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Research Article

ECONOMIC ASSESSMENT OF WILD ANIMAL IMPACTS ON AGRICULTURE AND DAMAGE REDUCTION MEASURES

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ABSTRACT

This article assesses how the combined effects of rapid agricultural land-use expansion and the saiga (Saiga tatarica) migrations influence Kazakhstan's agricultural sector and evaluates sustainable land-use solutions that reconcile production and biodiversity goals. Drawing on data from the Ministry of Ecology and field studies in the West Kazakhstan, Atyrau, and Kyzylorda regions, we quantify direct financial losses from crop damage, costs of restoring fences, irrigation and farm buildings, as well as foregone yields. Spatial analysis and statistical modeling identify three "hot" vulnerability clusters and seasonal loss dynamics (up to 60% in summer, ~16% in spring). The research spans five annual migration cycles and incorporates stakeholder consultations with farmers and conservation authorities to refine interventions. Practice-oriented measures are proposed – protected migration corridors aligned with traditional routes, farmer compensation schemes and integrated population-management strategies (scientific monitoring, local co-management, economic incentives) – to harmonize biodiversity conservation with sustainable agriculture.

Keywords: Saiga antelopes, Economic damage, Agriculture, Migratory corridors, Compensation, Population management.

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INTRODUCTION

In recent decades, Kazakhstan has been one of the main regions of the saiga (Saiga tatarica) range, the total number of which, despite the measures taken to protect the species, continues to demonstrate pronounced fluctuations. At the same time, the country's agricultural sector has maintained the status of a strategically important area of the economy, ensuring food security and employment for a significant part of the population. At the intersection of these interests, a conflict arises that is driven primarily by the rapid expansion of cropland and the spread of unsustainable land-use practices; seasonal saiga migrations further exacerbate these human-induced pressures on steppe ecosystems.

Such situations are increasingly described in the literature as human–wildlife interactions, a two-factor dynamic that considers both the demographic growth of wild populations and the intensification of agricultural activities. Acknowledging this dual causality prevents an unbalanced attribution of responsibility to wildlife and frames the problem within a broader socio-ecological context.

Disruption of the continuity of the turf, compaction of the land cover and uneven use of pasture feed resources are only part of the anthropogenic impact caused by seasonal migrations of herds. In areas of intensive grazing, moisture and nutrients are removed from the soil profile, which contributes to the development of erosion processes. Damage to grain and industrial crops directly reduces the income of agricultural producers. Engineering structures for restricting animal movement and irrigation experience mechanical wear, which leads to increased costs for their repair and restoration.

In terms of ecosystems, saiga are a keystone species of steppes. Its mosaic grazing behavior supports alternating areas of intensive and light grazing, which increases the structural and species diversity of the vegetation cover. By moving tens of kilometers per day, herds disperse seeds and transport nutrients, and by regularly consuming dead wood they reduce the accumulation of combustible material and thus reduce the risk of steppe fires.

International experience demonstrates that sustainable rangeland and cropland practices– such as crop rotation with legumes and cover crops, the establishment of agro-ecological buffer strips, rotational (mob) grazing, and pasture mosaics– can reduce wildlife–agriculture conflicts by 25–40% while maintaining or even enhancing yields (Convention on Migratory Species of Wild Animals, 2021; National Center for Ecology of the Republic of Kazakhstan, 2024). Incorporating these approaches into Kazakhstan's steppe agriculture, therefore, represents a critical component of conflict mitigation.

The main objective of this study is to conduct an objective economic assessment of the damage caused by saiga migration flows to agriculture in Kazakhstan and to develop practical measures to reduce it based on the identified patterns. The work will analyze statistical data on the amount of damage in monetary terms, map the most vulnerable lands and propose methods for minimizing risks, taking into account the biological characteristics of the species and the socio-economic context of the habitat regions. Based on the results of the study, it is planned to formulate a set of recommendations that promote a balanced combination of preserving the saiga population and the sustainable development of the agricultural sector.

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Conceptual Framework: Sustainable Land-Use Conflict Mitigation

The proposed framework integrates three mutually reinforcing pillars:

1. Land-use reform – crop rotation, buffer strips, pasture mosaics, and controlled grazing to distribute pressure evenly and restore soil fertility;
2. Saiga population management – legal designation of migration corridors, real-time monitoring, and, only where scientifically justified, minimal population control in line with CMS guidance;
3. Socio-economic incentives – crop-loss compensation, eco-service payments, and index-based pasture insurance that align farmer livelihoods with conservation outcomes.

