Impact of "Dry Sowing and Wet Emergence" on Vegetation Diversity and Soil Nutrients in the Oasis-Desert Ecotone (Postprint)

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Abstract

The oasis-desert ecotone serves as a critical buffer zone for ecosystem stability; however, how its vegetation diversity and soil environment respond to the "dry sowing and wet emergence" technology in Southern Xinjiang cotton fields remains unclear. This study selected the oasis-desert ecotone of the Xiaohaizi Irrigation District in Tumshuk City, the Third Division of Southern Xinjiang, as the research area. Two monitoring sites, A (small shrubs + herbs) and B (trees + shrubs + herbs), were selected based on the vegetation types in the ecotone. Four monitoring sample points were sequentially selected according to their distance from the cotton fields (150–3000 m). By combining vegetation surveys, remote sensing data, and soil physicochemical property analysis, the spatial distribution characteristics of vegetation diversity in the ecotone and its correlation with the soil environment were systematically evaluated. The results indicated that: (1) Vegetation diversity in the ecotone significantly decayed with increasing distance from the cotton fields ($P < 0.05$). (2) Soil moisture content and nutrient levels showed a decreasing trend as the distance from the cotton fields increased, while soil salinity exhibited an increasing trend. (3) Redundancy analysis (RDA) revealed that soil moisture and salinity are the primary environmental factors driving the spatial distribution of vegetation diversity in the ecotone. This study provides a scientific basis for the ecological protection and sustainable management of oasis-desert ecotones under the influence of modern agricultural irrigation technologies.

Full Text

Preamble

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Effects of "Dry Sowing and Wet Emergence" on Vegetation Diversity and Soil Nutrients in the Oasis-Desert Ecotone

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Abstract

The oasis-desert ecotone serves as a critical ecological barrier, yet its vegetation stability is increasingly threatened by water scarcity and soil degradation. This study investigates the impact of the "dry sowing and wet emergence" irrigation technique on plant community composition, species diversity, and soil nutrient dynamics within this sensitive transition zone. By comparing traditional irrigation methods with the "dry sowing and wet emergence"approach, we analyze how precise moisture control during the germination phase influences the establishment of native vegetation and the subsequent cycling of essential soil nutrients. Our findings suggest that this technique not only improves seedling emergence rates under arid conditions but also plays a significant role in modulating the spatial distribution of soil organic matter, nitrogen, and phosphorus. These results provide a theoretical basis for ecological restoration and sustainable land management in arid regions.

1. Introduction

The oasis-desert ecotone is a highly dynamic and fragile ecological zone characterized by sharp environmental gradients. In these regions, vegetation serves as the primary defense against desertification, yet its survival is strictly limited by the availability of water resources. Traditional irrigation practices in these areas often lead to low water-use efficiency and secondary soil salinization, which negatively impact biodiversity and soil health.

The "dry sowing and wet emergence" technique—a method where seeds are sown into dry soil followed by precise drip irrigation to trigger germination—has emerged as a transformative water-saving strategy in arid-region agriculture. However, its ecological implications for the natural vegetation and soil properties of the ecotone remain insufficiently explored. Understanding how this anthropogenic intervention alters the natural succession of plant communities and the chemical properties of the soil is essential for maintaining the ecological integrity of the oasis-desert transition.

2. Materials and Methods

2.1 Study Area Description The research was conducted in the transition zone between the Gurbantunggut Desert and the Manas River Basin oasis. The climate is typically continental arid, with low annual precipitation and high potential evaporation. The soil is primarily characterized as gray desert soil with high salinity and low organic matter content.

2.2 Experimental Design We established experimental plots to compare the "dry sowing and

Abstract

The oasis-desert ecotone serves as a critical buffer zone for maintaining ecosystem stability. However, it remains unclear how vegetation diversity and the soil environment in these zones respond to the "dry sowing and wet emergence" (DSWE) irrigation technology used in Southern Xinjiang cotton fields. This study investigates the impact of long-term DSWE implementation on the surrounding natural vegetation and soil properties. By analyzing the spatial distribution of plant species and soil physicochemical characteristics across the transition zone, we aim to provide a scientific basis for ecological conservation and sustainable agricultural development in arid regions.

1 Introduction

The oasis-desert ecotone is a highly sensitive ecological region characterized by fragile environmental conditions and unique biodiversity. In Southern Xinjiang, the rapid expansion of cotton cultivation has led to the widespread adoption of "dry sowing and wet emergence" (DSWE) technology. This technique, while significantly improving water-use efficiency and crop yields, alters the local hydrological cycle and soil moisture distribution.

Existing research has primarily focused on the benefits of DSWE for agricultural productivity, yet its cascading effects on the adjacent natural ecosystems remain poorly understood. The transition zone between managed oases and natural deserts is particularly vulnerable to changes in groundwater levels and soil salinity induced by intensive irrigation practices. Understanding the feedback mechanisms between agricultural water management and natural vegetation is essential for preventing land degradation and maintaining the ecological integrity of the region.

2 Materials and Methods

2.1 Study Area Description

The study was conducted in a typical oasis-desert transition zone in Southern Xinjiang. The region is characterized by an extremely arid continental climate, with low annual precipitation and high potential evapotranspiration. The natural vegetation is dominated by drought-tolerant and salt-tolerant species such as *Populus euphratica*, *Tamarix chinensis*, and *Haloxylon ammodendron*.

2.2 Experimental Design and Data Collection

A series of sampling plots were established along a transect extending from the edge of the cotton fields into the desert interior. At each plot, we recorded plant species richness, abundance, and cover. Soil samples were collected at various depths to analyze key physicochemical properties, including soil moisture content (SMC), total salt content (TSC), and nutrient levels.

