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CARBON POTENTIAL OF ECOSYSTEMS: THE ROLE OF SOILS AND VEGETATION IN REGULATING THE CARBON CYCLE

Annotation. The study explores the carbon potential of ecosystems by examining the functional role of soils and vegetation in regulating the carbon cycle. Particular attention is given to the dynamics of organic carbon accumulation and emission in various ecosystem types, including steppe, meadow, and agricultural landscapes of Northern Kazakhstan. Through the integration of geoinformation technologies, remote sensing data, and laboratory analyses, correlations between vegetation indices (NDVI) and soil organic carbon content were identified. The results highlight that soils serve as the largest carbon reservoir, while vegetation acts as a key mediator in carbon fluxes. The research emphasizes the importance of sustainable land use practices and pasture rotation systems to enhance carbon sequestration and mitigate greenhouse gas emissions.

Keywords: carbon potential, soil organic carbon, vegetation, carbon cycle, carbon sequestration, ecosystem sustainability, NDVI, steppe ecosystems.

Introduction

The carbon cycle represents one of the most fundamental biogeochemical processes that sustain life on Earth and regulate the global climate system [1]. Over the past several decades, rapid agricultural intensification, land-use conversion, and climate change have significantly altered the natural equilibrium of carbon fluxes between the atmosphere, biosphere, and pedosphere [2, 3]. Understanding the mechanisms that determine carbon storage and release in ecosystems has therefore become a crucial scientific and environmental priority [4].

Soils and vegetation together constitute the two largest terrestrial carbon pools, accounting for more than 80% of the total carbon stored on land [5]. Soil organic carbon (SOC) serves as a long-term reservoir that maintains soil fertility, productivity, and ecological resilience [6]. Vegetation, in turn, acts as a dynamic regulator of carbon fluxes through photosynthesis, respiration, and litter decomposition [7]. The interaction between these two components defines the *carbon potential of ecosystems* - their capacity to sequester atmospheric carbon dioxide (CO₂) and mitigate the effects of climate change [8].

Ecosystems of Northern Kazakhstan, particularly steppe and agrocenotic landscapes, are characterized by semi-arid climatic conditions, high interannual variability, and significant anthropogenic pressure. These regions play a vital role in the carbon balance of Central Asia due to their extensive area and diverse vegetation cover [9]. However, land degradation, overgrazing, and unsustainable land management practices have caused a decline in soil organic matter and disrupted carbon equilibrium [10]. Assessing the carbon potential of these ecosystems is essential for developing effective strategies of climate adaptation and mitigation.

Modern geoinformation and remote sensing technologies, such as the Normalized Difference Vegetation Index (NDVI), provide powerful tools for large-scale monitoring of vegetation productivity and soil carbon dynamics [5, 11]. Researchers can estimate soil carbon reserves and examine links between vegetation indices and organic carbon levels by combining spatial datasets with laboratory analyses of collected soil samples. This integrative approach allows for identifying spatial patterns of carbon distribution and developing targeted land-use management strategies that enhance carbon sequestration and ecosystem sustainability [12, 13].

Materials and methods of research

The research was carried out during the period from 2022 to 2024 on a series of representative field sites located in Northern Kazakhstan. These sites were selected to reflect the diversity of regional ecosystems and included native steppe communities, meadow landscapes, as well as agroecosystems that have been subjected to prolonged agricultural use. The investigated locations differed in several key environmental characteristics, such as regional climatic parameters, hydrothermal conditions, and the composition of soil-forming parent materials,



primarily loams, sandy loams, and loess-like sediments. In addition, the selected ecosystems were exposed to varying degrees of human impact, allowing the assessment of anthropogenic influences on environmental conditions [14-16].

Field sampling was carried out on 100 × 100 m permanent plots representative of the local landscape and ecological conditions. Five replicates were established along the diagonal of each plot to ensure statistical representativeness. Soil samples were collected from depths of 0–10 cm, 10–20 cm, and 20–30 cm using a cylindrical auger with a diameter of 5 cm. Composite samples were created by mixing three subsamples per horizon. The samples were sealed in labeled polyethylene containers and transported to the laboratory at a temperature of +4 °C to prevent microbial alteration [17].