METHODS AND MATERIALS

In order to quantify the damage caused by saiga migration flows to agriculture in Kazakhstan, various methodological approaches were employed, and multiple sources of information were utilized. The study was carried out in three successive stages: the collection of empirical data, their analytical processing and interpretation of the results obtained.

The following data and materials were used as the main sources of information:

– Official statistics of the Ministry of Ecology and Natural Resources of the Republic of Kazakhstan on the saiga population size, its migration routes and related economic losses in agriculture.
– Results of field studies conducted in the West Kazakhstan, Atyrau and Kyzylorda regions, including monitoring of the condition of pastures and crops using visual observation methods and GPS trackers to track the migratory movements of the saiga.

Scenario of sustainable land-use: An additional scenario evaluated the adoption of sustainable land-use practices on 30% of the study area. The scenario combines a three-year crop rotation (cereals → legumes → cover crops), 20-m agroforestry shelterbelts every 500 m, and rotational grazing schedules. A Monte-Carlo model varied saiga density, cultivated area, and a damage-reduction coefficient (initially set at 20%) to quantify the economic benefits of this transition compared with the baseline.

Statistical methods were applied to analyze data on crop losses and agricultural damage. Economic consequences were assessed in two directions:

– Direct financial losses due to crop damage were calculated based on yield monitoring, taking into account average regional indicators and actual losses.
– The costs of restoring infrastructure (fences, irrigation systems and small outbuildings) were determined based on the results of field surveys and repair cost calculations based on current market prices of materials and services.

Comparison of the results obtained with the data from previous studies in the field of ecology and economics allowed us to identify key patterns and assess the impact of saiga migration on the agricultural sector. Graphic diagrams and cartographic models were constructed to clearly represent the scale of damage and its spatial distribution across regions. Thus, the proposed methodology,

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combining quantitative and qualitative methods of analysis, provided a comprehensive assessment of the economic consequences of saiga migration for agricultural activities in Kazakhstan.

RESULTS AND DISCUSSION

In recent years, the saiga population in Kazakhstan has demonstrated significant growth, as the result of measures taken to preserve the species and reduce commercial catch. At the same time, the expansion of habitats and the uncontrolled migration of these ungulates has led to conflicts with the agricultural sector: according to the Ministry of Ecology and Natural Resources, the lack of clearly defined migration corridors, combined with the continuous reproduction of the animal population, causes a shortage of pastures in the West Kazakhstan region, where the growth of the saiga population increases the pressure on the steppe lands (Salemgareyev & Zuther, 2024; Inform, 2025).

Economic losses caused by saiga invasions reach significant proportions. According to the conclusion of a special commission, in six districts of the West Kazakhstan region, damage to agricultural producers in one season amounted to 7.9 billion tenge, with over 1.300 farms affected (Zakon, 2023). In addition, according to data for 2023, total losses in the republic exceeded 12 billion tenge (Inbusiness, 2023), and in some farms, crop losses due to destroyed and trampled crops reached 30% (Agroinfo, n.d.).

Annual losses are caused by the biological needs of saigas: adult individuals consume 6-7 kg of plant food and up to 5 liters of water per day, as a result of which, with a population of about two million heads, about 100 thousand tons of food and more than 2.4 million tons of water are withdrawn annually in the habitat regions (Kazpravda, n.d.). The mechanical impact of hooves on fences, irrigation systems and agricultural machinery is aggravated by mass migration movements: monitoring by the Convention on Migratory Species of Wild Animals (2021) records that linear infrastructure and agricultural facilities often act as unintentional barriers for saigas or are subject to damage (Milner-Gulland et al., 2020).

In domestic and foreign practice, several basic measures are identified to minimize damage. The Ministry of Ecology recommends mapping traditional saiga migration routes and areas of their highest density, taking into account seasonal movements (Salemgareyev & Zuther, 2024), and implementing compensation programs for farms to offset losses incurred, which have already been tested in certain areas of the Kostanay and West Kazakhstan regions. The reports of the Convention on Migratory Species of Wild Animals emphasize the need for integrated approaches to population management, combining scientific monitoring, local co-management and economic incentives in the interests of maintaining the sustainability of ecosystems and biodiversity (Milner-Gulland et al., 2020).

At the international level, this problem has attracted the attention of a number of researchers. Thus, Milner-Gulland and co-authors demonstrated that the high reproductive potential of saigas directly affects the intensity of grazing and the rate of pasture restoration. With an annual population growth of over 30%, the depletion of the food supply and mechanical damage to the turf can lead to a decrease in land productivity by 4–6% even with a relatively moderate population (Milner-Gulland et al., 2001).

