# Drought Impacts on Cattle Stocking Rate

# Introduction

Stocking rate is a fundamental decision in grazing management, directly affecting forage utilization, ecological resilience, and long-term rangeland sustainability (Smart et al. 2010; Holechek 1988). An optimal stocking rate maximizes forage use while preventing overgrazing, whereas improper stocking - whether too high or too low - can lead to land degradation, reduced biodiversity, and lower livestock productivity (National Drought Mitigation Center, n.d.; Redfearn and Bidwell 2017).

According to Dennis (2021), cattle stocking rates have been declining over time as more acres are required per cow to sustain grazing. This trend can be driven by multiple factors, including climate variability, increasing cattle weights affecting harvesting practices, and land-use shifts driven by crop prices. Among these, climate variability - marked by rising temperatures and shifting precipitation patterns - has emerged as one of the key determinants of stocking rates (Mu, McCarl, and Wein 2013). Insufficient precipitation reduces hay yields and crop residue, while excessive rainfall can cause waterlogging, nutrient loss, and increased reliance on irrigated feed resources. Additionally, more frequent and intense droughts disrupt the balance between stocking rates and forage availability, posing risks to agricultural systems and rangeland sustainability (Leeper et al. 2022; Iglesias, Travis, and Balch 2022). Given these dynamics, this study focuses on the relationship between weather variability and cattle stocking rates.

Previous studies have explored the relationship between climate variability and cattle production. Klemm and Briske (2019) conducted a retrospective assessment of spatial and temporal distribution of beef cow numbers in relation to climate variability from 1978 to 2017 in the U.S. Great Plains. They found that cattle numbers correlate positively with precipitation and negatively with temperature. Rodziewicz, Dice, and Cowley (2023) conducted an econometric analysis of drought’s impact on cattle herd management, hay production, prices, and farm income from 2000 to 2022. Using USDA CropScape Data, the U.S. Drought Monitor, and a fixed-effects panel regression, they found that drought reduces hay production, raises hay prices, and leads to herd liquidation, ultimately lowering long-term farm income. Mu, McCarl, and Wein (2013) explore how U.S. agricultural producers are adapting to climate change, particularly through changes in land use and cattle stocking rates. They found that higher summer temperatures and reduced precipitation lead to significant declines in stocking rates. They projected that stocking rates will decline by 10–15% under climate change scenarios, driven by rising temperatures and shifts from cropland to pastureland. Ritten et al. (2010) examined optimal stocking decisions on rangelands in the context of unpredictable weather patterns and climate change impacts. Their findings highlight the importance of flexible stocking rates to mitigate financial risks under increasing drought and extreme weather events. While these studies provide valuable insights, they primarily focus on broad economic trends and long-term projections rather than short-term producer decisions in response to climate stress.

Using USDA Census of Agriculture and PRISM weather data, we expand the scope of existing research by incorporating a broader set of climate stress indicators to capture the multifaceted impacts of climate variability on stocking rates. Specifically, Potential Evapotranspiration (PET), Growing Degree Days (GDD), and Extreme Degree Days (EDD) account for water availability, heat stress, and thermal exposure, respectively. Through an econometric framework, we analyze and quantify how drought frequency and severity influence producer decisions, offering insights into adaptive management strategies for sustainable grazing.

We found that stocking rates are strongly influenced by drought conditions and hay availability. Drought effects persist over time, with severe droughts reducing stocking rates by up to 18%. Hay stock has a nonlinear impact, where low levels reduce stocking rates, but higher levels help stabilize them. Projections from multiple climate models suggest that under moderate climate change stocking rates decline gradually over time. In contrast, under severe climate change, stocking rates drop sharply and illustrate more volatile patterns. These findings highlight the need for adaptive grazing strategies to sustain livestock production under changing climate conditions.

This paper is organized as follows: this section is followed by data, econometric methods, results, discussion and concludes with final remarks and policy implications.

# Data

## Stocking rate

To estimate cattle stocking rates, we retrieve county-level beef cow inventory data and pastureland data from the USDA Census of Agriculture for the period 1982-2017[[1]](#footnote-1) (USDA 2024). Figure 1 illustrates historical trends in pastureland use and beef inventory data (as of December) across the United States. Over time, beef cow inventory has fluctuated, with notable declines observed around 1983, 2012, and 2018, while pastureland use has exhibited a steady decline.

