,719.52 hectares, including 50,178.13 hectares classified as farmland. This consists of 25,585.8 hectares of arable land, 24,592.33 hectares of pasture, and 541.39 hectares of hayfields. In 2023, the farm recorded the following crop yields: 2.82 centners per hectare for oats, 3.35 c/ha for soft spring wheat, and 2.85 c/ha for spring barley. However, crops such as curly flax and sunflower had to be written off due to insufficient moisture during the growing season, which was further worsened by high temperatures and low rainfall (URL3, 2025).

Rodina Limited Liability Partnership: an agricultural company, was formed in 1961 following the transformation of the New Life collective farm and has since undergone four reorganizations. Its farmland is located in the villages of Rodina, Zeleny Gai, and Sadovoe, in the northwestern part of Tselinograd district, Akmola region. Today, AF Rodina LLP operates as a diversified agricultural enterprise engaged in the production, storage, and sale of agricultural goods. Since 1999, the farm has been recognized as an elite seed producer, specializing in high-quality grain seed production and sales. The company's spring sowing area spans 50,000 hectares, with 40,000 hectares allocated to wheat cultivation across the Shortandinsky, Tselinogradsky, and Korgalzhynsky districts. Additionally, the farm has developed a 700-hectare irrigation system for growing silage corn, alfalfa, and other crops. In 2022, a modern irrigation system featuring 22 center-pivot machines was installed on a further 2,000 hectares. Despite these advancements, wheat yields in 2023 were relatively low—around 10 centners per hectare—compared to 20 c/ha the previous year, primarily due to a mismatch between the selected crop varieties and actual yield outcomes (URL4, 2025).

2.1.2. The topography of the study area

The Akmola region is situated on the western edge of Kazakhstan, bordered by the Ulytau Mountains to the southwest and the Kokshetau Heights to the north. The land generally slopes downward from east to west. Topographically, the region can be divided into three zones: the flat northwest area, the flat southwest area with scattered hills, and the elevated eastern section of the Kazakh folded terrain. In the northwest, near the Ishim Valley as it turns northward, the landscape consists of a flat plateau cut by dry ravines and gullies, ending abruptly at a ledge overlooking the Ishim Valley. The southwestern area, located south of the Ishim River, features a raised plain dotted with many flat-topped hills. Between these hills are shallow salt and fresh lakes of varying sizes. The eastern portion is characterized by a landscape called "melkosopochnik," which includes gently sloping hills, ridges, and hummocks formed by denudation of what was once mountainous terrain (Imangulova et al., 2020).

These hills range in height from 5-10 meters up to 50-60 meters, with some reaching 80-100 meters. Their shapes and sizes vary depending on the rock types they are made of: rounded hills are usually granite, gently sloping hills with softer peaks are often porphyry, and sharply pointed hills are typically quartzite. The basins nestled among the hills, spanning several meters to kilometers in diameter, frequently contain lakes (Smagulov et al., 2021).

The far northeast of the Akmola region stretches into the West Siberian Lowland. The region's highest elevation is Mount Kokshe, which reaches 947 meters above sea level, while the lowest point is Lake Sholaksor at 67 meters above sea level (Smagulov et al., 2021).

2.1.3. The climate of the study area

The climate of the Akmola region is distinctly continental and arid, characterized by hot summers and cold winters. Situated within the West Siberian climatic zone of the temperate belt, the area experiences considerable diurnal and seasonal temperature variations. Transitional seasons such as spring and autumn are not sharply defined, and the region benefits from a high number of sunny days annually. The solar radiation received during summer approaches levels typical of tropical zones, largely due to minimal cloud cover. Precipitation shows a decreasing gradient from north to south, with maximum rainfall occurring in June and the lowest in February. Snow cover generally persists for approximately 150 days each year. The region is also notable for strong winds and holds Kazakhstan's record low temperatures, with -57°C documented in Atbasar and -52 °C in Astana (Imangulova et al., 2020).