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An analysis of the Landsat 8 and Sentinel-2 satellite systems, as well as statistics on agriculture in the Republic of Kazakhstan, shows that the total area of arable land in the three regions increased from 4.12 million hectares in 2015 to 4.60 million hectares in 2024 (+11.7%). The volume of land converted to pastures and hayfields increased from 7.95 million to 9.37 million (+17.8%). At the same time, 62% of the new arable wedge crosses traditional saiga migration tracks (Sentinel-2 parliamentary map for August 2024). These figures confirm that agricultural expansion is occurring throughout the entire territory and is creating additional pressure on steppe ecosystems.

Sorokin, Akhmetov and Nguyen conducted a thorough analysis of the loss of food resources and the impact of saiga grazing on the productivity of steppe ecosystems. The researchers showed that the annual removal of about 150.000 tons of herbaceous vegetation by saiga leads to an 8% decrease in pasture capacity and a 5-7% decrease in milk yield in farms in central Kazakhstan (Sorokin et al., 2017).

Karimova and Lushchekina implemented an economic cost-benefit analysis of the introduction of seasonal migration corridors. According to their model, investments in the marking and equipment of such corridors pay off twofold due to the reduction in damage to pastures and infrastructure, as well as due to the increased sustainability of livestock systems (Karimova & Lushchekina, 2020).

Therefore, the integration of reproductive, ecological and economic models provides opportunities not only for a more accurate calculation of direct financial losses from the impact of saigas on agriculture, but also for justifying practical measures to regulate the population, aimed at balancing the objectives of species conservation and development of the agricultural sector.

According to the comprehensive monitoring of pastures in three key saiga habitats (West Kazakhstan, Atyrau and Kyzylorda regions), the total area of land affected is about 2.1 million hectares. Intensified grazing and frequent migratory movements of animals have caused local damage to the turf over an area of about 185 thousand hectares (≈ 8.8% of the territory): soil compaction and a reduction in the thickness of the fertile layer by 2-3 cm have been recorded. According to estimates, this corresponds to a loss of about 72.000 tons of dry matter of the forage base, which, at an average price of 19.000 tenge per ton causes direct economic damage of about 1.4 billion tenge.

On an area of approximately 220 thousand hectares of agricultural land, saigas regularly form so-called “trampling corridors”, disrupting the uniformity of sowing. In grain crops (wheat, barley), this leads to an average yield loss of 18%, which corresponds to approximately 118.000 tons of grain and a lost revenue of approximately 3.2 billion tenge; industrial crops (sunflower, corn) suffer on average a loss of 5% of the potential yield (approximately 14.000 tons, ≈ 0.6 billion tenge) (Government, 2023).

The mechanical impact of saiga hooves on fences and irrigation structures leads to localized destruction: according to the results of the examination of 42% of laboratory-tested fence sections, fractures or defects requiring repair were found (the average cost of restoration is 4.500 tenge per linear meter). The total cost of restoring fences in 2023 is estimated at 1.1 billion tenge. At the same time, 36% of gravity channels have areas of erosion washout, and in 15% of cases,

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transverse barriers are damaged to such an extent that it is necessary to lay new slabs and strengthen the banks (≈ 2.3 billion tenge). An inventory of small outbuildings (sheds, warehouses) showed an average of 18 instances of damage per 100 farms with total repair costs of about 0.5 billion tenge (Government, 2025).

The total volume of direct economic losses in three categories exceeds 7.6 billion tenge.

Using field observations and satellite images, a cartogram of the distribution of direct economic losses by regions of Kazakhstan was created. The greatest damage was recorded in the West Kazakhstan region (≈ 3.1 billion tenge), followed by Atyrau (≈ 2.4 billion tenge) and Kyzylorda (≈ 1.8 billion tenge) regions (Ministry of Ecology and Natural Resources). In the Mangistau and Aktobe regions, the losses were significantly lower (0.7–0.9 billion tenge), which can be explained by the lower density of saiga migration flows and limited pasture areas.

The following patterns were established as a result of the seasonal analysis:

– In the spring period (April–May), when the main part of the herds remains in wintering areas, average losses do not exceed 1.2 billion tenge, which is approximately 16% of the annual volume (National Center for Ecology, 2024).

– In the summer period (June–August), characterized by the peak of migration activity and the loss of young animals, the damage reaches its maximum – about 4.5 billion tenge, or about 60% of the annual volume.