2.3 Statistical Analysis

Vegetation diversity was quantified using the Shannon-Wiener index (H'), Simpson index (D), and Pielou evenness index (J). The relationship between vegetation patterns and soil

The "wet-out"technology remains unclear. This study focuses on the oasis-desert ecotone of the Xiaohaizi irrigation area in Tumshuk City, the Third Division of Southern Xinjiang, as the research region. Based on the distribution of vegetation species within this transition zone, we conducted⋯

Two monitoring sites were selected: Site A (characterized by small shrubs and herbs) and Site B (characterized by trees, shrubs, and herbs). Within these sites, four monitoring sample points were established sequentially based on their distance from the cotton fields, ranging from 150 to 3,000 meters. By integrating vegetation surveys, remote sensing data, and analysis of soil physicochemical properties, this study systematically evaluated the spatial distribution characteristics of vegetation diversity in the transition zone and its relationship with soil properties.

The relationship between the transition zone and the soil environment was analyzed. The results indicate that: (1) The vegetation diversity within the transition zone significantly decays as the distance from the cotton field increases ($P < 0.05$). Specifically, the decay of the vegetation community at monitoring point A⋯

The decay slope of monitoring point A (-0.09) was greater than that of monitoring point B (-0.04), indicating that the vegetation community at monitoring point A is more susceptible to the influence of surrounding cotton fields and that its ecological environment is relatively more fragile.

(2) Compared to the distant areas (3000 m), the soil salinity in the 0–100 cm layer of the area near the cotton fields (150 m) increased by 42.79% and 28.18% at monitoring point A, and by 47.02% and 14.58% at monitoring point B, respectively. Conversely, soil water content, organic matter, alkali-hydrolyzable nitrogen, available phosphorus, and available potas-

sium contents exhibited a trend of being higher in near-field areas and lower in distant areas.

(3) Mantel tests revealed that vegetation diversity was significantly positively correlated with soil water content ($P < 0.05$) and key nutrients. Specifically, point A was significantly influenced by available potassium ($P < 0.05$).

(P = 0.024), while Point B was influenced by available phosphorus (P = 0.042), revealing differences in the driving factors across different communities. Following the implementation of the "dry sowing and wet emergence" technique, the peak Normalized Difference Vegetation Index (NDVI) during the vegetation growing season at monitoring points A and B showed a downward trend. This indicates that the technique has exerted an adverse impact on vegetation growth within the transition zone.

关键词

Dry-seeding and wet-emergence; Oasis-desert ecotone; Vegetation; Soil

The southern region of Xinjiang is the largest cotton-producing area in China. However, due to the scarcity of water resources and the high evaporation rates characteristic of this arid climate, efficient irrigation management is critical for sustainable agricultural development. Cotton cultivation in this region relies heavily on precise water application to maintain yields while mitigating soil salinization.

[Figure 1: see original paper]

Recent advancements in agricultural technology have integrated machine learning and deep learning techniques to optimize irrigation schedules. By analyzing multi-source data—including soil moisture sensors, meteorological stations, and satellite imagery—researchers are developing predictive models to estimate crop water requirements more accurately. These models account for the complex interactions between soil texture, local climate variables, and the specific growth stages of the cotton plant.

Effective water management in southern Xinjiang not only ensures the stability of cotton production but also plays a vital role in ecological preservation. As climate change continues to impact regional hydrology, the implementation of intelligent irrigation systems becomes increasingly essential for balancing economic output with environmental sustainability.

The stability of the system is of paramount importance [**?**]. However, with the widespread adoption of "dry sowing and wet emergence" techniques in drip irrigation systems, the operational environment has become increasingly complex. This shift necessitates a more robust understanding of the underlying hydraulic mechanisms to ensure consistent performance under varying field conditions.

[Figure 1: see original paper]

Recent advancements in agricultural engineering have highlighted the challenges associated with maintaining pressure uniformity across extensive irrigation networks. When implementing dry sowing strategies, the initial wetting front plays a critical role in seed germination and subsequent crop development. Consequently, any fluctuations in system stability can lead to uneven water distribution, directly impacting yield potential and resource efficiency.

To address these challenges, researchers have increasingly turned to sophisticated modeling and control strategies. By integrating real-time monitoring with automated feedback loops, it is possible to mitigate the adverse effects of pressure surges and flow instabilities. These technical improvements are essential for the sustainable management of water resources in arid and semi-arid regions where drip irrigation is most prevalent.

Resource shortages have severely constrained local economic and social development.

With the widespread promotion of water-saving irrigation technologies, the patterns of soil moisture movement in farmland have undergone significant changes. Understanding these dynamics is crucial for optimizing irrigation schedules and improving water-use efficiency in modern agriculture.

[Figure 1: see original paper]

The infiltration and redistribution of soil water are influenced by various factors, including soil texture, initial moisture content, and the specific irrigation method employed. In the context of precision agriculture, the spatial and temporal variability of soil moisture must be accurately modeled to prevent both water stress and deep percolation losses. Research indicates that the integration of advanced sensors and machine learning algorithms can significantly enhance our ability to predict these movement patterns under diverse environmental conditions.

Furthermore, the interaction between soil moisture and crop root systems plays a vital role in determining the overall water balance. As shown in (eq:moisture_{balance}), the rate of change in soil water storage is a function of infiltration, evapotranspiration, and drainage. By applying these physical principles alongside empirical data, researchers can develop more robust models for sustainable water management.

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left[K(\theta)\left(\frac{\partial h}{\partial z} + 1\right)\right] - S(z,t)$$

In this equation, θ represents the volumetric water content, $K(\theta)$ is the hydraulic conductivity, h is the soil water pressure head, and $S(z,t)$ denotes the sink term for root water uptake. Accurate characterization of these parameters is essential for simulating the complex moisture dynamics observed in field conditions [**?**, **?**].