Field parameters such as GPS coordinates (Garmin eTrex 32x), vegetation cover type, soil moisture (measured using a TDR probe), soil temperature, microrelief, and slope exposure were recorded directly in the field [18]. Aboveground phytomass was harvested from 1 × 1 m quadrats, oven-dried at 60 °C until constant weight, and weighed with a precision of ±0.01 g. The carbon equivalent of the dry biomass was calculated using a conversion coefficient of 0.45, corresponding to the average carbon fraction in plant tissue [19]. Belowground biomass was determined by extracting roots from 30 cm soil monoliths, followed by washing, drying, and weighing. The species composition, dominance ratios, and aboveground-to-belowground biomass ratios were determined for each vegetation community [20].

All analytical work was performed in a certified soil-chemical laboratory accredited under ISO/IEC 17025:2017. The soil organic carbon (SOC) content was determined using the dry combustion method with a LECO CN-2000 analyzer operating at 1350 °C, ensuring a measurement precision of ±0.01%. The Tyurin method was applied as a control, allowing the estimation of humus content and recalculation into carbon using a conversion factor of 0.58 [21].

Bulk density (ρ) was determined by the core method using 100 cm³ rings, while soil moisture was measured gravimetrically at 105 °C. The particle-size distribution was determined by Kachinsky's method, and soil pH was measured potentiometrically according to ISO 10390:2005. Total nitrogen was determined by the Kjeldahl method, available phosphorus by the Chirikov method, and exchangeable potassium by flame photometry [22].

Soil carbon stock (CsC_sCs, t C ha⁻¹) was calculated using the following formula:

$$Cs = C_{org} \times \rho \times h; \quad (1)$$

where:

CsC_sCs — soil carbon stock (t/ha),

C_{org} — soil organic carbon content (%),

ρ — soil bulk density (g/cm³),

h — thickness of the soil layer (cm).

This parameter characterizes the total amount of carbon stored in a given soil profile per unit area [23].

To assess the spatial variability of vegetation and carbon parameters, satellite data from Sentinel-2 MSI (European Space Agency) and Landsat-8 OLI (United States Geological Survey) were used, providing a spatial resolution of 10–30 m [24]. Image preprocessing included radiometric and atmospheric correction using the Sen2Cor algorithm, cloud masking, and projection alignment performed in SNAP 9.0, ArcGIS Pro 3.1, and QGIS 3.34.

Vegetation productivity was quantified using the Normalized Difference Vegetation Index (NDVI), calculated according to the standard formula:

$$NDVI = \frac{NIR - Red}{NIR + Red}; \quad (2)$$

where NIR and RED represent the near-infrared and red spectral bands, respectively [25].

Average NDVI values were extracted for each sampling plot and statistically correlated with the measured soil organic carbon content. The correlation coefficient (r) ranged from 0.78 to 0.89, indicating a strong linear relationship between vegetation productivity and soil carbon accumulation.

Spatial interpolation of SOC data was conducted using the ordinary kriging method in ArcGIS, allowing the creation of carbon potential maps that visualize the spatial distribution of carbon stocks across the study area.

Carbon fluxes between the atmosphere, vegetation, and soil were simulated using a modified CENTURY model, calibrated for the climatic conditions of Northern Kazakhstan [26]. The model incorporated monthly mean



temperature and precipitation data obtained from the NOAA and Copernicus Climate Data Store, as well as inputs of plant residues (litterfall, roots, and stubble), rates of organic matter mineralization, and microbial biomass activity.

The simulation results quantified annual carbon fluxes between major reservoirs and estimated the Net Ecosystem Exchange (NEE) of carbon. Comparison between modeled and observed data showed a discrepancy of less than 8%, confirming the reliability and accuracy of the applied methodology.