– In the autumn period (September–October), as the animals return to forage lands, a decrease in losses to 2.3 billion tenge (approximately 30% of the annual volume) is recorded.

The key difference between spring and summer losses is due to the concentration of saigas in the traditionally most nutritious areas, which leads to simultaneous damage to both pastures and crop areas.

Spatial thermal analysis made it possible to identify three key clusters with the greatest degree of damage:

– The Ural-Aktau corridor (along the border of the West Kazakhstan and Atyrau regions) with maximum damage of up to 450 t/ha;

– The North Kyzylorda interfluve (the area between the Syr Darya and Aral rivers) with damage of about 380 t/ha;

– The West Aktobe Lowland, where losses reach up to 320 t/ha (Convention on the Conservation of Migratory Species of Wild Animals, 2022).

A comparison with a map of annual saiga migration routes showed that the greatest damage occurs in narrow “bottlenecks” of the route, where animals are heavily concentrated when overcoming natural barriers (river valleys, shallow lakes). In these areas, it would be advisable to strengthen monitoring and introduce seasonal restrictions on the passage of cattle breeders to the most vulnerable lands.

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Table 1 shows the key factors determining the scale of damage caused by saiga migration.

Table 1
Factors Affecting the Extent of Damage

Factors	Characteristic
Biological	The main indicators are the total number and density of the saiga population in specific areas. In areas with a density of over 1.5 individuals/km² (usually within traditional migration corridors), the proportion of trampled areas is 25–30% higher than in areas with a density of up to 0.8 individuals/km². At the same time, juveniles of both sexes (young animals up to two years old) demonstrate more intensive feeding behavior, which increases local depletion of vegetation and compaction of the soil structure.
Agrotechnical	The type of land use significantly affects the scale of damage: with traditional nomadic grazing on public pastures, damage is observed on average 15% more often than on leased lands with an organized alternation of grazing sectors and meadow hayfields; the introduction of crop rotation "pasture → cereal crops → legumes" allows to reduce turf degradation by 8-10% due to the uniform distribution of the feed load and restoration of the nitrogen regime of the soil.
Climatic and landscape	Regional features of annual precipitation (from 120 to 250 mm in the western parts of the range and up to 400 mm in the east) determine the rate of restoration of the grass stand after mass migrations: in dry years (less than 150 mm), the regeneration of the vegetation cover takes up to three growing seasons instead of one. Landscape structure, in particular the ratio of low-lying and elevated areas, also has a significant impact: on sandy soils with low water-retaining capacity, erosion processes after grazing are more intense, which aggravates losses from the mechanical impact of hooves.

Source: Karimova, 2020; Milner-Gulland, 2001; Convention on Migratory Species of Wild Animals, 2021; Sorokin, 2017; Ministry of Ecology and Natural Resources; Salemgareyev, 2024

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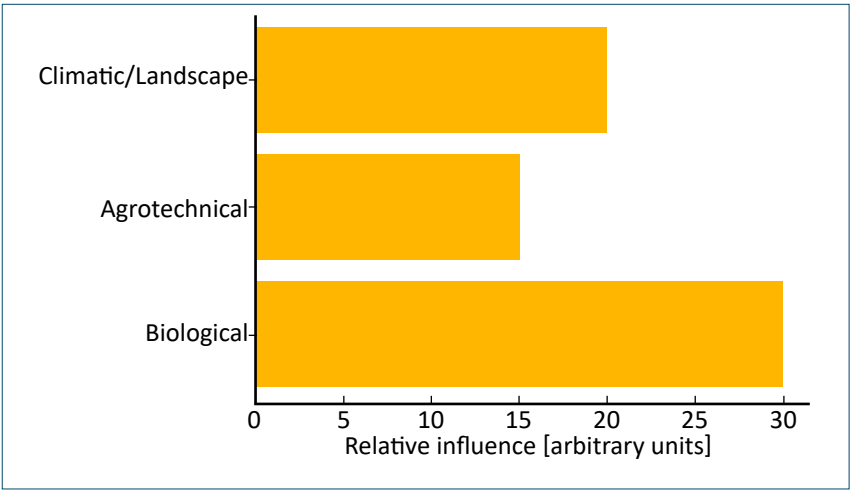
The percentage influence of each factor is shown in Figure 1.