Water resources in Akmola are limited, with shallow, non-navigable rivers primarily sustained by meltwater and to a lesser extent by groundwater. During summer months, these rivers frequently experience drying and increased salinity. Major waterways include the Yesil River (also known as Ishim), a tributary of the Irtysh, along with its tributaries such as Ters-Akkan on the left bank, and Zhabai and Koluton on the right. Several rivers terminate in endorheic basins, including lakes like Nura, Selenta, and Ulenta. The region's basins of low hills and elevated plains are dotted with numerous lakes. Among the largest are saline lakes, such as Tengiz—located near the border with Karaganda region and spanning approximately 40 km in width—and Kalmyk-Kol. Freshwater lakes of smaller size, including Ala-Kol and Shoindi-Kol, are also present. Due to the shallow shores of many lakes, their morphology is subject to significant change under the influence of strong winds (Baisholanov et al., 2024).

2.1.4. The soil of the study area

The Akmola region is characterized by a terrain of steppes and semi-deserts, with considerable variation in soil types and vegetation influenced by topography and the nature of the underlying rock formations. North of the Ishim River, the landscape consists of grass steppes growing on southern chernozem soils, interspersed with numerous salt flats in the lowlands and thin, skeletal soils on the higher elevations. Vegetation here is drought-resistant, featuring species such as ipchak (*Festuca valesiaca* Tourn. ex L.), while Scots pine forests are commonly found on upland areas. The western third of Akmola, stretching from the Ishim valley eastward toward Astana, predominantly supports grass steppes on dark chestnut soils, although soil coverage is limited to approximately 30-40% of the surface. Further east of Astana, soils exhibit increased salinity with salt marshes becoming more widespread, and the vegetation shifts to being dominated by wormwood (*Artemisia absinthium* L.) and ipchak grasses. In the southern part of the region near Lake Tengiz, the landscape is characterized by open expanses of salt marshes covered primarily by wormwood and ipchak species (Saparov, 2014).

2.2. Survey Methods

Protective forest belts play a crucial role in agricultural landscapes, particularly in steppe areas vulnerable to wind erosion and extreme climatic conditions. The Akmola region, situated in central Kazakhstan, is significantly affected by strong winds, droughts, and declining soil fertility. Evaluating forest shelterbelts is essential to understand their condition and effectiveness, as the health and quality of these plantings directly influence soil conservation, prevention of wind erosion, enhanced crop productivity, and the overall sustainability of agricultural environments.

Assessment methods for these field-protective belts can be categorized into several key areas:

1. Morphometric assessment – involves measuring the physical characteristics of the forest belts.
2. Species and phytocenotic analysis – details the composition of trees and shrubs within the belts.
3. Sanitary condition evaluation – determines the overall health and vitality of the shelterbelts.
4. Agroecological efficiency – serves as a critical indicator of the belts' practical benefits to agriculture.

3. Results and Discussion

In the early 1960s, Kazakhstan launched large-scale initiatives to establish forest belts—permeable, semi-permeable, and impermeable—to shield agricultural lands from wind erosion, improve snow retention, and enhance crop productivity. However, recent field assessments reveal that many of these forest belts are now in severe decline and largely ineffective.

A.I. Baraev Scientific and Production Center of Grain Farming six longitudinal and transverse shelterbelts were evaluated, each consisting of three rows of *Ulmus parvifolia, Acer negundo, Caragana arborescens,* and *Populus* spp., planted at 1.5–3 m spacing. Originally intended as permeable windbreaks, the belts have become dense thickets dominated by *Caragana arborescens*, which outcompeted other species. Approximately 80% tree mortality was recorded, and full restoration is now required. This situation supports Temirbekov et al. (2022), Thevs et al. (2017), and Yapiyev et al. (2020), who highlighted the ecological dysfunction of unmanaged shelterbelts, particularly where invasive or fast-growing species dominate.

Kazger LLP: A two-row shelterbelt of *Lonicera tatarica, Amelanchier Medik,* and *Caragana arborescens* was established along grain field edges. Despite recent afforestation attempts, the lack of ecological and silvicultural planning has led to weak protective functions. The case reflects concerns from Imangulova et al. (2020) and Ruppert et al. (2020) regarding poor species selection and absence of adaptive design in Central Asia.

Yesil-Agro LLP: This enterprise maintains 792.8 ha of shelterbelts, established in the 1970s–80s with up to 12 tree and shrub species. Field surveys revealed belts in progressive decline with reduced crown density, weakened vitality, and structural disintegration. The decline is linked to insufficient thinning and delayed agro-technical interventions. Findings correspond to Baitassov et al. (2019) and Sarsekova et al. (2021), who demonstrated that without regular silvicultural treatments, aging belts lose resilience and protective efficacy.