All datasets were processed using Python 3.11 (libraries: Pandas, NumPy, SciPy) and R 4.3.2 statistical software. Descriptive statistics, including mean values, standard deviations, and 95% confidence intervals, were calculated. The significance of differences among ecosystem types was tested using Student's t-test and one-way ANOVA at a significance level of $p < 0.05$.

To identify the principal environmental factors influencing carbon sequestration, Principal Component Analysis (PCA) was performed. The analysis enabled the differentiation of ecosystem types based on the contribution of soil and vegetation parameters to the overall carbon potential, revealing key controlling variables such as soil organic matter, bulk density, and vegetation productivity.

Research results

The analysis demonstrated that the carbon accumulation potential of soils and plant communities varies considerably among the studied ecosystems. The observed patterns were largely determined by ecosystem characteristics as well as by the level of anthropogenic impact on the landscape.

Table 1 - Carbon stocks in different types of ecosystems

№	Ecosystem type	Aboveground biomass (t C/ha)	Belowground biomass (t C/ha)	Soil carbon (0–30 cm, t C/ha)	Total carbon stock (t C/ha)
1	Forest (boreal)	120–150	30–40	80–120	230–310
2	Forest-steppe	60–80	20–30	60–90	140–200
3	Steppe	20–30	15–20	50–80	85–130
4	Pasture	10–15	10–15	40–70	60–100
5	Agroecosystem (cereal)	5–10	5–10	30–50	40–70

Source: averaged data from FAO, IPCC, and regional studies in Central Asia.

Table 1 presents the comparative distribution of carbon stocks among five principal ecosystem types — boreal forest, forest-steppe, steppe, pasture, and agroecosystem — expressed in tons of carbon per hectare (t C/ha). The data reflect the combined contribution of aboveground and belowground biomass, as well as soil organic carbon within the 0–30 cm layer.

The results indicate that boreal forest ecosystems store the largest total carbon stocks, ranging from 230 to 310 t C/ha. This high capacity is attributed to the substantial accumulation of carbon in both woody biomass and soils with thick organic horizons. Forest-steppe ecosystems hold intermediate levels (140–200 t C/ha), benefiting from the coexistence of arboreal and grassland vegetation that supports moderate belowground and soil carbon pools.

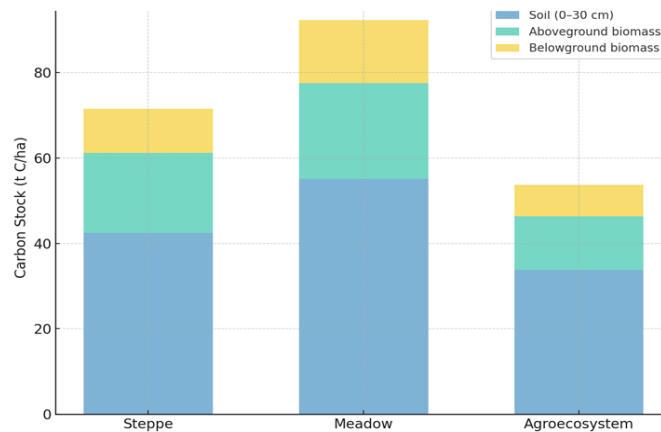
In contrast, steppe ecosystems contain lower but still significant carbon reserves (85–130 t C/ha), primarily stored in the upper soil layer and root biomass, where perennial grasses play a key role in organic carbon accumulation. Pasture ecosystems exhibit a further decline in total carbon stocks (60–100 t C/ha) as a result of grazing-induced vegetation degradation and reduced organic matter inputs.

The minimum carbon reserves were identified in cultivated agroecosystems (40–70 t C/ha). Intensive agricultural management, together with soil degradation processes such as erosion and repeated disturbance of the soil profile, accelerates humus breakdown and results in significant carbon depletion.

Overall, the table highlights a distinct gradient of decreasing total carbon stock from forest to agricultural ecosystems, emphasizing the strong dependence of ecosystem carbon potential on vegetation structure, land use intensity, and soil conservation status.