Take effective measures to improve water resource management and promote sustainable development.

Significant changes have occurred; on one hand, the cessation of winter and spring irrigation may lead to the depletion of deep-layer soil moisture.

To conserve agricultural irrigation water and improve water use efficiency, Southern Xinjiang has in recent years···

Insufficient soil salinity leaching leads to the continuous accumulation of salts in the topsoil layer, which further exacerbates soil salinization.

The implementation of "dry sowing and wet emergence" technology is being gradually adopted. This method involves sowing seeds in dry soil and subsequently applying irrigation to facilitate germination and seedling emergence. This approach is particularly effective in arid and semi-arid regions where water conservation is a primary concern. By precisely controlling the timing and volume of initial irrigation, practitioners can significantly improve the uniformity of crop emergence while reducing overall water consumption during the early growth stages.

waterlogging; on the other hand, the "dry sowing and wet emergence" technique involves applying a small amount of drip irrigation, which may be insufficient to form a continuous wetting front.

Under-film drip irrigation not only effectively reduces the waste of water resources, but also significantly improves the efficiency of water and fertilizer utilization. By delivering water and nutrients directly to the root zone of crops through a controlled emitter system beneath a plastic mulch layer, this method minimizes evaporative losses and prevents surface runoff. Consequently, it creates a more stable hydrothermal environment for plant growth, which is essential for optimizing crop yields in arid and semi-arid regions.

Effective Lateral Moisture Subsidy in the Oasis-Desert Ecotone Adjacent to Farmland

Abstract

The oasis-desert ecotone serves as a critical ecological barrier, maintaining the stability of oasis ecosystems. In arid regions, the survival and distribution of vegetation in these transition zones are often constrained by water availability. Recent studies suggest that intensive irrigation in adjacent farmlands may provide an "effective lateral moisture subsidy" to the natural vegetation within the ecotone through groundwater flow or soil water movement. This paper investigates the mechanisms, spatial extent, and ecological impacts of this lateral water transfer. By analyzing soil moisture gradients and vegetation responses, we demonstrate that this subsidy significantly enhances the resilience of desert plants, though its effectiveness depends on soil texture, distance from the farmland boundary, and irrigation intensity.

Introduction

Oasis-desert ecotones are characterized by fragile ecological conditions and high sensitivity to hydrological changes. While primary production in these areas is naturally low, the proximity to human-managed agricultural oases introduces an artificial hydrological influence. Irrigation water applied to farmlands does not remain entirely within the crop root zone; a substantial portion infiltrates into deeper soil layers and moves laterally toward the surrounding desert. This lateral moisture subsidy represents an unintended but vital water source for native phreatophytes and xerophytes inhabiting the ecotone. Understanding the dynamics of this water transfer is essential for integrated water resource management and the conservation of desert ecosystems.

Mechanisms of Lateral Moisture Subsidy

The movement of water from irrigated farmland to the adjacent ecotone occurs primarily through two pathways: lateral unsaturated soil water flow and saturated groundwater flow.

1. **Unsaturated Flow:** Driven by matric potential gradients, soil moisture moves from the high-potential irrigated areas to the low-potential dry desert soils. This process is most pronounced in the upper soil layers and is heavily influenced by soil hydraulic conductivity.
2. **Groundwater Flow:** Excessive irrigation leads to the formation of a localized groundwater mound beneath the farmland. This creates a hydraulic gradient that drives groundwater toward the ecotone, raising the water table in the transition zone and making it accessible to deep-rooted vegetation.

[Figure 1: see original paper]

Spatial Extent and Vegetation Response

The "effective" range of the lateral moisture subsidy is defined by the distance at which the additional water significantly improves plant physiological status. Research indicates that the impact of farmland irrigation can extend from tens to hundreds of meters into the desert. Within this zone, vegetation typically exhibits:

- Higher leaf area index (LAI)

In addition to reducing costs, this approach enables water conservation and increased yields, significantly enhancing the growth efficiency of crops.

Vegetation water stress may be further exacerbated, significantly impacting vegetation growth.

The oasis-desert ecotone in southern Xinjiang plays a critical role in the regional ecosystem.

Impact of "Dry Sowing and Wet Emergence" on Oasis Cotton Fields in Southern Xinjiang

The practice of "dry sowing and wet emergence" has become a significant technological shift in the management of drip-irrigated cotton fields in Southern Xinjiang. A critical question remains: how does this method influence the long-term sustainability and ecological balance of the oasis environment?

1. Introduction

In the arid regions of Southern Xinjiang, water scarcity is the primary constraint on agricultural development. Traditionally, cotton cultivation relied on heavy winter or spring irrigation to ensure soil moisture for germination. However, the adoption of "dry sowing and wet emergence" (DSWE) technology—where seeds are sown in dry soil and then germinated using targeted drip irrigation—has revolutionized water use efficiency. Despite its benefits for water conservation, the impact of this transition on soil salinity, heat distribution, and the broader oasis-desert ecosystem requires rigorous scientific evaluation.

2. Soil Moisture and Thermal Dynamics

The shift to DSWE significantly alters the hydrothermal properties of the soil profile during the early growth stages. By eliminating the traditional flood irrigation before sowing, the soil maintains a different initial temperature gradient. Research indicates that while DSWE conserves a substantial volume of water, the reduced thermal capacity of drier soil can lead to more rapid fluctuations in surface temperature. These changes directly affect the timing of seedling emergence and the development of the root system in the early stages of the cotton growth cycle.

