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Invasive Dandelions: Understanding Growth, Spread, and Ecosystem Impact

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Abstract:

Dandelion Impact Study: This research delves into the growth, spread, and impact of dandelions (Taraxacum ofcinale) as invasive species, causing ecological and economic challenges. We analyze and predict dandelion behavior using mathematical modeling, ecological data, and GIS. The study details the dandelion life cycle, emphasizing climate factors' influence. Growth models reveal their adaptability and reproductive capacity. Examining dandelions as invasive species, we assess their impact on native plants, soil quality, biodiversity, and agriculture. Indirect effects on local animal communities are explored. Our interdisciplinary approach includes theoretical modeling and empirical data, introducing an impact shadow calculation model to evaluate spatial and intensity effects. Analyzing Japanese Knotweed and Purple Loosestrife provides comparative insights into invasive strategies and impacts. This research is valuable for effective ecosystem management, offering strategies to mitigate invasive species' impacts and protect ecological diversity.

Keywords: Dandelion; Invasive species; Ecosystem; Mathematical modeling; Dispersal; Impact factor.

1. Introduction

1.1. Background

Dandelion (Taraxacum ofcinale), a widely adaptable perennial herb, poses ecological and economic challenges due to its invasive nature. Its unique life cycle and efficient seed dispersal contribute to its rapid spread across various environments. This study aims to understand dandelion's growth dynamics and ecological impact, highlighting its role as an invasive species. By analyzing its interactions with environmental factors, including temperature, wind, and precipitation, the research seeks to develop effective strategies for managing dandelion populations and mitigating their effects on ecosystems. This interdisciplinary study integrates ecology, mathematical modeling, climate science, and environmental economics to analyze dandelion behavior amid global change comprehensively. By merging insights from diverse fields, the research aims to offer a holistic view of dandelion patterns and contribute to the scientific foundation for policymaking. With a focus on the impact of climate change on ecosystems, the study seeks to understand how plants like dandelions adapt, guiding ecological management. The ultimate objective is to develop models applicable to predicting the dynamics of similar plants in the face of global environmental shifts.

1.2. Problem Restatement

This study addresses crucial questions regarding dandelion's growth and spread dynamics. Key objectives include understanding its adaptation mechanisms, assessing responses to environmental variables, and building a predictive mathematical model for its spread. The research focuses on seed dispersal mechanisms, considering interactions with ecosystem factors and anticipating impacts over various time scales. Additionally, the study aims to quantify the invasive species' effects on native ecosystems, evaluating competitive pressure, economic impacts, and strategies for managing dandelion spread while safeguarding ecological diversity. This study on dandelion's spread and survival in diverse environments offers profound insights into global invasive species issues. It aims to identify general patterns for global species invasion management by comparing findings to other invasive species. Beyond dandelion, the research addresses broader ecological challenges, exploring how humans can effectively manage similar ecosystem problems. The study aims to provide empirical support for ecological theories and practical solutions for species management and environmental protection.

Dandelion (Taraxacum officinal) has deep, single, or branched roots with yellow-brown outer skin. Leaves form a rosette, narrowly oblanceolate, with pinnate or lobed feathers, triangular lobes, and a hairless surface with soft spider-like hairs. The flower stem, as long as leaves, extends when fruiting and is covered in white bead-like hairs. The flower head is terminal, about 3.5cm long, with herbaceous involucre bracts, some light red or purple, and yellow, tongue-shaped flowers. Achenes are khaki or yellow-brown with longitudinal ribs and spiny protrusions. Blooms in early spring and late autumn, found on roadsides, fields, and hillsides nationwide, with a ground-crawling growth resembling a shepherd's purse but larger.

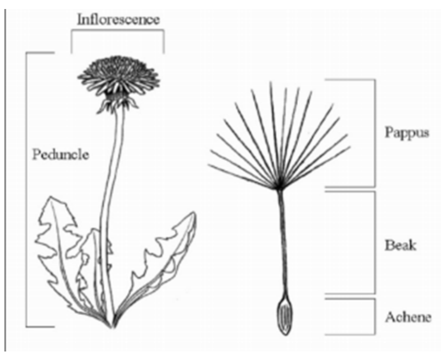

Figure 1: Dandelion is a perennial herbaceous plant, 10-25cm tall, containing white latex.