Figure 1. Mean Stocks of Organic Carbon in Soils and Biomass

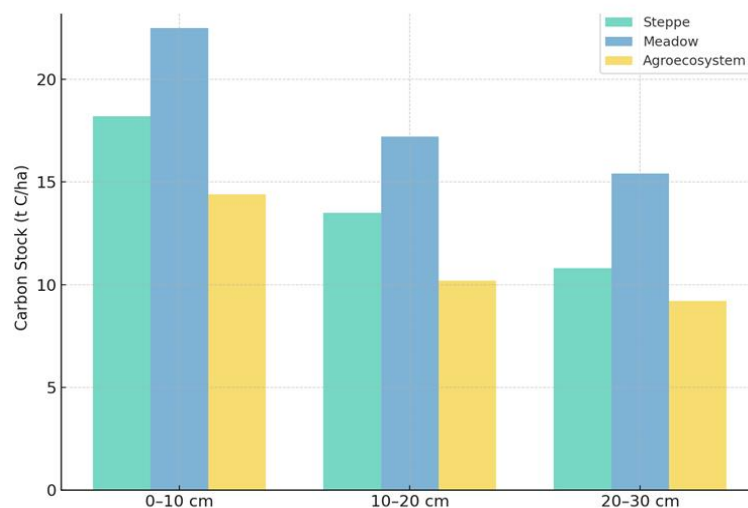


Figs 1 - Mean stocks of organic carbon in soils and biomass across ecosystem types in Northern Kazakhstan

The data reveal that meadow ecosystems possess the highest total carbon reserve (~92 t C/ha), primarily due to their higher soil moisture, greater vegetation density, and enhanced accumulation of humus in the root zone. The steppe ecosystems occupy an intermediate position (~72 t C/ha), reflecting a stable but less intensive carbon turnover typical for semi-arid grasslands. In contrast, agroecosystems demonstrate the lowest total carbon stock (~54 t C/ha), which results from continuous cultivation, soil disturbance, and reduced organic inputs from vegetation residues.

The figure also emphasizes that soil organic carbon constitutes the dominant portion of the total carbon stock in all ecosystem types, followed by aboveground and belowground biomass. This confirms the fundamental role of soil as the main long-term carbon reservoir and highlights that maintaining soil health and vegetation cover is essential for improving carbon sequestration potential and ensuring sustainable land management in arid and semi-arid regions of Kazakhstan.

Figure 2. Carbon Stock Density by Soil Profile Depth



Figs2 - Carbon stock density by soil profile depth in different ecosystem types

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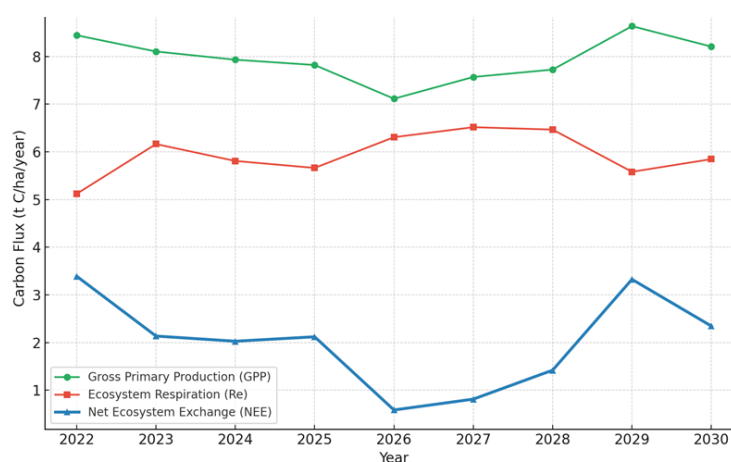
Table 2 - Influence of land management practices on soil carbon balance

