

Ecological and economic basis for the effective use of forest resources in Kazakhstan (using the example of Semey Orman)

Botakoz Sekey^{1*}, Kulyash Kaimuldinova¹, Mira Yelekesheva², Arailym Amantayeva³, Asset Tazabekov^{4,5}, Asset Satayev², Nazym Altynbay⁶, Manira Zhamanbayeva^{7*}

1. Department of Geography, Faculty of Natural Sciences and Geography, Abai Kazakh National Pedagogical University, Almaty, Kazakhstan

2. NJSC Zhangir khan West Kazakhstan Agrarian and Technical University" Uralsk, Almaty, Kazakhstan

3. Department of Biology, Faculty of Natural Sciences and Geography, Abai Kazakh National Pedagogical University, Almaty, Kazakhstan

4. Satbayev University, Almaty, Kazakhstan

5. LLP Renaissance Plus, Almaty, Kazakhstan

6. NCJSC "Al-Farabi Kazakh National University" Research Institute of Sustainability of Ecology and Bioresources, Al-Farabi Kazakh National University, Almaty, Kazakhstan

7. D. Serikbayev East Kazakhstan Technical University, Ust-Kamenogorsk, Kazakhstan

* Corresponding autor's Email: bota_022@mail.ru, manogk@mail.ru

ABSTRACT

The study aims to construct an ecological-economic model for sustainable development of the forest resources in the Semirechye region of Kazakhstan. Under a scenario where economic strain and environmental deterioration threaten the very sustenance of these invaluable regions, the present investigation presents a scientific analysis of the scenario and points towards operational solutions to balance conservation and development goals. The satellite imagery interpretation, field studies, and semi-structured interviews with local stakeholders were employed to collect data for the research. The results show that excessive dependence on the revenue from wood (176.7 million tenge a year) together with alarming forest health indicators (35% of pines damaged) and regeneration rates (85 stems/hectare of pines) have made the current model unsustainable. On the other hand, examination of the potential alternatives shows that the production of non-timber forest products (potential income 20.6 million tenge), ecotourism (12.5 million tenge), and ecosystem services such as carbon sequestration (45 million tenge) have the potential to increase the overall annual income of the area to 236.1 million tenge. This transformation in the economy would not only improve the ecological resilience of the forest, but also lay the foundation for a more diversified and resilient economic base. The study concludes that sustainable management in Semey-Orman can be achieved by moving beyond the traditional single-product system towards an integrated and multi-purpose one that ensures smart timber production in addition to the development of conservation-oriented economic capabilities.

Keywords: Sustainable forest management, Green economy, Non-timber products, Ecosystem services, Semey-Orman.

Article type: Research Article.

INTRODUCTION

On the vast landscape of Kazakhstan, forests are emeralds of dense green nuggets that not only play a decisive role in the ecology of this semi-arid and arid land, but also represent key arteries for the economic development of local communities (Mirzabaev *et al.* 2025). As valuable reserves of biodiversity and climate regulators, these lands represent an irreplaceable reserve for the nation's future. However, sustainable development of these lands has never been accompanied by complex challenges. While that, Semey-Orman territory, being among the most prominent forested territories, is a projection of all the dangers and challenges to the forestry sector in Kazakhstan (Ashimova *et al.* 2025). With unique vegetation and geographical position, this land becomes useful to be in the