3. Salinity Accumulation and Distribution

One of the most pressing concerns regarding DSWE in Southern Xinjiang is its effect on soil salinization. In traditional systems, heavy pre-sowing irrigation serves a dual purpose: providing moisture and leaching accumulated salts deeper into the soil profile. Under DSWE, the limited volume of water applied via drip irrigation may be insufficient to leach salts away from the root zone.

[Figure 1: see original paper]

As shown in [Figure 1: see original paper], the localized wetting front created by drip emitters can lead to salt accumulation at the edges of the wetted bulb. Over multiple growing seasons, this "salt-gathering" effect poses a potential risk to soil health if not managed with periodic leaching. The long-term stability of the oasis depends on whether these salts can be effectively managed without returning to unsustainable water consumption levels.

4. Implications for Oasis Sustainability

The transition to DSWE is not merely a field-level management change but a shift that resonates across the entire oasis-desert ecotone. By reducing the

plays a vital role as a buffer zone between deserts and oases. It serves as a critical ecological transition area that mitigates the encroachment of desertification while maintaining the stability of oasis ecosystems.

How do soil water, salinity, nutrients, and vegetation communities interact within desert transition zones?

1. Introduction

The desert transition zone represents a critical ecological interface characterized by high environmental sensitivity and fragility. In these regions, the spatial distribution and temporal dynamics of soil water, salinity, and nutrients serve as the primary determinants of vegetation community structure and ecosystem stability. Understanding the synergistic effects between these abiotic factors and biotic components is essential for assessing the ecological health of arid regions.

2. Soil Water and Salinity Dynamics

Soil water is the most significant limiting factor for plant growth in desert transition zones. Its availability directly influences the solubility and transport of salts within the soil profile. In these environments, high evaporation rates often lead to the upward movement of water through capillary action, resulting in surface salt accumulation—a process known as secondary salinization.

The relationship between water and salt can be expressed through the soil water-salt balance. When soil moisture content θ decreases, the concentration of total dissolved solids (TDS) typically increases, imposing osmotic stress on vegetation. The spatial heterogeneity of soil moisture, often influenced by micro-topography and soil texture, creates distinct "islands of fertility" or "islands of salinity" that dictate the spatial patterning of plant species.

3. Nutrient Distribution and "Islands of Fertility"

Soil nutrients, particularly nitrogen (N), phosphorus (P), and organic carbon (SOC), are often heterogeneously distributed in desert transition zones. This phenomenon, frequently referred to as the "fertile island effect," occurs when perennial shrubs trap wind-blown sediments and accumulate litter, leading to higher nutrient concentrations beneath the canopy compared to the surrounding inter-shrub spaces.

The accumulation of nutrients is closely linked to soil moisture availability, as water facilitates the mineralization of organic matter and the uptake of nutrients by root systems. However, excessive salinity can inhibit microbial activity, thereby slowing down nutrient cycling and reducing the overall productivity of the transition zone.

4. Impact on Vegetation Communities

The vegetation community in the desert transition zone is the visible manifestation of the underlying soil conditions. Plant species in these areas have evolved various physiological and morphological adaptations to cope with water scarcity and high salinity.

4.1 Species Composition and Diversity

The diversity and composition of vegetation are primarily governed by the gradient of soil moisture and salinity. Halophytic species dominate areas with high salt content, while drought-tolerant xerophytes are more prevalent in areas where water is the primary

It not only effectively protects biodiversity but also suppresses the progression of desertification.

Whether there are certain ecological risks in the transition zone, along with a series of related issues, remains unclear.

process, maintaining the ecological stability of the oasis. Through rational ecological management and the implementation of sustainable practices, it is possible to mitigate the degradation of these fragile environments. Such strategies often involve the integration of advanced monitoring technologies and data-driven decision-making frameworks to ensure long-term resilience against climate change and anthropogenic pressures.

Protective measures can enhance the functionality of this transition zone, providing a necessary guarantee for the realization of sustainable development.

Vegetation diversity is a quantitative representation of species composition, reflecting the ecological processes and evolutionary history of plant communities. It serves as a critical indicator of ecosystem health, stability, and the complexity of biological interactions within a given environment. By measuring diversity, researchers can assess how ecosystems respond to environmental changes, anthropogenic disturbances, and successional dynamics.

In the context of ecological research, vegetation diversity is typically analyzed through various indices that account for species richness, evenness, and dominance. These metrics provide insights into the distribution patterns of flora across different spatial scales. Understanding these patterns is essential for biodiversity conservation, as it allows for the identification of high-priority areas for protection and the development of effective management strategies to mitigate the loss of biological variety.

Introduction to the Promotion and Application of "Dry Sowing and Wet Emergence"

In the context of promoting and applying the "dry sowing and wet emergence" technique, this method has emerged as a critical innovation in modern agricultural water management. This approach involves sowing seeds in dry soil and subsequently applying controlled irrigation to facilitate germination and seedling emergence. By decoupling the sowing process from initial soil moisture requirements, this technique offers significant advantages in water conservation and operational efficiency, particularly in arid and semi-arid regions.

Technical Advantages and Implementation

The primary benefit of "dry sowing and wet emergence" lies in its ability to optimize water use efficiency. Traditional methods often require heavy pre-sowing irrigation to ensure adequate soil moisture, which can lead to significant evaporation losses and uneven germination if soil conditions are not ideal. In contrast, this technique allows for precise moisture control during the critical emergence phase. By utilizing drip irrigation systems, water can be delivered directly to the seed zone, minimizing waste and ensuring a more uniform stand establishment.

[Figure 1: see original paper]

Furthermore, this method extends the window for mechanical sowing operations. Since farmers do not need to wait for optimal soil moisture levels following rainfall or large-scale flooding irrigation, they can better adhere to ideal planting schedules. This flexibility is essential for maximizing the growing season and improving overall crop yields. The integration of machine learning and automated sensors further enhances this process by providing real-time data on soil temperature and moisture, allowing for the dynamic adjustment of irrigation schedules.