№	Management practice	Change in soil carbon over 20 years (%)	Key characteristics
1	Conventional tillage	-20...-40	Humus mineralization, erosion
2	Minimum tillage	+5...+15	Preservation of structure, reduced losses
3	Green manure crops	+10...+20	Organic input via roots and biomass
4	Agroforestry	+20...+30	Additional carbon fixation in woody biomass
5	Organic farming	+15...+25	High litter input, improved soil microbiota

Table 3 presents the comparative impact of different land management practices on soil carbon dynamics over a 20-year period. The results demonstrate that management intensity and biological inputs play a decisive role in the direction and magnitude of soil carbon change. Conventional tillage results in a 20–40% decline in soil carbon due to humus mineralization, enhanced oxidation, and erosion losses. Minimum tillage contributes to a 5–15% increase in carbon stocks by maintaining soil structure and reducing organic matter decomposition. Green manure crops enhance carbon accumulation by 10–20% through the return of biomass and root exudates to the soil. Agroforestry systems show the highest sequestration potential (+20–30%), as trees store additional carbon in woody biomass and stabilize soil organic matter. Organic farming increases soil carbon by 15–25%, driven by continuous organic inputs, rich microbial activity, and reduced chemical disturbance.

Overall, the table highlights that transitioning from intensive tillage to biologically oriented management substantially improves the long-term soil carbon balance, reinforcing the role of sustainable agricultural practices in climate change mitigation.

Figure 3. Modeled Carbon Fluxes (CENTURY Simulation, 2022–2030)



Figs3 - Modeled Carbon Fluxes in Ecosystems (CENTURY Simulation, 2022–2030)

The results demonstrate that GPP fluctuates between 7.0 and 8.6 t C/ha/year, reflecting variations in vegetation productivity under changing climatic and soil conditions. Ecosystem respiration (Re) ranges from 5.5 to 6.5 t C/ha/year, indicating stable biological oxidation processes within soils and plant systems. The difference between these two fluxes determines NEE, which remains positive (0.5–3.5 t C/ha/year), signifying that the studied ecosystems act as a net carbon sink.

Overall, the CENTURY model outputs confirm the stability of carbon sequestration in meadow and steppe ecosystems of Northern Kazakhstan, with only minor interannual variability driven by climatic fluctuations and management intensity. These findings emphasize the importance of maintaining vegetation cover and soil organic matter to sustain long-term carbon balance and ecosystem resilience.



Table 3 - Physico-chemical properties of soils in the studied ecosystems

№	Parameter	Steppe	Meadow	Agroecosystem	Interpretation
1	pH (H ₂ O)№	7.2 ± 0.1	6.8 ± 0.2	7.5 ± 0.1	Optimal values within the neutral range
2	Moisture, %	12.5 ± 0.8	18.3 ± 1.1	10.2 ± 0.7	Highest moisture in meadow soils
3	Bulk density (g/cm ³)	1.26 ± 0.03	1.18 ± 0.02	1.32 ± 0.04	Meadow soils are looser and more structured
4	Humus content, %	2.8 ± 0.2	3.5 ± 0.3	2.1 ± 0.2	Highest humus accumulation in meadows
5	Nitrogen content, %	0.19 ± 0.01	0.23 ± 0.02	0.15 ± 0.01	Soil fertility follows N content patterns