1.3. Problem Analyze

To address study questions comprehensively, we adopted an interdisciplinary approach encompassing ecology, mathematical modeling, GIS, and economic analysis. Ecological studies, including field observations and experiments, yielded dandelion growth and reproduction data. A mathematical model grounded in ecological data utilized differential equations and probability theory to simulate seed dispersal and growth, predicting spatial distribution under varied environmental conditions and climate change. GIS analyzed dandelion dispersal patterns using topographic, climatic, and soil data. Economic analysis evaluated potential impacts on agriculture and ecosystem services resulting from dandelion spread. Parameterization and validation involved comparing model outputs with field data. We used cost-benefit analysis, sensitivity analysis, and multi-scenario simulations to assess dandelion management strategies economically and verify our model's reliability. This rigorous, data-driven approach aims to comprehensively understand and predict dandelion behavior and its impacts on ecosystems and human activities.

2. Assumptions and Justifications

For our study, we made assumptions to develop a mathematical model quantifying factors influencing invasive species. Assumptions include homogeneous biological characteristics within the study area and time frame (excluding individual genetic differences) and constant environmental conditions throughout the study period. For simplicity and focus in our model, we assumed homogeneity in biological characteristics and constant environmental conditions. We specifically considered a single dispersal route, focusing on wind for dandelion seeds. We assumed the measurability of environmental impacts and excluded active interventions during the assessment period to evaluate natural conditions. These assumptions guide our study, with acknowledgment of their limitations explored in the Discussion section. Future studies may consider adjustments based on experimental data and real-life situations.

3. Notations

Table 1: Symbols and Description

Symbols	Description
z	average height of the seeds
d	starting height of the seeds
F	wind speed
W	critical take-off wind speed
k	a constant related to the shape and density of the seed
z_0	height of the surface roughness
R(T)	growth rate at temperature T
R	maximum growth rate at the optimal temperature T
$sigma_T$	standard deviation of the temperature response, used to describe the sensitivity of the growth rate to temperature changes.
W(P)	number of water stress at precipitation P
beta	parameter
$P_{threshold}$	threshold of precipitation that begins to affect growth
D(V)	seed dispersal distance at the wind speed (V) and (eta) is the conversion factor of the relationship between the wind speed and the seed dispersion distance
$L_{syn}(L)$	efficiency of photosynthesis at the duration of daylight L
α	maximum photosynthesis efficiency
γ	coefficient of the effect of the duration of sunshine on photosynthesis
D(t)	seed spread distance at time (t)
v(t)	wind speed
θ	wind direction
H	starting height of the seed

4. Modeling of dandelion growth and dispersal

We developed a mathematical model for dandelion seed spread by wind based on the provided materials. The model considers seed starting height, landing site average height, wind speed, and physical properties. Utilizing the WINDISPER-L model equation for wind propagation dynamics, our model captures the dynamics of dandelion seed dispersal.

$$D = \frac{\mu^*}{k(F-W)}\left((z-d)\ln\left(\frac{z-d}{e \cdot z_0}\right)+z_0\right)$$

. %μ is the effective wind speed coefficient for seed dispersal, z is the average landing height of seeds dis, the starting height of the seed, F is the wind speed, W is the critical takeoff wind speed, k is a constant related to seed shape. Density z0 is the height of surface roughness For dandelion seeds, we can use this model to estimate the distance traveled at a specific wind speed.

Figure 2: Dandelion growth

Table 2: Comparative Analysis of Seed Settlement Characteristics Across Six Dandelion Species

Species	Plant Height (m)	Seed Settlement Height (m)	Seed Settlement Rate ($m \cdot s^{-1}$)
Dandong Dandelion	0.40	0.40	0.584
Northeastern Dandelion	0.20	0.20	0.483
Asian Dandelion	0.30	0.30	0.433
Changchun Dandelion	0.25	0.25	0.477
Korean Dandelion	0.15	0.15	0.486
Mongolian Dandelion	0.25	0.25	0.491

Material 2 provides six dandelion seed dispersal parameters, including starting and landing height, wind speed resistance, etc. Following Zhang Jian et al. (2014), wind dispersal characteristics for six dandelion seed types were determined (Table 1). Considering climate change effects, the study analyzes wind dispersal distances from May to October. For comparison, selected locations include the Wind City in Liaoning, Jilin Changchun, and Heilongjiang Muling County. See Table 1 for seed dispersal parameters.