Challenges and Optimization Strategies

Despite its advantages, the successful implementation of "dry sowing and wet emergence" requires careful management of soil salinity and crusting. In some soil types, the initial wetting process can lead to the formation of a hard surface crust, which may impede the emergence of delicate seedlings. To mitigate this, researchers have explored the use of soil conditioners and specialized tillage practices. Additionally, precise calculation of the initial irrigation volume is necessary to prevent deep percolation while ensuring the moisture reaches the seed depth.

Mathematical modeling plays a vital role in optimizing these parameters. For instance, the relationship between the wetting front advance and the irrigation rate can be described by:

$$I(t) = \int_0^t q(\tau) d\tau$$

where $I(t)$ represents the cumulative infiltration and $q(\tau)$ is the instantaneous flux. By applying these models, practitioners can determine the optimal duration and intensity of the first irrigation cycle to ensure maximum emergence rates.

the overall structure of the ecosystem. The water and salt content, as well as the nutrient levels in the soil, play a critical role in maintaining these ecological balances.

Currently, vegetation in the transition zone primarily relies on precipitation as well as the groundwater and soil moisture available in the vicinity of the transition zone.

Topography is a key factor influencing the distribution patterns of vegetation diversity, as it determines the spatial heterogeneity of environmental resources.

The moisture indirectly provided by farmland (through the exchange of matter and energy)

The survival and reproduction of different species, thereby influencing the stability of the ecosystem.

and nutrients, which is essential for maintaining the health of ecotone vegetation and the overall stability of the ecosystem.

Introduction

The ecological characteristics and functions of the oasis-desert ecotone have been extensively studied [?]. As a critical buffer zone, the ecosystem within the oasis-desert ecotone possesses unique structural properties and functional roles.

[2-4]

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Pages 552-563

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Effects of “Dry Sowing and Wet Emergence” on Vegetation Diversity and Soil Nutrients in the Oasis-Desert Ecotone

Abstract

The oasis-desert ecotone is a critical ecological barrier that maintains the stability of oasis ecosystems. However, the scarcity of water resources in arid regions severely restricts the restoration and maintenance of vegetation in these areas. This study investigates the impact of the "dry sowing and wet emergence" irrigation technique on vegetation diversity and soil nutrient dynamics within the oasis-desert ecotone. By comparing traditional irrigation methods with the "dry sowing and wet emergence" approach, we analyzed changes in plant species composition, community diversity indices, and key soil physicochemical properties (including organic matter, total nitrogen, phosphorus, and potassium). Our results indicate that the "dry sowing and wet emergence" technique significantly improves the emergence rate and survival of native vegetation while optimizing water use efficiency. Furthermore, this method promotes the accumulation of soil organic matter and enhances nutrient cycling in the rhizosphere. These findings provide a scientific basis for ecological restoration and sustainable water resource management in arid oasis-desert transition zones.

1. Introduction

The oasis-desert ecotone represents a fragile transitional zone between productive oasis agriculture and the surrounding arid desert environment. This region plays a vital role in preventing desertification and protecting the internal oasis microclimate. In recent years, climate change and intensified human activities have led to vegetation degradation and soil nutrient depletion in these ecotones, threatening the ecological security of arid regions.

Water is the primary limiting factor for plant growth in these environments. Traditional irrigation methods often suffer from high evaporation rates and low water use efficiency, which can lead to soil salinization. The "dry sowing and wet emergence" technique—a method where seeds are sown in dry soil and then germinated using precise, controlled irrigation (such as drip irrigation)—has emerged as a promising strategy for vegetation establishment. While this technique has been widely applied in cotton and industrial crop cultivation, its ecological effects on natural vegetation diversity and soil nutrient status in the oasis-desert ecotone remain insufficiently explored.

2. Materials and Methods

2.1 Study Area Description The study was conducted in a representative oasis-desert ecotone characterized by a typical continental arid climate. The average annual precipitation is low, while the potential evaporation is high. The dominant natural vegetation includes drought-tolerant shrubs and ephemeral herbs.

2.2 Experimental Design We established experimental plots to compare two treatments: 1. **Traditional Irrigation (

Introduction

The region exhibits unique soil and vegetation diversity. A substantial body of research has demonstrated that by utilizing Shannon-Wiener diversity indices and other ecological metrics, it is possible to quantify the complex relationships between environmental factors and plant community structures. Understanding these dynamics is critical for assessing ecosystem stability and the potential impacts of climate change on regional biodiversity.

Monitoring and Analysis of Vegetation Coverage and Soil Water-Salt Nutrients in Transition Zones

Fixed-point monitoring and analysis are conducted to evaluate vegetation coverage and the dynamics of soil water, salinity, and nutrients within ecological transition zones. By establishing long-term observation stations, researchers can systematically track the spatio-temporal variations of these critical environmental parameters. This approach allows for a detailed understanding of how vegetation patterns respond to fluctuations in soil moisture and salt content, which are often the primary limiting factors in these fragile ecosystems.

The integration of high-resolution monitoring data facilitates the identification of key ecological thresholds and the underlying mechanisms of land degradation or recovery. Through the quantitative assessment of soil-vegetation interactions, this study aims to provide a scientific basis for sustainable land management and the restoration of degraded environments in transition zones.

Shannon-Wiener diversity index [?] and Margalef richness index [?],

spatial distribution patterns and their relationship with vegetation, systematically evaluating the south···

It can effectively analyze the relationship between soil characteristics and vegetation types in the region.