A graph showing the growth of cattle

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**Figure 1. Annual US national beef cow inventory and pastureland data.**

Source: USDA, NASS (2024).

Stocking rate is commonly expressed in Animal Units (AU) or Animal Unit Months (AUM) per unit of land, where AU is defined as a mature cow weighing approximately 1,000 pounds, and AUM represents the amount of forage required to sustain one AU for one month (Redfearn and Bidwell 2017). To calculate total forage demand, the number of AUs is multiplied by the grazing duration (in months), yielding total AUMs required for the grazing period. Using this methodology, we compute the stocking rate (expressed in AUMs per acre) for a given county and year using the following formula:

This formula accounts for three key components: the number of animals (inventory), forage demand, and available pastureland. The term  standardizes forage requirements based on average cattle weight and grazing duration. By adjusting for grazing duration and dividing by total pastureland, the stocking rate reflects both forage availability and land constraints[[2]](#footnote-2).

## Weather data

Drought mechanisms are influenced by a complex interplay of climatic, hydrological, and ecological factors that affect water availability in ecosystems (Srivastava and Maity 2023). A key aspect of drought is the imbalance between water supply, primarily driven by precipitation, and water demand, which is influenced by temperature, vegetation, and atmospheric conditions. Understanding drought requires quantifying these components, particularly evapotranspiration, which represents the loss of water through evaporation and plant transpiration (Granger 1989). To construct a drought indicator, we estimate potential evapotranspiration (PET), which measures the amount of water that could evaporate under prevailing weather conditions. PET is calculated using the Thornthwaite method (Palmer and Havens 1958):

where is a monthly normative potential evapotranspiration (mm ); is the monthly average temperature (); is an annual heat index; is a monthly heat index; is a constant. To assess water balance, precipitation data is integrated with PET to calculate the water surplus or deficit for each month:

where is a monthly precipitation level (mm ).

Temperature plays a central role in both drought dynamics and crop growth conditions. While precipitation regulates water supply, temperature influences plant development through heat stress and thermal accumulation (Prasad, Staggenborg, and Ristic 2008). To quantify these effects, we use Growing Degree Days (GDD) and Extreme Degree Days (EDD), widely recognized metrics for assessing thermal impacts on crops. GDD captures the accumulation of thermal time (DTT) above a base temperature, reflecting growth potential (Zhou and Wang 2018), while EDD accounts for periods of extreme heat that may inhibit crop development (Huang, Sassenrath, and Lin 2023). Following Zhou and Wang (2018), these metrics are computed as:

where , is base temperature and is upper threshold temperature. Critical temperature thresholds of 10°C and 31°C are used for this analysis (Schlenker and Roberts 2009).

These metrics enable a comprehensive assessment of both the beneficial and adverse effects of temperature on agricultural systems, providing valuable insights into the interaction between climate variability and ecosystem productivity. To support this analysis, we retrieve high-resolution data from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) for the period of interest. PRISM data includes precipitation, minimum, maximum, and mean temperatures, along with other weather-related variables across the United States (PRISM Climate Group, Oregon State University 2024).

## Hay stocks

Hay stocks serve as another key explanatory variable in this analysis, representing a critical supplemental feed source when forage availability is limited by adverse weather conditions. During droughts, reduced pasture growth restricts natural forage for grazing, making hay an essential alternative. Incorporating hay stocks into this study allows us to assess their role in mitigating the effects of drought on forage availability and stocking rates. This approach provides a comprehensive perspective on the interaction between drought, supplemental feeding, and grazing management. To ensure robustness, we utilize annual nationwide hay stocks data from USDA NASS (2024) for the period of interest, enabling a detailed evaluation of supplemental feeding during forage scarcity.