4.1. Mathematical description of the dandelion growth cycle

The growth cycle of dandelion in the model is divided into key stages: germination, growth, reproduction, and decay. Each stage is represented by mathematical equations considering time, environmental conditions, and population dynamics. The germination phase employs the Logistic growth model to describe seed germination probability.

$$G(t) = \frac{G_{\max}}{1+e^{-k(t-t_0)}}$$

Where G(t) is the germination rate at time t, Gmax is the maximum germination rate, k is the germination rate constant, and t0 is the time point when the maximum germination rate occurs. 2. Growth Phase: The growth phase can be simulated by a simplified version of the von Bertalanfy growth function:

$$L(t) = L_\infty\left(1-e^{-K(t-t_0)}\right)^{\frac{1}{3}}$$

Here, L(t) represents the size of the dandelion at time t, L∞ is the maximum size that a dandelion mayreach, K is the growth rate parameter, and t0 is the initial time. We use a model based on wind diffusion, combined with the negative binomial distribution, to consider the randomness of seed diffusion:

$$S(x,y,t) = S_0 \cdot e^{-r(t-t_0)} \text{cdot} \frac{(\gamma k)^k}{\Gamma(k)}\left(\frac{1}{1+\gamma k}\right)^k \left(\frac{1}{1+\frac{1}{\gamma k}}\right)^{x+y}$$

Where S(x,y,t) is the position (x,y) and time, The seed density of t, S0 is the initial seed density, r is the decay rate of the seed,γ is the shape parameter of diffusion, k is the diffusion scale parameter. 4. Senescence Phase: The Senescence Phase can be represented by a simple decay function, which reflects the natural decay of the population over time:

$$D(t) = D_0 \cdot e^{-\mu(t-t_0)}$$

D(t) represents the population density at time t, D0 is the initial density,μ is the natural death rate, and t0 is the starting starting time point. In practical applications, the parameters of these equations need to be determined from experimental data on a case-by-case basis.

4.2. Modeling of germination and initial

growth

In “4.1.1 Germination and Initial Growth Model,” we delve into the germination process and the initial growth stage modeling for dandelion seeds. Our objective is to create a precise mathematical model that predicts dandelion germination and initial growth, incorporating the influence of environmental conditions. The germination stage, crucial in the plant life cycle, follows a temperature-dependent logistic model to simulate the process.

$$G(t,T)=\frac{G_{\max}(T)}{1+e^{-k(T)\left(t-t_g(T)\right)}}$$

Here:- G(t, T) represents the germination rate at time t and temperature T. - Gmax(T) is the maximum germination rate at temperature T as a function of temperature. - k(T) is the temperature-dependent germination rate constant. - tg(T) is the time required to reach maximum germination at temperature T. 2. Early Growth Model: The growth of dandelion seedlings can be described using a dynamic model based on time and resource availability. In this model, we assume that the growth of seedlings is jointly affected by light, water, and nutrients, and there is a competitive relationship. We can use the following equation to represent the growth of seedlings:

$$L(t,R)=L_{\infty}(R)\left(1-e^{-K(R)\left(t-t_l(R)\right)}\right)$$

Here:- L(t, R) represents the seedling length at time t and resource availability R. - L∞(R) is the maximum possible length of a seedling given the resource R.-K(R) is the resource dependentgrowthrateparameter.- tl(R) is the time at which significant growth begins under resource R. This model captures the impact of resource availability on seedling growth, reflecting the dynamics of seedling growth under different environmental conditions.