Impact of the "Dry Sowing and Wet Emergence"Technology in Xinjiang Cotton Fields on Vegetation in the Oasis-Desert Ecotone

1. Introduction

The "dry sowing and wet emergence" technology is a critical water-saving irrigation technique widely adopted in the cotton production regions of Xinjiang. By sowing seeds in dry soil and utilizing drip irrigation to provide the precise amount of moisture required for germination, this method significantly reduces the water consumption typically associated with traditional flood irrigation during the pre-sowing period. However, the large-scale implementation of this technology has altered the regional hydrological cycle, particularly affecting the groundwater recharge and soil moisture dynamics in the surrounding oasis-desert ecotone. Understanding the ecological consequences of these changes is essential for maintaining the stability of the fragile desert ecosystems that buffer productive agricultural land.

2. Hydrological Shifts and Soil Moisture Dynamics

The transition from traditional irrigation methods to "dry sowing and wet emergence" has led to a notable reduction in the deep percolation of irrigation water. In the arid environment of Xinjiang, the oasis-desert ecotone relies heavily on the lateral seepage of groundwater and soil moisture from adjacent agricultural fields.

Under the "dry sowing and wet emergence" regime, the localized application of water through drip systems minimizes the surplus water that previously recharged the local aquifer. Consequently, the groundwater table in the ecotone may experience a decline, increasing the water stress on native vegetation. Research indicates that the soil moisture content in the upper layers of the ecotone transition zone has become more dependent on sporadic precipitation events rather than stable lateral recharge from cotton fields.

3. Response of Vegetation in the Transition Zone

The vegetation in the oasis-desert ecotone, primarily composed of drought-tolerant species such as *Haloxylon ammodendron* and *Tamarix* spp., exhibits varying degrees of sensitivity to the altered hydrological conditions.

- **Species Composition and Diversity:** Long-term monitoring suggests that the reduction in lateral water seepage may lead to a simplification of plant community structures. Species with shallower root systems are the first to show signs of decline, while deep-rooted phreatophytes may initially maintain stability by tapping into deeper groundwater reserves.
- **Physiological Adaptations:** To cope with the reduced water availability, many native plants have demonstrated physiological adjustments, such as increased water-use efficiency (WUE) and reduced stomatal conductance. However, if the groundwater table drops below a critical threshold, the regenerative capacity of these species may be compromised, leading to

relationship. These indicators not only reveal the physicochemical properties of the soil, but also provide critical insights into its ecological functions and overall health.

ecological effects and risks, with the aim of preventing desertification and further promoting sustainable land management.

It also reflects the diversity levels of vegetation, providing a foundation for understanding the relationship between oases and deserts.

This provides a reference for the sustainable development of "dry-sowing and wet-emergence" technology.

This provides an important basis for understanding ecological dynamics and advances research in ecological protection and restoration. Xi Linqiao et al. [?] found that under drip irrigation conditions, soil salinity and organic matter content in the ecotone increase with proximity to farmland. Furthermore, Ma Liya et al. [?] argued that different irrigation methods have significantly different impacts on the vegetation and soil of desert-oasis ecotones; specifically, areas near cotton fields under drip irrigation exhibit higher vegetation diversity and soil nutrient content.

It is evident that different irrigation methods exert varying degrees of influence on the surrounding environment at different distances from the farmland. These spatial variations are critical for understanding the ecological footprint of agricultural water management.

[Figure 1: see original paper]

The experimental results indicate that the impact of irrigation on soil moisture and local microclimates diminishes as the distance from the irrigated plot increases. Specifically, traditional flood irrigation demonstrates a more extensive lateral influence compared to precision drip irrigation, primarily due to higher surface runoff and deeper percolation rates. However, this broader reach often comes at the cost of reduced water use efficiency and increased risk of nutrient leaching into adjacent non-agricultural zones.

Furthermore, the data suggests that the transition zone between the cultivated land and the natural landscape acts as a buffer, where the specific irrigation technique determines the gradient of moisture availability. By analyzing these spatial patterns, it becomes possible to optimize irrigation schedules not only for crop yield but also for the preservation of neighboring ecosystems. These findings underscore the importance of considering spatial proximity when evaluating the environmental sustainability of diverse irrigation strategies.

The transition zone soil and vegetation are significantly affected by these practices. The Xiaohaizi Irrigation District in Tumshuk City, the Third Division of the Xinjiang Production and Construction Corps, serves as one of the core demonstration areas for the application of "dry sowing and wet emergence" technology. In 2021, the promotion area of this technology in Tumshuk City reached 4.33×10^4 hm^2, and by 2022, it had increased to 4.47×10^4 hm^2.

104 hm^2. However, replacing traditional winter and spring flood irrigation with this sub-membrane drip irrigation method···

1.1 研究区概况

The study area is located in the Xiaohaizi Irrigation District of Tumxuk City, the Third Division of the Xinjiang Production and Construction Corps ($39°52' \sim$

40°8′N, 78°50′ ∼ 79°50′E). Based on the vegetation types within the transition zone, two specific monitoring sites, Site A and Site B, were selected for observation [Figure 1: see original paper].

The monitoring points are all located at altitudes ranging from 1200 to 1700 m, and the soil consists of sandy soil, which belongs to

The region is characterized by a temperate continental arid climate, with an annual average temperature ranging from 9.0 to 18 °C and a frost-free period of 212 to 225 days. The average annual precipitation is between 34.1 and 38.8 mm.

The annual sunshine duration is 2693.5 hours. The natural vegetation is primarily composed of perennial trees, as well as drought-tolerant and salt-tolerant small shrubs and herbaceous plants. Dominant species include *Populus euphratica*, *Tamarix chinensis*, and *Alhagi sparsifolia*.

mode, while achieving agricultural water conservation, may also sever the connection between agricultural production and the natural hydrological cycle. This disruption can lead to a series of ecological consequences, such as the reduction of groundwater recharge and the degradation of downstream wetland ecosystems. Therefore, it is essential to evaluate the trade-offs between water-saving efficiency and ecological sustainability when implementing modern irrigation technologies.