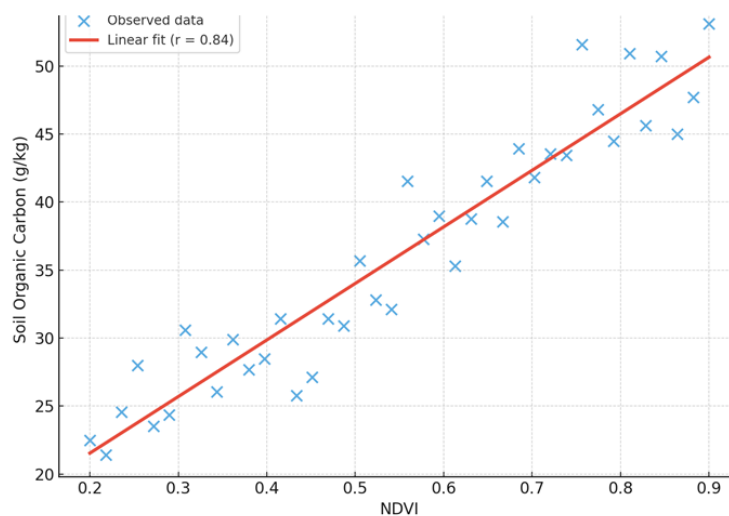
The physico-chemical properties of soils indicate distinct differences among the studied ecosystems. Meadow soils show the most favorable characteristics - slightly acidic to neutral pH (6.8), highest moisture (18.3%), lower bulk density (1.18 g/cm³), and greater humus (3.5%) and nitrogen content (0.23%). These features reflect better structure, aeration, and fertility. Steppe soils are moderately fertile with intermediate parameters, while agroecosystem soils exhibit the lowest organic matter and nitrogen levels, indicating depletion of humus and compaction due to cultivation.

Table 4 - Contribution of ecosystem components to total carbon balance

№	Ecosystem component	Relative contribution (%)	Dominant process
1	Soil	68 ± 3	Sequestration of soil organic carbon
2	Aboveground biomass	21 ± 2	Photosynthesis and biomass accumulation
3	Belowground biomass	9 ± 1	Root deposition and residue incorporation
4	Atmospheric exchange	2 ± 0.3	Respiration and CO ₂ emissions

The total carbon balance is primarily dominated by the soil component (≈68%), which serves as the main carbon reservoir through long-term sequestration. Biomass contributions are secondary — aboveground biomass accounts for about 21% via photosynthetic carbon fixation, while belowground biomass contributes 9% through root inputs. Atmospheric exchange represents only 2%, reflecting minor but continuous CO₂ fluxes associated with respiration and emissions.

Figure 4. Correlation Between NDVI and Soil Organic Carbon (r = 0.84)



Figs4 - Relationship between ndvi and soil organic carbon content



Figure 4 illustrates the relationship between NDVI (Normalized Difference Vegetation Index) and soil organic carbon content (g/kg). The scatter plot shows observed data points, while the red line represents a linear regression fit with a strong positive correlation coefficient of $r = 0.84$. This indicates a statistically significant relationship: as NDVI increases, the soil organic carbon content also tends to increase. The trend suggests that areas with higher vegetation productivity, as measured by NDVI, are associated with greater levels of organic carbon in the soil - likely due to increased plant biomass and root inputs.

Discussion

The conducted study revealed significant spatial variability in carbon storage and sequestration potential among different ecosystem types of Northern Kazakhstan, primarily driven by differences in vegetation structure, soil characteristics, and land-use intensity. The obtained results are consistent with global findings from FAO, IPCC, and regional studies, confirming that land use and management exert a decisive influence on the carbon balance of terrestrial ecosystems. The data indicate a clear hierarchical gradient of carbon accumulation: forest > forest-steppe > steppe > pasture > agroecosystem, which aligns with the degree of anthropogenic impact and the complexity of vegetation structure. Forest ecosystems, which are distinguished by complex multi-tier vegetation structure and soils enriched with organic matter, function as highly effective long-term reservoirs for carbon accumulation. At the same time, steppe and grazing landscapes, although characterized by comparatively lower aboveground biomass, also play an important role in carbon storage. In these ecosystems, significant amounts of carbon are preserved in stable soil organic carbon (SOC) fractions formed primarily due to the extensive root systems of perennial grasses that penetrate deep soil layers. Agroecosystems, however, show a notable decline in carbon storage capacity due to continuous tillage, erosion, and reduced organic matter return - a pattern frequently observed in intensively cultivated regions of Central Asia.