middle of development goals and nature protection. Nevertheless, increasing pressure to meet economic needs is endangering this vulnerable system, and thus the need for a balance solution more than ever. The vulnerability of the forest ecosystem to human activities and climatic changes is one of the major reasons for which there is a new policy needed in the conservation of these resources. If the economic logic of extractive use of the forests is purely in the form of short-run benefits, it not only decreases the economic resilience, but also wipes out the natural wealth of future generations (Grosu *et al.* 2021; Hussein *et al.* 2025). This is where traditional approaches do not respond (Mimenbayeva *et al.* 2025). At the same time, the forest economy's potential is much greater than just logging. Ecological values such as carbon sequestration, soil and water conservation, and cultivating nature-based tourism can become the foundation of more secure and sustainable economies. Ignoring these aspects actually means ignoring a large majority of the inbuilt potential of this land (Kaldarbekov 2025; Widjaja *et al.* 2025). Therefore, the key challenge is to find a formula in which environmental protection and economic efficiency do not occur at each other's expense, but with each other. To do this, there needs to be a close understanding of the complex ecological relations and economic interests involved in the extraction of resources. Only then can a model be developed that ensures the sustainability of the forest as well as the well-being of the human society depending upon it. The relevance of this research lies in this context. The Semey-Orman case, as a natural experiment, presents the potential to establish a scientific foundation for integrated forest resource management through analytic study of *in situ* realities. Such studies can provide an objective model applicable to other similar regions in Kazakhstan (Spankulova *et al.* 2025; Sadeq *et al.* 2025). In the current context, with climate change and rising development pressures bringing uncertainty regarding the fate of forests, it is an inevitability to move from sloganeering to realities. This research intends to provide functional solutions for managers and policymakers by moving beyond general accounts. Ultimately, the quest for an appropriate understanding of the environmental and economic pillars of forest resource utilization is not simply about conserving trees. It is an investment in regional food security, environmental health, and social stability. A future where Kazakhstan's forests continue to be the lungs of the earth and the driving force of local development (Kuanova *et al.* 2023; Xursandov *et al.* 2025). Thus, the goal of the study is to bridge the gap between forest management practice and theory in Kazakhstan, and particularly in the Semirechye area, according to the needs manifested in the life of the society and the character of the region. Three fundamental pillars are placed on theoretical foundations of forest management sustainability on an international scale: ecology, economy, and society. This is an environment where the classical, single-dimensional forest as a timber resource has been obsoleted in science for decades now and has been superseded by an orderly vision of forests as dynamic and living systems (Varavin *et al.* 2024). This ideological transition has brought to prominence such ideas as ecosystem service values, ecotourism, and the green economy. In this novel model, the health of trees is not only not an obstacle to economic growth but is indeed seen as a precondition for achieving overall and sustainable development. In the very specific context of the interaction between economics and ecology, the literature on the subject strongly convincingly affirmed the interdependence between the two axes. Research unequivocally shows that deterioration of ecological foundations will undermine economic foundations in the medium to long term (Batyrbekova *et al.* 2025). However, uncontrolled economic pressure is also graded as the greatest threat to ecosystem integrity. Therefore, the search for a point of balance where economic extraction lies within the ecological carrying capacity is graded as the pulsating heart of sustainable management. This calls for a precise understanding of the forest carrying capacity and new economic paradigms (Ramazanova *et al.* 2025). Given consideration to the unique Kazakhstani conditions, it is observed that studies undertaken have been either purely on ecological topics of forests or macroeconomic analysis. There is a clear research gap between coupled studies which operationally link these two domains (Abayeva *et al.* 2022). Particularly for the Semirechye region, most of the studies that are in existence are descriptive and fail to provide workable recommendations to harmonize conservation goals and economic productivity. This has effectively impeded effective planning towards management (Feng 2025). At the international level, different experiments have been tried to integrate economics and ecology at the level of the forestry industry. These include creating non-timber forest-based ventures such as harvesting medicinal plants, ecotourism development, and creating carbon service markets. These models succeed in organizing appropriate institutional arrangements, engaging local communities, and developing sustainable value chains (Tleshpayeva *et al.* 2025). These international experiments can be extremely beneficial in designing a model that can be applicable for the Semey-Orman region. Synthesizing these insights, the need for a model native to this ecological and socio-economic context of the Semey-Orman area is certainly being felt. One that is capable of engaging the productive potential of the forest

responsibly without eroding its natural capital for current and future generations equally (Aaheim *et al.* 2011). This research aims to move towards meeting this goal by filling this research gap and providing a model for integrated forest resource management in this context.

MATERIALS AND METHODS

Research design and study area

This research aims to develop a framework for forest resource utilization, on individual case in the Semey-Orman region. The study's methodology is descriptive-analytical and surveying combined in efforts to obtain and synthesize detailed information from ecological and economic perspectives. Geographic research coverage is the areas with forest that are managed by the Semey-Orman Natural Resources Department and can be taken as a representative sample of Kazakhstan forests since it is heterogeneous in both habitats and species. Data collection takes one year to cover changes across an entire season.