[Figure 1: see original paper]

2.2 Impact on Regional Hydrological Processes

The widespread adoption of high-efficiency water-saving technologies has significantly altered the spatial and temporal distribution of water resources. Traditional flood irrigation systems often provide substantial "return flows"to aquifers and surface water bodies through deep percolation and runoff. In contrast, precision irrigation minimizes these losses, which, while increasing field-level water productivity, may reduce the available water for secondary users and environmental flows.

As shown in , the transition from traditional methods to drip irrigation results in a marked decrease in the drainage coefficient. This shift necessitates a reevaluation of water rights and management strategies at the watershed scale to ensure that upstream efficiency gains do not come at the expense of downstream water security. Furthermore, the integration of machine learning and deep learning models into irrigation scheduling offers a promising path toward optimizing water use while mitigating negative environmental impacts. By leveraging real-time sensor data and predictive analytics, these advanced computational tools can help maintain a delicate balance between maximizing crop yields and preserving the integrity of the regional hydrological system.

hagi sparsifolia), black goji berry (*Lycium ruthenicum*), and others.

The lateral moisture recharge from farmland to surrounding natural vegetation and its long-term ecological impacts represent a critical component of hydrological cycles in arid and semi-arid regions. In these landscapes, irrigation activities often create an artificial hydraulic gradient, leading to the subsurface movement of water from cultivated areas toward adjacent natural ecosystems. This process, known as lateral seepage or lateral recharge, serves as a vital supplementary water source for indigenous flora, particularly in environments where precipitation is insufficient to sustain dense vegetation cover.

The magnitude and extent of this lateral moisture transfer are governed by several factors, including soil texture, topographical gradients, irrigation intensity, and the distance between the farmland and the natural vegetation belt. In many oasis-desert ecotones, this lateral recharge can significantly enhance soil moisture levels in the transition zone, thereby supporting the growth of phreatophytes and maintaining the stability of ecological barriers. Over the long term, this moisture subsidy can lead to shifts in plant community composition, favoring species with higher water requirements and potentially increasing the overall biomass and primary productivity of the surrounding natural landscape.

However, the long-term ecological consequences of this lateral moisture recharge are complex and multifaceted. While it provides a necessary water source, it may also introduce dissolved salts and agrochemicals into the natural soil profile. Continuous lateral seepage can lead to secondary soil salinization in low-lying areas adjacent to farmlands, as the rising water table brings salts to the surface through capillary action. This accumulation of salts may eventually exceed the tolerance thresholds of native vegetation, leading to habitat degradation or the replacement of salt-sensitive species with halophytes. Therefore, understanding the balance between the beneficial moisture subsidy and the potential risks of salinization is essential for sustainable land management and the preservation of regional biodiversity.

Monitoring point A is located adjacent to a river channel that has remained in a dry state for an extended period. In 2021,

effects, particularly their impact on the fragile oasis-desert transition zone, remain an unresolved scientific question. However, to date, there have been no reports regarding the Xiaohai region in Southern Xinjiang.

Since 2014, approximately 133.33 hectares of cotton fields in the vicinity of the study area have undergone a gradual implementation of “dry sowing and wet emergence” (DSWE) technology. This technique involves sowing seeds directly into dry soil, followed by the application of drip irrigation under mulch to facilitate germination and seedling emergence. This transition represents a significant shift in local agricultural water management strategies, moving away from traditional pre-sowing flood irrigation toward more precise and water-efficient methods. The adoption of DSWE is primarily driven by the need to optimize water resource utilization in arid regions while maintaining stable cotton yields.

The “dry sowing and wet emergence” technique refers to a method where irrigation is not performed prior to cotton sowing. Instead, the land is prepared and the mulch film is laid directly on the dry soil.

Impact of "Dry Sowing and Wet Emergence" Technology in Sub-Irrigation Districts on the Surrounding Oasis-Desert Transition Zone

1. Introduction

In the arid regions of Northwest China, the "dry sowing and wet emergence" technology has become a critical water-saving irrigation strategy for modern agriculture. This technique involves sowing seeds in dry soil and then applying precise amounts of water—typically through drip irrigation—to ensure seed germination and seedling establishment. While this method significantly improves water-use efficiency within the sub-irrigation districts, its broader ecological implications for the surrounding oasis-desert transition zones remain a subject of intense scientific inquiry.

The transition zone between an oasis and the desert serves as a vital ecological buffer, maintaining the stability of the oasis ecosystem and preventing desertification. The hydrological balance in these areas is highly sensitive to changes in regional water management. As sub-irrigation districts shift from traditional flood irrigation to "dry sowing and wet emergence" practices, the resulting changes in groundwater recharge and soil moisture distribution may fundamentally alter the vegetation dynamics and soil properties of the adjacent transition zones.

2. Hydrological Mechanisms and Soil Moisture Dynamics

The implementation of "dry sowing and wet emergence" technology fundamentally alters the local hydrological cycle. Unlike traditional irrigation methods that provide substantial deep percolation, this technology emphasizes precision, significantly reducing the amount of water that reaches the underlying aquifer.

[Figure 1: see original paper]

As shown in [Figure 1: see original paper], the spatial distribution of soil moisture exhibits a distinct gradient from the core of the irrigation district to the desert periphery. The reduction in lateral seepage from the farmland can lead to a decline in the water table depth (WTD) in the transition zone. According to the relationship defined by $\mathcal{W}_z = f(P, I, E, G)$, where P is precipitation, I is irrigation input, E is evapotranspiration, and G represents groundwater contribution, the decrease in I and subsequent G can stress native phreatophytes.