## Summary statistics

The summary statistics provide a detailed breakdown of stocking rates across U.S. regions[[3]](#footnote-3) and decades, highlighting both national and regional trends. The Northern Plains experienced a significant decline, with stocking rates dropping from 0.80 AUMs per acre in the 1980s to 0.43 in the 2020s. Similarly, the Mountain region exhibited consistently low rates, likely reflecting limited grazing capacity. In contrast, the Lake States demonstrated remarkable growth, increasing from 0.58 AUMs per acre in the 1980s to 1.33 in the 2020s, with a notable 40.27% increase between the 2000s and 2010s. While regions such as the Pacific and Southern Plains maintained relatively stable but low stocking rates over time, other regions displayed greater sensitivity to climatic and economic factors, highlighting differences in resilience and management practices. These results suggest that, despite a gradual national recovery in stocking rates, regional disparities persist, emphasizing the complex interplay between drought conditions, forage availability, and grazing capacity. Understanding these variations is crucial for assessing the relationship between climate stress and stocking rate adjustments.

**Table 1. Stocking rate by US geographical region, 1990-2020.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Region | Year | | | | Percent Change (%) | | |
| 1980-1989 | 1990-1999 | 2000-2009 | 2010-2019 | 1990-1980 | 2000-1990 | 2010-2000 |
| Appalachia | 1.1 | 1.4 | 1.37 | 1.43 | 27.43 | -2.01 | 3.83 |
| Corn Belt | 1.1 | 1.18 | 1.34 | 1.53 | 7.69 | 13.15 | 14.68 |
| Delta States | 1.02 | 1.12 | 1.08 | 1.22 | 9.49 | -3.22 | 13.21 |
| Lake States | 0.58 | 0.71 | 0.95 | 1.33 | 23 | 33.33 | 40.27 |
| Mountain | 0.17 | 0.2 | 0.15 | 0.16 | 12.64 | -22.6 | 2.87 |
| Northeast | 0.58 | 0.74 | 0.75 | 1.02 | 28.15 | 1.36 | 34.74 |
| Northern Plains | 0.8 | 0.7 | 0.42 | 0.43 | -12.04 | -40.48 | 1.82 |
| Pacific | 0.27 | 0.3 | 0.28 | 0.29 | 9.39 | -4.86 | 1.18 |
| Southeast | 0.97 | 1.05 | 0.93 | 1.09 | 7.93 | -11.5 | 17.29 |
| Southern Plains | 0.32 | 0.34 | 0.34 | 0.3 | 7.32 | -1.47 | -11.52 |
| National | **0.69** | **0.77** | **0.76** | **0.88** | **12.03** | **-1.68** | **15.41** |

Source: USDA NASS (2024) and authors' calculations.

# Econometric Methods

Drought can influence stocking rates both immediately and over the long term, with its effects often lagging behind the onset of drought conditions. Klemm and Briske (2019) highlight that the full impact of drought may not be immediately reflected in ranchers’ decisions, as forage depletion occurs gradually. Initially, producers may rely on hay reserves or supplemental feed to sustain their herds, temporarily delaying necessary adjustments to stocking rates. However, as drought conditions persist, the depletion of hay stocks and the rising costs of replenishment can force producers to lower stocking rates to prevent overgrazing and long-term pasture degradation. Even after normal precipitation resumes, pastures often require extended periods to recover, further prolonging the effects of drought on forage availability.

To capture both the immediate and delayed impacts of drought, this study incorporates lagged variables of drought-related climate measures, specifically the water deficit or surplus variable . By including up to five lagged years in our analysis, we account for the persistent effects of water shortages or surpluses on stocking rates. To address potential multicollinearity and summarize the influence of multiple drought variables over time, we apply Principal Component Analysis (PCA) to construct a single drought index. This allows us to extract the dominant variation among drought-related measures, refining our estimates and ensuring a more comprehensive understanding of how drought influences livestock management decisions.

Our empirical approach employs the following panel fixed-effects model:

where the dependent variable is the natural logarithm of the stocking rate[[4]](#footnote-4) for county and year . is first principal component derived from the lagged water surplus or deficit measures using PCA. and correspond to GDD and EDD values capturing the effects of heat stress on grazing land productivity. Hay stock is modeled with both linear and quadratic terms to capture potential diminishing returns or other non-linear effects. Finally, the county fixed effects (​) account for unobserved heterogeneity across counties (time-invariant factors such as soil quality and geographic features). This comprehensive approach provides a robust framework to analyze how climatic factors and feed availability interact to influence stocking rates. It highlights the importance of supplemental feeding strategies and the role of climatic variability in shaping livestock management decisions.