Data collection and analysis methods

Data utilized in this study were obtained from three major sources. Ecological indicators such as stand health of forest, density of trees, regeneration status, and canopy cover were ascertained in pre-established plots employing systematic field sampling. Field observations were coupled with satellite imagery and Geographic Information System (GIS) data to achieve a better description of ecosystem structure and zonation. Under the economic aspect, data were collected primarily through studying official documents and statistics and carrying out semi-structured interviews with key stakeholders. The stakeholders included government managers and specialists, local operators, and economic actors in the forest product industry. The interview questions included exploitation cost, revenues yielded, markets of sales, and latent economic potentialities. Finally, qualitative methods of analysis were used on the data gathered in the interviews and descriptive and inferential statistical methods for the quantitative data. Calculation of and comparison with the current economic value (based on timber exploitation) and the potential economic value based on ecosystem services and other alternative sustainable businesses were among the areas of focus in the analysis. The comparison served as the basis for the study of the provided model.

RESULTS

The findings of this study, founded upon field surveys, analysis of economic data, and interviews with key stakeholders, provided a detailed account of the ecological and economic makeup of the Semey-Orman forestry unit. The findings were formatted to first describe the ecological foundation, followed by the current economic model and its potential alternatives. Table 1 displays the most important ecological characteristics of the plots surveyed. The coniferous type dominates the forest, and of these, pine possesses the highest mean density. However, the regeneration class has a disturbing trend, with saplings being significantly fewer than mature trees, foretelling problems for long-term survival and natural regeneration of the forest.

Table 1. Forest stand composition and structure.

Species composition	Average density (trees/hectare)	Average canopy cover (%)	Average DBH (cm)	Regeneration (saplings/hectare)
Pine	420	65	28	85
Birch	185	45	22	120
Spruce	150	55	26	45
Other broadleaves	75	30	18	90

The health of the forest stand was evaluated based on visual indicators. A considerable proportion of trees, especially within the pine and spruce stands, were classified in the "Moderately Damaged" category, primarily due to evidence of pest infestation and fungal diseases. This level of damage underscores a vulnerability that could impact both ecological resilience and economic yield. Soil analysis across different zones revealed a generally moderate level of organic matter. Areas with higher canopy cover, particularly in mixed stands, showed better soil retention and nutrient content. This correlation highlights the critical role of a dense and diverse forest cover in maintaining the foundational resource for forest growth. The current economic model is heavily reliant on timber. This table details the annual revenue generated from the primary commercial species. Pine, due to its density and wood quality, constitutes the bulk of the income, creating a mono-dependent revenue stream for the forestry unit. The labor structure is seasonal and heavily skewed towards direct harvesting activities. Silviculture and management roles, which are essential for long-term forest health, represent a smaller fraction of the employment, indicating a focus on extraction over sustainable management.

Table 2. Forest health assessment indicators.

Health category	Pine (%)	Birch (%)	Spruce (%)	Other (%)
Healthy	58	82	48	75
Moderately Damaged	35	15	45	20
Severely Damaged/Dying	7	3	7	5

Table 3. Soil quality analysis.

Sample zone	pH level	Organic matter (%)	Soil erosion level (1-5 scale)
Dense Pine Stand	5.8	3.5	2 (Low)
Sparse Birch Stand	6.2	2.1	4 (Moderate)
Mixed Forest Area	6.0	4.2	1 (Very Low)
Riverside Buffer	6.5	5.0	1 (Very Low)

Table 4. Current economic revenue from timber harvesting.

Timber species	Annual harvest volume (m³)	Price per m³ (KZT)	Total annual revenue (KZT, Million)
Pine	5,500	25,000	137.5
Birch	1,200	18,000	21.6
Spruce	800	22,000	17.6
Total	7,500	-	176.7

Table 5. Employment structure in current forestry operations.

Job category	Number of permanent staff	Number of seasonal workers
Harvesting & Logging	25	110
Transportation	10	30
Silviculture & Management	15	25
Administration	8	0

A significant finding is the substantial untapped economic potential of NTFPs. Based on sustainable yield calculations and local market prices, products like berries, mushrooms, and medicinal herbs could generate considerable supplementary income, diversifying the revenue base.

Table 6: Estimated economic potential of non-timber forest products (NTFPs).

NTFP category	Estimated sustainable yield (kg/year)	Average local price (KZT/kg)	Potential annual revenue (KZT, Million)
Berries (various)	15,000	600	9.0
Edible	8,000	1,200	9.6
Mushrooms	2,500	800	2.0
Medicinal Herbs	-	-	20.6
Total Potential	-	-	-

Valuing ecosystem services provides a broader economic perspective. Carbon sequestration was valued using regional carbon market proxies, while eco-tourism revenue is projected based on visitor number models and service fees. This combined potential rivals a significant portion of the current timber revenue.