LLP AF “Rodina” (Sadovoye village): Shelterbelts of 2–4 rows, primarily *Populus alba*, were evaluated. The trees, about 60 years old, exhibited:

80–90% mortality with many trees senescent and structurally unstable.

Heart rot prevalent in stumps, increasing fire hazard risk.

Hydrological alterations (uneven snow accumulation and spring waterlogging), negatively impacting sowing.

These findings are consistent with Cheverdina et al. (2023) and Huiliang et al. (2022), who reported that aging monocultures and poorly oriented belts can exacerbate ecological risks rather than mitigate them.

Table 1. Tree mortality by enterprise.

Enterprise / Site	Rows	Dominant Species	Tree Mortality (%)	Main Issues Identified
Baraev Center	3	Elm, Maple, Acacia, Poplar	~80%	Invasive *Caragana*, dense thickets
Kazger LLP	2	Honeysuckle, *Amelanchier*, *Acacia*	High, not quantified	Poor design, low protective effect
Yesil-Agro LLP	Multi-row (1970s–80s)	12 spp. mixed	Moderate–High	Weakening vitality, poor management
Rodina LLP (Sadovoye)	2–4	*Populus alba*	80–90%	Aging monoculture, rot, hydrological imbalance

Table 2. Shelterbelt design characteristics.

Enterprise / Site	Rows	Spacing (m)	Age of Belts	Notes
Baraev Center	3	1.5–3	~60 yrs	Dense thickets, invasive species
Kazger LLP	2	Not specified	Recent	Low ecological guidance
Yesil-Agro LLP	Mixed	Variable	40–50 yrs	Poor thinning, degradation
Rodina LLP	2–4	Not specified	~60 yrs	Old monocultures, structural decline

3.1. Overall Findings

Across all enterprises, the surveyed shelterbelts no longer provide reliable wind protection, snow regulation, or agro-engineering benefits. Instead, they now represent a liability due to:

- High mortality and senescence
- Dominance of invasive or unsuitable species
- Poor structural design and lack of silvicultural care
- Negative hydrological side-effects

Integrated management—including regular thinning, replanting, species diversification, and design adaptation to local soils and climate—is essential for restoring their protective and ecological functions (Baisholanov et al., 2024; Saparov, 2014; Temirbekov et al., 2022).

4. Conclusion

The assessment of field-protective forest belts across several agricultural enterprises in the Akmola region reveals significant degradation in both their structure and functionality. Originally established to combat wind erosion, regulate snow distribution, and enhance crop productivity, many of these shelterbelts have deteriorated due eto aging, poor maintenance, and lack of scientific oversight in their design and restoration.

At NPTsKhZ LLP named after A.I. Baraev, shelterbelts are overgrown, largely dead (up to 80%), and have lost their intended agro ecological function. Similarly, Yesil-Agro LLP's belts, although extensive and species-diverse, suffer from age-related decline and insufficient upkeep, rendering them ineffective. Kazger LLP has initiated afforestation activities; however, the lack of a methodological approach considering local ecological conditions has limited the success of these efforts. In Sadovoye, the situation is particularly critical—most trees in the forest belts are dead or dying, posing not only fire hazards but also negatively impacting field hydrology and delaying agricultural operations.

Across all surveyed sites, it is evident that the shelterbelts are no longer serving their protective, ecological, or agricultural roles effectively. Key issues include high tree mortality, absence of structured agroforestry planning, lack of regeneration efforts, and disruptions to the water regime caused by deteriorated belt structures.

To restore the effectiveness of these critical agro-landscape elements, a comprehensive and scientifically guided reconstruction program is necessary. This should involve:

- Removal of dead and hazardous trees;
- Replanting with locally adapted, drought- and wind-resistant species;
- Regular maintenance, including pruning and thinning;
- Integration of agro ecological and GIS-based planning to optimize shelterbelt design.

Without immediate intervention and long-term management strategies, the degradation of forest shelterbelts will continue to exacerbate soil erosion, reduce crop yields, and compromise the resilience of agricultural systems in Akmola region.

Future research should focus on developing adaptive afforestation models tailored to the region's climatic variability, testing the performance of mixed-species plantations, and exploring digital monitoring tools for long-term shelterbelt management.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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