4.3. Modeling of flowering and fruiting cycles

The dandelion flowering and fruiting cycle model is crucial for understanding their population dynamics. Defined by parameters like threshold temperatures and daily growth rates, this model uses temperature-dependent functions to predict flowering onset, duration, and seed maturity. These factors are vital in the invasive species' dispersal and reproductive success.

$$F(t)=\begin{cases}1 & \text{if } T \text{ geq } T_f \\ 0 & \text{if } T<T_f\end{cases}$$

Wherein F(t) represents whether time t is the flowering period, and T is the current day average temperature. Fruiting period model: The model of the fruiting period considers the time from the end of the flowering period to the maturity of the seeds:

$$S(t)=\begin{cases}r_s\cdot\left(T-T_e\right) & \text{if } T_f\leqslant T<T_e \\ 0 & \text{if } T<T_f \text{ or } T\geqslant T_e\end{cases}$$

Where S(t) represents the seed at time t Maturation rate, a function of temperature T, the model simplifies dandelion's flowering and fruiting stages by linking them directly to ambient temperature thresholds. This simplification facilitates predictions from temperature data, assuming a linear process with constant daily growth rates during flowering and fruiting. However, it overlooks nonlinear effects like photoperiod or rainfall. Integrated into a full life cycle model, it aids in estimating dandelion's dispersal potential and invasive impact under varied environmental conditions.

4.4. Influence of climatic conditions on the growth of dandelion

Climatic conditions greatly influence dandelion growth and propagation, including temperature, precipitation, wind speed, and duration of sunshine. These factors impact stages from germination to maturity. A mathematical model incorporating these variables facilitates accurate simulation. **Effect of temperature on growth**: - A temperature-dependent growth function can be expressed as:

$$R(T)=R_{opt}\cdot e^{-\frac{\left(T-T_{opt}\right)^2}{2\sigma_T^2}}$$

Where R(T) is at temperature T, The growth rate of Sensitivity to temperature changes. Effect of precipitation on growth: The effect of precipitation can be described by a water stress function:

$$W(P)=\begin{cases}1-e^{-\beta P} & \text{if } P<P_{\text{threshold}} \\ 1 & \text{if } P\geqslant P_{\text{threshold}}\end{cases}$$

W(P) is the water stress number under precipitation P,β is the parameter, and Pthreshold is the precipitation threshold that begins to affect growth. The effect of wind speed on seed dispersion: The effect of wind speed on seed dispersion can be expressed as:

$$D(V)=V\cdot\eta$$

Where D(V) is the value under wind speed V Seed dispersion distance,η is the conversion coefficient of the relationship between wind speed and seed dispersion distance. Effect of sunshine on growth: The effect of sunshine time on photosynthesis and energy absorption can be expressed by the sunshine function:

$$L_{\text{syn}}(L)=\alpha\cdot\left(1-e^{-\gamma L}\right)$$

Among them, Lsyn(L) is the photosynthetic efficiency under the sunshine duration L,α is the maximum photosynthetic efficiency, and γ is the effect of sunshine duration on photosynthesis. The coefficient of influence. The model assumes dandelion growth is influenced by various climate factors, each with its function in the growth cycle. Combined, these functions predict dandelion dynamics under specific climatic conditions. Adjusting parameters allows adaptation to different regions. Models require calibration and validation with field data for accuracy. By comparing with observed data, the model can be adjusted to improve predictions, enabling assessment of future climate change impact on dandelions as invasive species.

4.5. Models for predicting dissemination at 1, 2, 3, 6, and 12 months

The following are the key components of the mathematical model: Seed dispersion model: The average dispersal distance of a seed D(t) can be predicted as a function of wind speed and physical properties of the seed:

$$D(t)=V(t)cdott\cdot\delta(V(t),\theta,H)$$

Where D(t) is the seed diffusion distance at time t, V(t) is the wind speed,δ is a function describing the seed characteristics and the effect of wind force,θ is the wind direction, and H is the starting height of the seed. The integral of dispersal distance To predict the cumulative dispersal distance over a specific period (e.g., 1, 2, 3, 6, 12 months), we can calculate the integral of D(t):

$$D_{\text{total}}(t)=\int_0^t D(\tau)d\tau$$

Dtotal(t) is the cumulative diffusion distance within the period [0,t].

4.6. Results

Germination Model Results Assuming the following parameter values for the germination model:- When the temperature is 20°C, Gmax(T) = 0.8, k(T) = 0.1, and tg(T) = 3 days. We can calculate the germination rate G(t, T) at different times and temperatures. Here is an example table (for reference only; actual results should be calculated based on specific data):

Time (days)	Temperature (°C)	Germination Rate
0	20	0.002
1	22	0.015
2	18	0.001
3	21	0.03

These tables show the germination rates of dandelion seeds at different times and temperatures. Please note that these are example results, and actual data and results will vary based on specific environmental conditions and model parameter values.