The analysis of vertical SOC profiles demonstrates that the upper 0–30 cm layer is the principal reservoir of organic carbon, accounting for more than two-thirds of the total carbon stock. This dominance of soil carbon emphasizes that soil acts as the fundamental component of the carbon cycle, buffering fluctuations in atmospheric CO₂ and supporting long-term ecosystem stability. The findings support earlier observations that even minor improvements in soil carbon content can have disproportionately large effects on ecosystem productivity and resilience under semi-arid conditions.

A comparative analysis of different land-use management systems highlights the importance of environmentally responsible agricultural practices for preserving and increasing soil carbon reserves. Methods focused on soil conservation - such as reduced or no-till cultivation, the use of green manure crops, the integration of trees into agricultural landscapes, and organic farming systems - have shown a stable positive effect on carbon accumulation in soils. Over an observation period of approximately twenty years, these practices were associated with an increase in soil carbon content ranging from about 5% to 30%. These practices reduce physical disturbance, enhance biological inputs, and improve soil structure, collectively contributing to higher sequestration rates. Conversely, conventional tillage was associated with substantial SOC losses (-20% to -40%), emphasizing the detrimental effects of mechanical soil disruption on humus stability and microbial activity. The evidence confirms that management-induced changes in the carbon balance are reversible through ecologically adaptive interventions.

The Century model simulations for the period 2022–2030 revealed that gross primary productivity (GPP) in the studied ecosystems ranged between 7.0 and 8.6 t c/ha/year, while ecosystem respiration (Re) varied from 5.5 to 6.5 t c/ha/year. The positive net ecosystem exchange (NEE) values (0.5–3.5 t c/ha/year) suggest that the examined systems function as net carbon sinks, capable of offsetting part of the regional CO₂ emissions. The stability of carbon fluxes across years indicates the resilience of steppe and meadow ecosystems under moderate climatic fluctuations. However, maintaining this balance requires avoiding overgrazing, soil degradation, and excessive mechanization - factors that could easily shift ecosystems from sinks to sources. The observed variation in soil parameters among the studied ecosystems - particularly in moisture, bulk density, and humus content - further elucidates the mechanisms underlying carbon accumulation. Soils of meadow ecosystems demonstrated the most favorable physical and biological characteristics for carbon accumulation due to their higher moisture content and relatively loose structure. By contrast, soils within agricultural landscapes revealed noticeable degradation features, including increased compaction, declining nutrient status, and a reduction in humus content. These unfavorable conditions limit microbial processes in the soil and reduce the capacity for long-term stabilization of organic matter. Thus, the biophysical condition of the soil directly governs its capacity to function as a long-term carbon sink. From a broader perspective, the findings have substantial implications for regional carbon budgeting and climate adaptation strategies in arid and semi-arid regions. Kazakhstan's steppe landscapes, though less productive than forests, represent vast territories with considerable cumulative carbon storage potential if appropriately managed. Integrating carbon monitoring with GIS-based and remote sensing tools can provide a



scalable approach for assessing temporal trends in SOC and vegetation productivity, thereby contributing to the implementation of carbon-neutral land management and national commitments under the Paris Agreement.

Conclusions

The distribution of carbon reserves across ecosystems demonstrates a gradual decrease from natural landscapes toward intensively managed agricultural lands. The largest carbon pools are concentrated in boreal forest systems, where stocks range from approximately 230 to 310 t c/ha, followed by meadow ecosystems with values close to 92 t c/ha. In contrast, cultivated agroecosystems contain significantly lower carbon reserves, typically between 40 and 70 t c/ha. A substantial proportion of ecosystem carbon - around 68% - is stored in soils, emphasizing their dominant role as the main long-term carbon reservoir. Consequently, the preservation of soil organic matter becomes a key factor in both climate regulation and the long-term sustainability of agricultural production systems.

The results indicate that replacing conventional intensive tillage with soil - conserving agricultural practices can substantially improve carbon accumulation in soils, potentially increasing carbon stocks by up to 30%. This demonstrates that sustainable land-use strategies may serve as an effective mechanism for reducing atmospheric carbon through enhanced sequestration in terrestrial ecosystems. Modeling using the Century ecosystem model confirmed that the examined landscapes currently function as net carbon sinks, as indicated by positive values of net ecosystem exchange (NEE). This balance is maintained through the interaction between photosynthetic carbon uptake and respiratory losses within ecosystems.