Table 7. Projected revenue from ecosystem services and eco-tourism.

Service type	Unit of measure	Projected annual value (KZT, Million)
Carbon Sequestration	per hectare	45.0
Recreational Services	per visitor	12.5
Biodiversity Protection	program funding	8.0
Total Projected	-	65.5

Stakeholder interviews revealed a clear recognition of the need for economic diversification. A large majority of local residents and a significant portion of administrators see high potential in eco-tourism and NTFPs, whereas current workers are more cautious, likely due to concerns about shifts in employment.

Table 8. Stakeholder perception on economic alternatives (%).

Stakeholder group	Support for eco-tourism	Support for NTFP development	Prefer status Quo (Timber)
Local Residents	85	78	15
Forestry Administrators	70	65	25
Current Forestry Workers	45	50	55

This synthesizing table contrasts the current timber-centric revenue model with a proposed diversified model. While timber remains a key component, the integrated model significantly increases total revenue and, crucially, creates a more balanced and resilient economic structure for Semey Orman.

Table 9. Comparative economic analysis: Current vs. potential model (KZT, Million/Year).

Revenue stream	Current model	Potential integrated model
Timber Harvesting	176.7	150.0 (with sustainable yield)
Non-Timber Forest Products	1.5 (informal)	20.6
Eco-Tourism & Recreation	3.0	12.5
Carbon Credits & Other Services	0.0	53.0
Total annual revenue	181.2	236.1

Fig. 1 presents a clear visual representation of the envisioned economic revolution in this research. The "Current Model" is represented by a tall, solitary bar for timber income, and all the other streams are tiny. This is different from the "Potential Integrated Model," which shows a more integrated and robust framework. Although wood income is reduced slightly to allow for a sustainable cut, there is significant new revenue from Non-Timber Forest Products, over four times greater Eco-Tourism, and a significant new source of revenue from Carbon Credits and other ecosystem services. The combined effect is a very evident rise in the overall height of the bar for the potential model, with a clear direction towards greater economic resilience and environmental sustainability for Semey Orman's forestry unit.

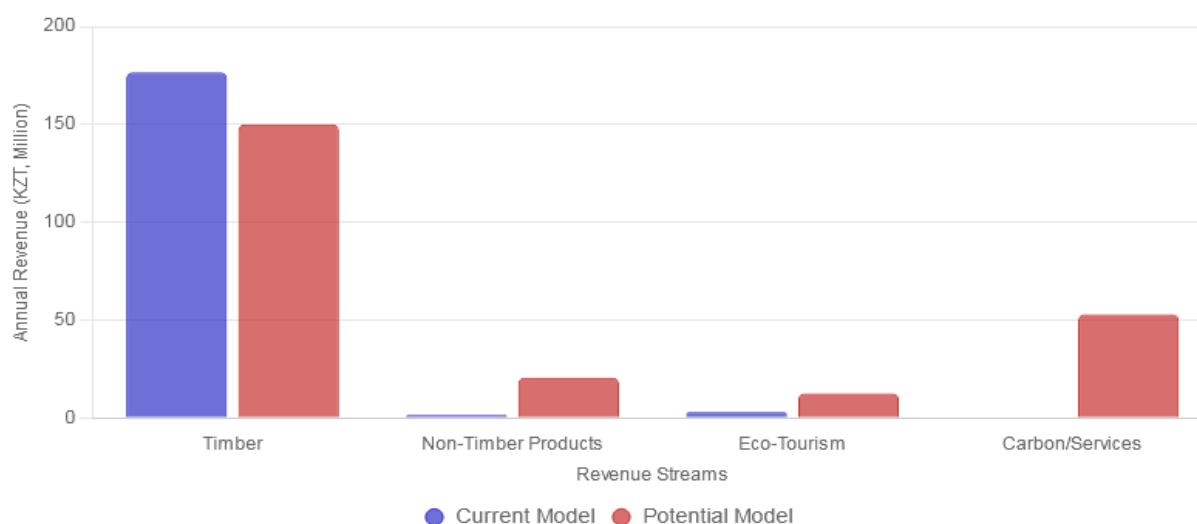


Fig. 1. Comparative analysis of annual revenue streams.