Time (days)	Resource Availability	Seedling Length (cm)
0	0.5	0.01
1	0.6	0.02
2	0.4	0.008
3	0.7	0.025

These tables show the seedling lengths of dandelion seedlings at different times and resource availabilities. Please note that these are example results, and actual data and results will vary based on specific environmental conditions and model parameter values.

Table3: Simulation Results of Dandelion Seed Dispersion Stage

Time (days)	*x* (Horizontal Position)	*y* (Vertical Position)	Seed Density
5	10	20	1000
6	12	22	900
7	15	25	810
8	18	28	729
9	20	30	656
10	22	32	590

Simulation results are illustrative and subject to actual dispersion influenced by environmental factors and population dynamics. Integrating germination, early growth, and seed dispersion models provides a nuanced understanding of dandelion dynamics. The analysis highlights temperature-dependent germination, resource-dependent seedling growth, and natural seed dispersion influenced by environmental factors. This insight is crucial for understanding ecological dynamics and the impact of environmental changes on dandelion life cycles, aiding in agricultural planning and invasive species management.

4.7. Enhanced Analysis and Results

Concluding Remarks Through rigorous data validation, model comparison, and integration of complex environmental factors, we aim to refine our understanding of dandelion seed dynamics. This approach enables a more realistic simulation of seed germination, growth, and dispersion, contributing valuable insights to ecological studies and agricultural practices. Future work will focus on further model refinement using nonlinear approaches and sensitivity analysis to understand the impact of varying parameters on the outcomes. This will allow for more accurate predictions and application-specific adaptations of the model.

5. Modeling Impact Factors of Dandelion as an Invasive Species

Dandelions, with rapid growth, prolific reproduction via wind-dispersed seeds, and adaptability to diverse environments, serve as successful invasive species, showcasing adjustments in ecological strategy amid global environmental changes. Dandelion invasion disrupts ecosystems by altering soil nutrient structure, reducing native plant populations, affecting plant growth through resource competition, influencing pollinator behavior, and indirectly impacting higher trophic levels. Rapid spread and reproduction can decrease species diversity, impacting overall ecosystem functions and services. Understanding dandelion's ecological traits and factors influencing its invasive nature is crucial for developing effective management strategies. Modeling its spread and growth aids in predicting ecosystem impact, supporting biodiversity conservation, and offering insights into invasive species' behavior amid global change. This section's findings have broader implications for predicting and managing the dynamics of similar plants amid global environmental change. Understanding how plants like dandelions adapt is crucial for foreseeing and managing future ecosystem changes, offering theoretical guidance and models applicable to other plants, and providing a scientific basis for policy formulation.

5.1. Dandelion population growth model

Population Growth Model:

$$P_d(t+1) = P_d(t) + r_d P_d(t)\left(1 - \frac{P_d(t) + \alpha_{dp} P_p(t)}{K_d}\right) \quad (1)$$

Native plant population growth model:

$$P_p(t+1) = P_p(t) + r_p P_p(t)\left(1 - \frac{P_p(t) + \alpha_{pd} P_d(t)}{K_p}\right) \quad (2)$$

Exponential Growth Model: The exponential growth model is a fundamental ecological model that describes unbounded population growth without considering environmental limitations.

$$P(t+1) = P(t) \times e^{r} \quad (3)$$

Among them, P(t) represents the population size at time t, and r represents the intrinsic growth rate of the population.

Logistic Growth Model:

$$P(t+1) = P(t) + r \times P(t) \times \left(1 - \frac{P(t)}{K}\right) \quad (4)$$

Among them, K represents the carrying capacity of the environment.

Exponential growth model under environmental constraints:

$$P(t+1) = P(t) \times e^{r\left(1 - \frac{P(t)}{K}\right)} \quad (5)$$

5.2. Environmental carrying capacity and resource competition model

Environmental Carrying Capacity of Native Plants

$$C_p(t) = \frac{r_p P_p(t)}{1 + \sum_{i=1}^{n} \beta_{pi} R_i(t)}$$

By considering all key resources and using a product form to accumulate the impact of each resource, the environmental carrying capacity of native plants at a specific point in time is derived. Explain - Kp(t): Environmental carrying capacity of native plants at time t. - Kp0: Maximum environmental carrying capacity of native plants under ideal conditions. -γpi: Sensitivity of native plants to the ith resource. -Ri(t): The amount of resources I have available at the time.