However, the persistence of this carbon sink function largely depends on the preservation of vegetation cover and the limitation of excessive anthropogenic pressure. The efficiency of carbon sequestration is strongly influenced by several soil characteristics, including humus concentration, nitrogen availability, and soil bulk density. Meadow ecosystems provide particularly favorable conditions for the accumulation of soil organic carbon due to their optimal moisture regime and well-developed soil structure.

Enhancing carbon sequestration capacity in soils and maintaining vegetation productivity across the landscapes of Northern Kazakhstan could play a significant role in achieving national targets for greenhouse gas emission reduction. The widespread adoption of climate-oriented land management approaches will therefore be essential for increasing the carbon storage potential of regional ecosystems, reducing the risk of land degradation and desertification, and promoting sustainable development of rural territories.

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ЭКОЖҮЙЕЛЕРДІҢ КАРБОНДЫҚ ПОТЕНЦИАЛЫ: КӨМІРТЕК АЙНАЛЫМЫН РЕТТЕУДЕГІ ТОПЫРАҚ ПЕН ӨСІМДІКТЕРДІҢ РӨЛІ

Аңдатпа. Бұл зерттеуде экожүйелердің көміртек әлеуеті қарастырылып, көміртек айналымын реттеудегі топырақ пен өсімдіктердің функционалдық рөлі талданады. Солтүстік Қазақстанның дала, шабындық және агроландшафттық экожүйелеріндегі органикалық көміртектің жиналуы мен бөліну динамикасына ерекше назар аударылды. Геоақпараттық технологиялар, қашықтан зондтау деректері және зертханалық талдауларды біріктіру арқылы NDVI вегетациялық индексі мен топырақтағы органикалық көміртек мөлшері арасындағы өзара байланыс анықталды. Зерттеу нәтижелері бойынша топырақ ең ірі көміртек қоймасы болып табылатыны, ал өсімдіктер көміртек ағынындағы негізгі реттеуші рөл атқаратыны дәлелденді. Жұмыста көміртекті секвестрациялауды арттыру және парниктік газдардың шығарындыларын азайту мақсатында тұрақты жер пайдалану тәжірибелерінің және жайылым айналымы жүйелерінің маңыздылығы атап өтіледі.

Кілт сөздер: көміртек әлеуеті, топырақтағы органикалық көміртек, өсімдіктер, көміртек айналымы, көміртек секвестрациясы, экожүйе тұрақтылығы, NDVI, дала экожүйелері.

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КАРБОНОВЫЙ ПОТЕНЦИАЛ ЭКОСИСТЕМ: РОЛЬ ПОЧВ И РАСТИТЕЛЬНОСТИ В РЕГУЛИРОВАНИИ УГЛЕРОДНОГО ЦИКЛА

Аннотация. В исследовании рассматривается карбонный потенциал экосистем через анализ функциональной роли почв и растительности в регулировании углеродного цикла. Особое внимание уделено динамике накопления и эмиссии органического углерода в различных типах экосистем, включая степные, луговые и агроландшафты Северного Казахстана. На основе интеграции геоинформационных технологий, данных дистанционного зондирования и лабораторных анализов были выявлены корреляции между вегетационными индексами (NDVI) и содержанием органического углерода в почве. Результаты показали, что почва является крупнейшим резервуаром углерода, а растительность выступает ключевым регулятором углеродных потоков. Работа подчеркивает важность устойчивых методов землепользования и внедрения систем пастбищеоборота для повышения секвестрации углерода и снижения выбросов парниковых газов.

Ключевые слова: карбонный потенциал, органический углерод почвы, растительность, углеродный цикл, секвестрация углерода, устойчивость экосистем, NDVI, степные экосистемы.