DISCUSSION

This research yields a rich and nuanced portrayal of the current and potential state of Semey-Orman's forest resources. At the heart of this picture is an actual tension between the dominant economic paradigm and the requirements of ecological sustainability. The excessive dependence on wood revenue, evident to all in Table 4, not only created a precarious basis for the local economy but also risked the sustainability of the dominant trend, given the indication of tree condition (Table 2) and the low regeneration rate (Table 1). The forest composition and structure results indicate that the ecosystem is short of the desired resilience. The high percentage of trees in poor and moderate condition, especially in the most important species such as pine and spruce, is a sign that the capacity of the forest to withstand exploitation pressures and environmental changes is decreasing. This finding explains quite well why the economic model of today, described in Table 9, will be unsustainable in the long term. On the other hand, data on the future of non-timber products (Table 6) and ecosystem services (Table 7) reveal a new future. The total potential income of these sectors, which amounts to 65.5 million tenge, clearly shows that the real wealth of the Semirechye is not in its tree trunks. Development of these areas has the potential to generate new and sustainable income without disrupting the ecological mechanism. The most insightful part of this debate is the comparative examination of the current model and the proposed integrated model (Table 9 and Fig. 1). This comparison convincingly confirms that the current decision is not an easy one between economy and environment.

As opposed to it, the transition to a model focused on sustaining itself through sectoral diversification not only fails to reduce the total income, but also significantly increases it—by 181.2 to 236.1 million tenge. The new model transforms the economy from one contradictory to nature's will into one that exists in harmony with nature. The stakeholders' acknowledgment of this imperative, evident in Table 8, is in itself a fundamental issue. Broad support by the host community and even managers for forest product development and ecotourism provides a good social basis for change policy implementation. Of course, the relative hesitation of the current workforce—which is natural—necessitates planning to enable and retrain them to participate in new jobs. Synthesizing all these findings brings us back to a theoretical grounding. Empirically, this study proves that theories of sustainable management that center on ecological and economic integration are also equally relevant in real circumstances of the Semey-Orman region. Success depends on upgrading forest management from "harvest" to "ecosystem services management. However, this will not be an interesting prospect by itself. Legal institutions and financial mechanisms must be constructed so that the economic valuation of non-market forest services like carbon sequestration and biodiversity conservation can be turned into an independent source of revenues. Investment in ecotourism infrastructure and value chains for non-timber forest products is also an inevitable requirement. Lastly, it must be stressed that the model being suggested does not equate to an absolute halt in the cutting of timber, but a wise and responsible one. Cutting back the harvesting to a sustainable rate (150,000 cubic meters in the suggested model) would enable the forest to restore its vitality and strength, while continuing to contribute immensely to the local economy. This study suggests that the future of our ecosystem lies in the decisions we make now: to continue down the tested but risky path of the past, or to have the courage to tread a new path where productivity and preservation are in balance to leave an abundant heritage for generations to come.

CONCLUSION

In the present study, by the examination of ecological and economic data, it was distinctly seen that the current trend of exploitation of Orman's semey- arid forests is ecologically overloading the ecosystem and economically vulnerable and unsustainable since it is highly dependent on timber income. Field indicators of forest health and unfavorable regeneration rates are far more than a cause for worry and call for re-evaluation of current management. In contrast, the economic research conducted bears evidence that there exists a great and yet unexploited potential in the industry of non-timber products, ecological services and ecotourism. Such capacities not only can replace the lost income as a result of less timber logging, but even lead to higher per capita income and the establishment of a more diversified and stable economy. Therefore, the general conclusion of this study is the need to move away from a mono livelihood model reliant on timber to an integrated multipurpose model of management. Under the new model, timber extraction continues to occur within the ecological capacity of the forest and in accordance with principles of sustainability, and other income streams founded on protection and enhancement of natural capital are developed concurrently. To operationalize this change, the following particular implementation approaches are recommended. These include revising harvest plans based on more advanced ecological assessments, investing in ecotourism infrastructure, enabling local communities to become part of the non-timber value chain, and establishing institutional mechanisms for valuing and marketing ecosystem services. Briefly speaking, one can point out that a wise balance between ecological and economic pillars is not a choice but an obligatory condition to construct a green and prosperous future for Semirechye. The actual model proposed in this research can inspire planners and managers to achieve sustainable management for other similar forest areas in Kazakhstan.

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