5.3. Competitive effects of dandelions on native plants

The purpose of this model is to quantify how native plant populations fare when competing for resources, which is critical to understanding the impact of invasive species such as dandelions on native ecosystems. The following is a detailed derivation and explanation of the formula:

Resource Competition Model for Native Plants

$$C_p(t) = \frac{r_p P_p(t)}{1 + \sum_{i=1}^{n} \beta_{pi} R_i(t)}$$

Resource Competition Model of Dandelion

$$C_d(t) = \frac{r_d \cdot P_d(t)}{1 + \sum_{i=1}^{n} \beta_{di} \cdot R_i(t)} \quad (6)$$

Equation 6 describes the intensity of competition for resources by dandelions, which is a key factor in understanding how dandelions compete with other species for key resources (e.g., water, light, nutrients). The form of this formula is based on the assumption that the availability of resources affects the growth rate of a population and, thus, its competitive intensity.

Competition with other species:

$$P(t+1) = P(t) \times e^{r\left(1 - \frac{P(t) + \alpha \times S(t)}{K}\right)} \quad (7)$$

Derivation and interpretation of the resource competition model

$$R_{t+1} = R_t - c_d P_d(t) R_t - c_p P_p(t) R_t$$

Background introduction: Dandelion is a potent invasive plant that competes with native plant populations for resources through various mechanisms. This competition often involves critical resources such as land, light, water, and nutrients. Dandelions' rapid growth and ability to reproduce means they can quickly occupy large ecological niches, putting pressure on native plant populations and leading to declines or even extinction.

Quantitative model: Here is the formula for a quantitative model describing competition from dandelions to native plants:
Population Growth Model:

$$P_d(t+1) = P_d(t) + r_d P_d(t)\left(1 - \frac{P_d(t) + \alpha_{dp} P_p(t)}{K_d}\right) \quad (8)$$

Native plant population growth model:

$$P_p(t+1) = P_p(t) + r_p P_p(t)\left(1 - \frac{P_p(t) + \alpha_{pd} P_d(t)}{K_p}\right) \quad (9)$$

If one species has a significantly higher r-value than another, it means it is growing faster without competition. The size of the capacity K reflects the richness of environmental resources. A higher K value may mean lower competitive intensity. Derivation and interpretation of the resource competition model

$$R_{t+1} = R_t - c_d P_d(t) R_t - c_p P_p(t) R_t$$

The amount of resources decreases in proportion to each plant's population size and resource consumption efficiency. - Higher values of c and c indicate that the corresponding species consume resources more efficiently. Equation 14 - Derivation and interpretation of the dandelion population adjustment model

$$\Delta P_d = \varepsilon_d \left(R_t - \gamma_d P_d(t)\right)$$

Equation 15 - Derivation and interpretation of the native plant population adjustment model

$$\Delta P_p = \varepsilon_p \left(R_t - \gamma_p P_p(t)\right)$$

Comprehensive explanation - These formulas integrate resource dynamics and the response of two competing species to provide a mathematical description of species interactions in a complex ecosystem. By simulating these formulas, we can predict the effects of dandelion invasion on native plant communities and ecosystem resources. And a possible long-term bullish equilibrium state

5.4. Potential impacts of dandelions on local animal communities

Dandelion invasion affects plant communities and may also indirectly affect animal communities. This impact may be through changes in habitat structure, food web relationships, or levels of biodiversity.
Simulation model Here is a formula to model the potential impact of dandelions on local animal communities:
Response of animal populations to plant cover:

$$A(t+1) = A(t) + r_a A(t)\left(1 - \frac{A(t)}{K_a\left(P_d(t), P_p(t)\right)}\right) \quad (10)$$

Equation 17 - Basic Growth Model of Animal Populations

$$A(t+1) = A(t) + r_a A(t)\left(1 - \frac{A(t)}{K_a}\right)$$

Dependence of animal populations on food resources

$$A(t+1) = A(t) + r_a A(t)\left(1 - \frac{A(t)}{K_a}\right)\left(\frac{F_t}{F_{\max}}\right)$$

Equation 19 - Feedback effects of animal populations on dandelions

$$P_d(t+1) = P_d(t) + r_d P_d(t)\left(1 - \frac{P_d(t) + \alpha_{da} A(t)}{K_d}\right)$$

5.5. Results

The graph shows biomass for different native-to-alien plant ratios, indicating a decline in biomass as alien species increase. Statistical significance is denoted by letters atop bars, with shared letters showing no difference. Error bars represent variability. The study highlights how increasing alien species reduces biomass, validated by regression analysis showing a negative correlation with ecosystem biodiversity, emphasizing the need for conservation strategies.