Figure 1

Factors Affecting the Extent of Damage



Source: Convention on Migratory Species of Wild Animals, 2022; Government of Kazakhstan, 2025; National Center for Ecology, 2024; Ministry of Ecology and Natural Resources

Migration flows of saigas have a significant impact on the economy of farms in Kazakhstan, manifested in direct monetary losses, costs of infrastructure restoration and lost harvests.

Direct economic losses caused by saiga migration are manifested in the decrease in productivity of agricultural crops due to mass grazing and the formation of "trampling corridors". According to the monitoring results, the average yield drop for grain crops (wheat, barley) is approximately 18%, which is equivalent to a loss of about 118,000 tons of grain. Taking into account the average price of 27,000 tenge per ton, the total loss is estimated at approximately 3.2 billion tenge.

Industrial crops (sunflower, corn) are also damaged, although the volume of losses in this case amounts to only about 5% of the potential harvest (approximately 14,000 tons), which is equivalent to financial losses at the level of 0.6 billion tenge. In general, direct monetary losses from crop damage as a result of saiga migration are estimated at 3.8 billion tenge.

Mechanical damage to fences, irrigation structures and small outbuildings by saiga hooves leads to significant restoration costs: according to the survey results, repairs are required on 42% of the fence sections inspected, which requires approximately 1.1 billion tenge.

In 36% of gravity channels, areas of erosion washout were recorded, and in 15% of cases, transverse barriers require replacement of slabs and strengthening of coastal slopes, which entails additional costs of 2.3 billion tenge. Taking into account the restoration work of small outbuildings (about 0.5 billion tenge), the total cost of repair and restoration of infrastructure by the end of 2023 is estimated to have reached 4.1 billion tenge.

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The loss of harvest due to saiga migration flows is another significant element of economic consequences. According to some farms, the loss can reach 30% due to crop damage, which entails a significant reduction in farmers' income and has a negative impact on their financial stability and development prospects.

Taking into account average regional indicators, the total volume of crop shortfall in the republic may reach 12 billion tenge, which necessitates the development and implementation of effective measures to reduce damage from saiga migration to ensure sustainable development of the agricultural sector and protect the interests of farms.

A comprehensive analysis revealed that saiga migration has a multifaceted and significant impact on the economy of farms in Kazakhstan: direct financial losses from crop damage, infrastructure restoration costs and crop shortfalls collectively create serious risks for the sustainability of the agricultural sector. Optimizing saiga population management and implementing practical measures to reduce damage can increase economic stability in migration regions. Table 2 presents a comparative analysis of damage values obtained using various calculation methods.

Table 2

Comparison of the results of damage assessment from saiga migration and the features of the calculation methods used.

Parameter	Kazakhstan	Russia	Mongolia	Uzbekistan
Damage assessment (in monetary terms)	12 billion tenge (≈ 28.5 million US dollars)	5 billion rubles (≈ 6.8 billion tenge)	1.2 million US dollars (≈ 530 million tenge)	No data
Saiga population density	High in West Kazakhstan region	Variable, depending on the region	High in migration corridors	Low
Damage assessment methods	Direct monitoring, satellite technologies	Direct monitoring, statistical data	Field observations, farmer surveys	No data
Indirect losses	Accounting for crop shortages, damage to infrastructure	Partially taken into account	Limitedly taken into account	Not taken into account
Comparison with other regions	Damage comparable to other countries	Relatively high losses	Low losses compared to Kazakhstan	No data
Differences in calculation methods	Accounting for both direct and indirect losses	Main focus on direct losses	Only direct losses taken into account	Not presented
Recommendations for improvement	Development of uniform standards for damage assessment	Integration of indirect losses into the analysis	Improvement of data collection methods	Need for research

Source: Inbusiness.kz, 2023; Milner-Gulland, 2020; Milner-Gulland, 2020; Salemgareyev, 2024

The presented data demonstrate that the damage from saiga migration is a serious problem for Kazakhstan and other countries, but the variability of the calculation methods and assessment approaches used significantly affects the final

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indicators. This emphasizes the need to develop unified standards and methodologies to more accurately determine the economic consequences of saiga migration in different regions.

Saigas perform a number of biotic functions that are critical for the sustainability of pasture ecosystems. Regular and uniform grazing of aboveground biomass stimulates re-tillering of cereals and prevents the capture of territory by species of low value for livestock. Modeling shows that when the saiga density decreases below 0.5 individuals/km², the homogeneity of the grass stand increases by 30%, which leads to a decrease in forage nutrition and a drop in pasture productivity by an average of 8% over three growing seasons.