# Results

Table 2 presents the regression results. Across all models, the coefficient of the first principal component (), derived from the lagged water surplus or deficit measures using PCA, is positive and statistically significant. This indicates that drought conditions, as measured by cumulative water availability, play a crucial role in shaping stocking rate decisions. Specifically, a one-standard-deviation increase in is associated with a 15% to 18% increase in stocking rates (AUMs per acre), depending on the model specification. This suggests that during periods of water surplus, ranchers are able to maintain higher stocking rates due to improved forage availability. The results further indicate that favorable growing conditions, as measured by Growing Degree Days (GDD), positively influence stocking rates. More days with optimal temperature conditions support pasture growth, allowing for increased grazing capacity. Conversely, the coefficient for Extreme Degree Days (EDD) is negative and statistically significant across all models, implying that exposure to extreme heat reduces stocking rates. A one-unit increase in EDD is associated with a 3.5% to 3.7% decline in stocking rates, likely due to heat stress on livestock and diminished forage productivity.

The analysis also reveals a nonlinear relationship between hay stock and stocking rates, as indicated by the inclusion of both linear and quadratic terms (Model 5). The marginal effect of hay stock on stocking rates depends on its level and follows the equation:

At lower hay stock levels, an increase in hay stock is associated with a decline in stocking rates, possibly reflecting producers’ reliance on hay as a substitute for grazing during periods of forage scarcity. However, as hay stock levels increase, this effect diminishes and may eventually reverse, suggesting that at higher levels, producers can sustain or increase stocking rates due to improved forage availability.

**Table 2. Regression analysis results.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable | (1) | (2) | (3) | (4) | (5) |
|  | 0.1637\*\*\* | 0.1797\*\*\* | 0.1638\*\*\* | 0.1597\*\*\* | 0.1535\*\*\* |
|  |  | 0.0082\*\*\* | 0.0119\*\*\* | 0.0115\*\*\* | 0.0113\*\*\* |
|  |  |  | -0.0368\*\*\* | -0.0372\*\*\* | -0.0348\*\*\* |
|  |  |  |  | -0.0002\*\*\* | -0.0051\*\*\* |
|  |  |  |  |  | 0.000001\*\*\* |
|  | 0.65 | 0.67 | 0.67 | 0.68 | 0.68 |
|  | 0.13 | 0.18 | 0.20 | 0.21 | 0.22 |
| N | 16,116 | 16,116 | 16,116 | 16,116 | 16,116 |

Source: Authors’ calculations.

Note: \*\*\* p < 0.01, \*\* p < 0.05, and \* p < 0.10.

While the full five-year-lag model captures the overall effect of drought over multiple years, it is useful to compare coefficients with lower lag specifications to observe how the influence of drought evolves over time. Table 3 summarizes the regression results for models incorporating one to five lagged drought years. Each model evaluates the cumulative impact of drought conditions (represented by PC1) alongside other key variables.

**Table 3. Regression results for delayed drought effects.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable | 1 Lag | 2 Lags | 3 Lags | 4 Lags | 5 Lags |
|  | 0.1538\*\*\* | 0.1572\*\*\* | 0.1692\*\*\* | 0.1656\*\*\* | 0.1535\*\*\* |
|  | 0.0100\*\*\* | 0.0111\*\*\* | 0.0110\*\*\* | 0.0111\*\*\* | 0.0113\*\*\* |
|  | -0.0257\*\*\* | -0.0267\*\*\* | -0.0260\*\* | -0.0301\*\*\* | -0.0348\*\*\* |
|  | -0.0044\*\*\* | -0.0042\*\*\* | -0.0052\*\*\* | -0.0047\*\*\* | -0.0051\*\*\* |
|  | 0.0000\*\*\* | 0.0000\*\*\* | 0.0000\*\*\* | 0.0000\*\*\* | 0.000001\*\*\* |

Source: Authors’ calculations.

Note: \*\*\* p < 0.01, \*\* p < 0.05, and \* p < 0.10.

Across all specifications, the coefficient for the first principal component (PC1), which represents cumulative drought conditions, remains positive and statistically significant. This suggests that prolonged drought conditions consistently influence stocking rates over time. The consistency of these coefficients across lag specifications indicates that the effects of drought persist, rather than being limited to a single year.