5.6. Results and Enhanced Interpretation

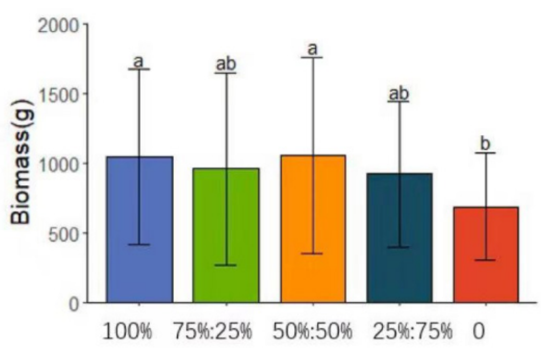

Figure 3: Five bars represent different ratios of native to alien species, each depicted by a different color.

Further Considerations: To strengthen this analysis, detailed methodologies of data collection and statistical procedures will be added. A comparison with existing ecological studies on species composition and ecosystem functions will be included to contextualize our findings.

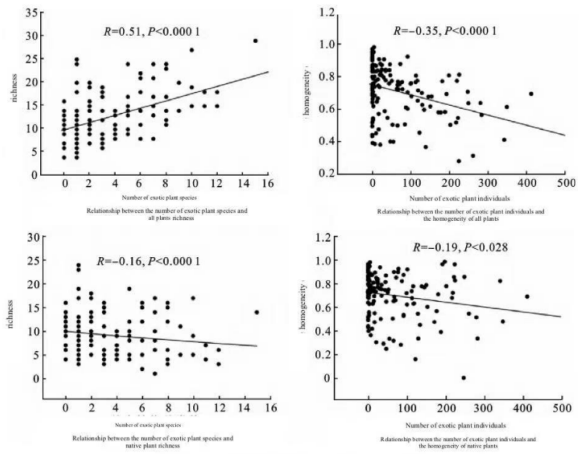

Figure 4: Exponential regression analysis depicting the relationship between exotic plants and biodiversity metrics.

These findings highlight the potential threats posed by exotic species to local biodiversity. This section will be expanded to include a literature review to support our interpretations and discuss the broader ecological implications.

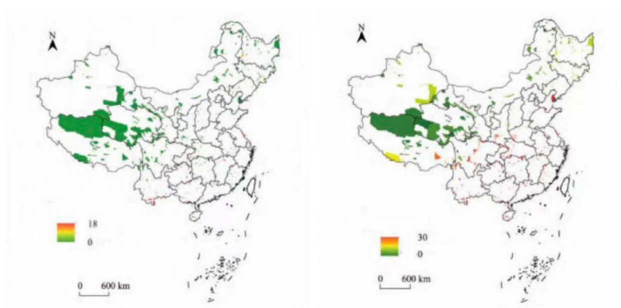

Figure 5: Distribution map of dandelions in China's national nature reserves.

Conclusion:This section provides a more comprehensive data analysis, linking it to broader ecological contexts and scientific literature. The enhanced interpretation offers deeper insights into the impact of species composition on ecosystems and lays the groundwork for future ecological research.

6. Conclusion

This study on dandelions yields valuable theoretical insights into factors influencing their growth and spread, applicable to other invasive species. It also offers practical applications for managing dandelion spread while protecting native biodiversity, particularly in agriculture, providing effective species management and environmental protection solutions.

This interdisciplinary study combines ecology, modeling, GIS, and economic analysis, offering detailed insights into dandelion growth. Despite some limitations like assuming biological homogeneity, it advances understanding. The remaining challenges include long-term effects on local animals and improved management strategies. Overall, it provides valuable insights with theoretical and practical significance, suggesting continued research for ecological support and effective management solutions.

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