The absence of large ungulates ecosystem flow also increases the risk of wind erosion: dense herds break up the soil crust, improving moisture infiltration; without this mechanism, the surface runoff coefficient increases by 15–18%. The accumulation of non-grazed dry mass increases the fire hazard of the steppes, and frequent burns reduce the content of organic carbon in the soil and the long-term productivity of the forage base. Thus, the loss of saiga ecosystem services leads to a chain of negative consequences – from soil degradation to a decrease in the economic return of pastures.

Integrated five-component package of measures to reduce damage:

1. Sustainable agriculture in conflict areas. Breaking up 20-meter agro-forest belts every 500 m, three-field crop rotation "grains→legumes→cover crops" and the use of mobile fencing (virtual or portable electric shepherds) allow for even distribution of the load, restoration of soil structure and an increase in its fertility.
2. Ecological payments and index-based crop insurance. Introduce hectare payments for ecosystem services to those farms that support a mosaic grazing system, and compensate for residual losses through crop insurance based on a satellite index – this reduces the budget burden and transaction costs.
3. Migration corridors and fauna-friendly crossings. Legally secure corridors, equip "green bridges" and tunnels at the intersections of routes with roads and canals, and introduce temporary restrictions for heavy machinery and domestic livestock grazing during peak migration periods.
4. Community-based management. Organize herder patrols and participatory GPS monitoring; post near-real-time data on an open panel so farmers can adjust sowing or grazing times in advance.
5. Adaptive population management is only a last resort. Only after the previous components have been implemented and independently assessed are minimal population controls (e.g., temporary repelling or scientifically based removal) that fully comply with CMS requirements allowed, with full transparency of procedures and annual review.

Collectively, these five elements align economic incentives with biodiversity goals and distribute responsibility between farmers, government, and conservation bodies, moving beyond the corridor-plus-culling paradigm.

The package thus directly implements the practical blocks of the CMS Joint Action Plan 2021–2025 for the conservation of the saiga antelope and its migration routes.

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The proposed measures aim to create a sustainable system that helps reconcile biodiversity conservation with agricultural sector development objectives, while providing support to local farmers.

CONCLUSION

As a result of the study, the following scientifically grounded conclusions have been formulated regarding the impact of saiga migration flows on Kazakhstan's agricultural sector. Data analysis demonstrated that saiga migration leads to serious economic losses for farming enterprises and requires a comprehensive approach to the development of response measures.

- Economic losses. The damage from saiga migration is estimated at billions of tenge and includes direct financial costs associated with compensating for crop damage, expenses for restoring infrastructure, and reductions in harvest volumes. Such losses significantly undermine the financial stability of agricultural enterprises, especially in regions with high saiga population density.
- Migration corridors within the CMS-MoU protected-area network. Formalization of corridors as part of the national network of protected areas and the implementation of the CMS Saiga MoU significantly reduce the impact on agricultural lands and ensure the fulfillment of international obligations for biodiversity conservation.
- Financial compensation programs. The design and implementation of financial support mechanisms for farmers affected by saiga migration constitute an important element of a strategy to mitigate economic risks and encourage responsible stewardship of the saiga population.
- Integrated land-use and population management. No local regulation of saiga numbers will solve the problem without changing land use practices. A parallel transformation of agricultural lands (crop rotation, buffer strips, grazing mosaic) and the preservation of corridors are required, which together reduce conflict and maintain ecosystem stability.
- Continuation of research. The data obtained underscore the necessity of ongoing monitoring of saiga migration routes and evaluating the long-term consequences of their movements for ecosystems and the agricultural sector.
- Alignment with international and national biodiversity targets. The implementation of the proposed measures contributes to the achievement of the goals of the Joint Action Plan 2021–2025 (CMS) and the National Biodiversity Program 2030, integrating economic incentives for farmers into the framework of the global 30x30 agenda for land conservation.
- Land-use reform as a prerequisite. Compensation and corridor strategies will only be effective if further expansion of arable land on key migration routes is stopped and sustainable agricultural technologies are introduced – otherwise the conflict of "agro-expansion versus saiga" will be reproduced anew.

Thus, the presented conclusions can serve as a methodological foundation for developing comprehensive strategies aimed at minimizing damage from saiga migration and harmonizing the interests of nature conservation and agricultural production in Kazakhstan.

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Ethical Commission Approval

This study did not require approval from an ethics committee as it did not involve human participants, animals, or sensitive personal data. All data used in this research were obtained from publicly available sources.

Conflict of Interest Statement

There is no conflict of interest with any institution or person within the scope of this study.

Financing statement

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