It is important to note that we cannot distinctly identify which specific year of drought contributes most to the observed effects, as our approach captures only the cumulative impact across multiple lagged years. Nevertheless, the findings strongly indicate that lagged drought effects exist and significantly influence grazing systems. However, to fully understand the role of individual years and their contributions to the cumulative impact, future studies must address these gaps. Collecting more granular annual data on stocking rates, as well as additional contextual variables, would help disentangle the effects of specific drought years.

## Stocking rate projections

This study utilizes climate projection data from the Multivariate Adaptive Constructed Analogs (MACA) dataset to estimate future stocking rates under Representative Concentration Pathways (RCP) 4.5 and 8.5, as part of the Coupled Model Intercomparison Project Phase 5 (CMIP5) (Multivariate Adaptive Constructed 2024). The MACA dataset provides high-resolution (4-km grid) downscaled climate data, aggregated at the county level across the United States.

RCP 4.5 represents a stabilization scenario in which radiative forcing is stabilized at 4.5 W/m² by 2100 through mitigation measures. In contrast, RCP 8.5 follows a high-emissions, “business-as-usual” trajectory, leading to radiative forcing of 8.5 W/m² (Multivariate Adaptive Constructed 2024). The weather variables analyzed include monthly precipitation, minimum temperature, and maximum temperature from 2020 to 2099, which were processed to derive agroclimatic indices relevant to forage growth and livestock productivity. It is important to note that MACA provides downscaled climate projections for individual Global Climate Models (GCMs) but does not generate multiple realizations (ensemble members) for each model. Each GCM within the MACA dataset is based on a single realization (typically r1i1p1), meaning that projections reflect model-specific climate trajectories rather than the ensemble-based uncertainties that would otherwise be captured through multiple realizations.

To enhance the robustness of projections, this study incorporates multiple GCMs to account for inter-model variability in climate projections. By averaging projected stocking rates across several GCMs, we aim to reduce model-specific noise and improve the reliability of long-term stocking rate estimates. Comparing RCP 4.5 and RCP 8.5 scenarios allows for an assessment of future stocking rate dynamics under different climate change trajectories. The results provide insights into how climate mitigation efforts (RCP 4.5) versus a high-emissions scenario (RCP 8.5) may influence forage availability and grazing capacity. These projections can inform adaptive grazing management strategies and policy interventions to enhance the resilience of livestock systems in a changing climate.A graph showing the growth of the stock market

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**Figure 2. Projected cattle stocking rates (2020-2099).**

Source: MACA weather projections

Figure 2 illustrates the projected cattle stocking rates across the United States from 2020 to 2099 under the RCP 4.5 and RCP 8.5 climate scenarios, based on multiple General Circulation Models (GCMs). The trends in stocking rates exhibit notable differences between the two scenarios, reflecting the varying impacts of climate change on grazing systems.

Stocking rates under RCP 4.5 (blue) show a clear long-term decreasing trend despite periodic fluctuations. While the initial years maintain relatively higher stocking rates, a noticeable decline occurs over the century, particularly in the latter half. This suggests that even under a moderate mitigation scenario, climate change still imposes stress on forage availability and livestock productivity. However, the rates do not decline as sharply as in RCP 8.5, indicating some level of resilience due to stabilized radiative forcing.

In contrast, RCP 8.5 (red) demonstrates a more pronounced decline in stocking rates earlier in the century, aligning with expectations of more extreme climate conditions under high emissions. However, an interesting reversal occurs toward the end of the century, with a visible increase in stocking rates. This unexpected late-century uptick could be attributed to regional climate shifts, changes in precipitation patterns, or model variability influencing forage conditions.

# Discussions

The results of this study provide valuable insights into the complex relationships between climate variability, hay stock, and cattle stocking rates. Our findings confirm that both favorable and extreme weather conditions, along with forage availability, play a critical role in determining the stocking capacity of pastureland. These results align with prior studies that have identified climate as a key driver of grazing management decisions (Klemm and Briske, 2019; Mu et al., 2013). However, this study adds specificity by quantifying the direct effects of water deficits, temperature extremes, and forage availability on stocking rates.

Furthermore, the findings resonate with the conclusions of Rodziewicz et al. (2023), who observed that extreme weather conditions often lead to herd reductions and economic strain on ranchers. While the established literature highlights the general impact of climate variability on livestock production, this study provides additional nuance by examining the persistence of these effects over time through lagged drought variables. The inclusion of multiple GCMs strengthens the robustness of these findings, ensuring that the projected impacts on stocking rates reflect a range of plausible climate futures.

A particularly notable trend observed in the analysis is the long-term decline in stocking rates under both RCP 4.5 and RCP 8.5 scenarios. The decline under RCP 4.5 suggests that even with mitigation efforts, climate stressors will continue to challenge grazing systems. Meanwhile, the more pronounced early-century declines under RCP 8.5 highlight the risks associated with extreme climate conditions under a high-emissions trajectory. The unexpected late-century increase in stocking rates under RCP 8.5 may indicate potential shifts in precipitation regimes, temperature fluctuations, or model-specific variability that temporarily improve forage conditions in certain regions. These findings emphasize the need for adaptive grazing strategies and proactive policy interventions to mitigate the risks associated with climate change.

## Policy implications

The findings of this study reinforce the importance of adaptive grazing practices that account for delayed drought impacts. Policies should incentivize ranchers to adopt strategies such as flexible stocking rates, rotational grazing, and pasture resting periods, which can help mitigate long-term pasture degradation and support recovery after drought events. Providing financial incentives or technical assistance for ranchers who implement these practices can help bridge the gap between short-term economic pressures and long-term sustainability goals.

Programs like the USDA’s Livestock Forage Disaster Program (LFP) have demonstrated their value in mitigating the immediate economic impacts of drought on ranchers. However, projections indicate that with increasing drought frequency and intensity under the high-emissions RCP 8.5 scenario, federal expenditures on such programs are likely to rise significantly. Policymakers should consider refining eligibility criteria and payment structures to enhance the program's fiscal sustainability while ensuring that assistance reaches the most affected regions. Additionally, integrating disaster assistance programs with broader climate adaptation frameworks, including early-warning systems and localized weather projections, can further strengthen the resilience of livestock systems.

Another key area for policy intervention is the management of forage and hay stocks. This study highlights the diminishing marginal returns of hay stock during prolonged drought periods, emphasizing the need for efficient hay management practices. Policymakers should incentivize investments in hay storage infrastructure, forage improvement programs, and market mechanisms to stabilize hay prices. These measures can help reduce the economic burden on ranchers and prevent overreliance on supplemental feeding, which is often unsustainable during prolonged drought conditions.

Overall, these findings underscore the necessity of proactive climate adaptation strategies in the livestock sector. As climate variability continues to pose challenges for grazing systems, policy-driven investments in sustainable rangeland management, climate forecasting, and economic support mechanisms will be crucial to ensuring the long-term viability of livestock production.

# Conclusion

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1. The Census of Agriculture reports come out every 5 years. [↑](#footnote-ref-1)
2. For example, suppose a pasture is used to graze 50 animals, each weighing 1,200 pounds, for six months. Assuming a standard AU represents 1,000 pounds, each animal equates to 1.2 AUs. If the pastureland is 100 acres, the stocking rate is 3.6 AUMs per acre. [↑](#footnote-ref-2)
3. Regions are grouped based on shared geography, climate, and agriculture. The Lake States (Michigan, Wisconsin, Minnesota) focus on dairy and forage, while the Corn Belt (Iowa, Illinois, Indiana, Ohio, Missouri) leads in grain and livestock feed. The Northern and Southern Plains emphasize beef cattle, with differences in grazing and irrigation. The Delta States and Southeast combine crop cultivation and cattle operations, while Appalachia supports small-scale farming. The Northeast features diversified farming and dairy, the Mountain region specializes in large-scale grazing, and the Pacific excels in diverse, high-value agriculture, with California pivotal for irrigated forage and beef cattle production. These regional adaptations highlight the diversity of U.S. agriculture. [↑](#footnote-ref-3)
4. The logarithmic transformation of the stocking rate is applied primarily for two reasons. First, it allows for the interpretation of explanatory variable effects in percentage terms, making results more intuitive and comparable. Second, it helps address potential heteroskedasticity by stabilizing variance, particularly when the dependent variable exhibits a right-skewed distribution. Additionally, the log transformation can be useful when the relationship between stocking rates and explanatory variables is multiplicative rather than additive. [↑](#footnote-ref-4)