3. Ecological Response of the Transition Zone

The vegetation in the oasis-desert transition zone, dominated by species such as *Haloxylon ammodendron* and *Tamarix* spp., relies on both soil moisture and groundwater. The shift in irrigation regimes affects these species through several pathways:

1. **Vegetation Vitality:** Reduced lateral water movement may lead to a decrease in the Normalized Difference Vegetation Index (NDVI

Direct sowing is performed immediately after the installation of the mulch film and drip irrigation tapes. The seeds then remain in the soil until the ambient temperature reaches the optimal threshold for seedling emergence.

related research accounting for the influences of soil and vegetation. Therefore, this study focuses on the southern region···

By applying small amounts of water through sub-film drip irrigation, the soil moisture content beneath the film can be maintained at a specific level.

The Xiaohaizi Irrigation District in Tumxuk City, the Third Division of the Xinjiang Production and Construction Corps, serves as the primary research area for this study. Located at a distance from···

Requirements for Cotton Seedling Emergence

Cotton seedling emergence is a critical phase in the crop' s development, requiring specific environmental conditions to ensure a uniform and healthy stand. Compared to traditional pre-sowing irrigation practices conducted during the winter and spring seasons, modern cultivation techniques emphasize more precise management of soil moisture and temperature.

Successful emergence primarily depends on the thermal environment of the soil. Cotton is a thermophilic crop, and the minimum soil temperature required for germination is typically around 12°C to 14°C. However, for rapid and uniform emergence, a stable soil temperature of 16°C or higher at the sowing depth is preferred. Fluctuations in temperature, particularly cold spells following sowing, can significantly delay emergence and increase the vulnerability of seedlings to soil-borne pathogens.

In addition to temperature, soil moisture availability plays a decisive role. The seed must imbibe sufficient water—typically reaching approximately 50% to 55% of its air-dry weight—to initiate the physiological processes of germination. While traditional winter and spring irrigation methods aimed to create a deep reservoir of soil moisture, they often resulted in lower soil temperatures and potential crusting issues. Modern approaches often utilize targeted irrigation or film mulching to maintain optimal moisture levels in the seed zone while simultaneously enhancing the soil' s thermal properties.

Soil aeration and physical structure also influence the emergence process. Cotton seeds require adequate oxygen for respiration during germination; therefore, waterlogged or overly compacted soils can lead to seed rot or "asphyxiation." Furthermore, the physical resistance of the soil surface, often manifested as soil crusting after rainfall or improper irrigation, can impede the hypocotyl' s ability to break through the surface. Managing these physical factors is essential for achieving the high emergence rates necessary for high-yield cotton production.

Multiple monitoring points were established at varying distances from a cotton field characterized by "dry sowing and wet emergence"(sowing in dry soil followed by drip irrigation to induce germination). [Figure 1: see original paper]

The experimental design aimed to evaluate the spatial distribution of soil moisture and salinity under this specific irrigation regime. By strategically placing sensors at incremental distances from the primary irrigation source and the field boundaries, we can characterize the horizontal migration patterns of water and solutes. This setup allows for a comprehensive analysis of how the "dry sowing and wet emergence" technique influences the micro-environment across different zones of the cotton field.

Data collection focused on key parameters including soil water content, electrical conductivity, and temperature at multiple depths. These monitoring points provide the empirical basis for modeling the hydrological dynamics and salt leaching efficiency inherent to this cultivation method. The resulting datasets are essential for optimizing irrigation schedules and improving water-use efficiency in arid region cotton production.

In the context of traditional flood irrigation patterns, the implementation of "dry sowing and wet emergence" technology has significantly conserved water resources.

1 Location of monitoring sites in the study area

Arid Regions

While securing the water source, this approach also significantly improved the seedling emergence rate.

Soil organic matter was determined using the potassium dichromate gravimetric method [?], and available nitrogen was measured using the alkaline hydrolysis diffusion method.

1.2 试验方法

The soil alkali-hydrolyzable nitrogen content was determined using the alkaline hydrolysis diffusion method [?], and the soil available phosphorus content was measured using the Bray method [?].

1.2.1 试验设计监测点 A 主要植被是小灌木和草

At monitoring site B, the primary vegetation consists of a combination of trees, shrubs, and herbs. Within each monitoring site, four representative sampling points were selected at increasing distances from the cotton field: A1, A2, A3, and A4 for site A, and B1, B2, B3, and B4 for site B.

Monitoring site A and monitoring site B are located approximately 25 km apart. The cotton fields adjacent to both sites utilize a unified "dry sowing and wet emergence" management model, ensuring that irrigation schedules, water volumes, and other management practices remain identical.

Detailed information regarding monitoring sites A and B is presented in .

Monitoring site A

40°0$ '29.37'' $N

79°22$ '12.15'' $E

40°0$ '36.92'' $N

79°23$ '42.08'' $E

Monitoring Point B

40°0$ '30.15' '*N*40°0' 51.71'' $N

79°22$ '58.10'' $E

79°24$ '12.92'' $E

39°57$ '23.98'' $N

39°57$ '10.19' '*N*79°33' 27.95'' $E

39°57$ '7.69'' $N

1.2.5 NDVI Data Acquisition

The Normalized Difference Vegetation Index (NDVI) data were obtained via the Google Earth Engine (GEE) platform.

The data were obtained through online calculations on the Google Earth Engine (GEE) platform, utilizing Sentinel-2 satellite remote sensing data. Within GEE, Sentinel-2 remote sensing imagery for monitoring sites A and B was filtered for the growing season (May to September) from 2020 to 2022. These images were then synthesized into monthly average NDVI raster data with a spatial resolution of 10 m.

1.3 数据统计与分析

Impact of "Sowing and Wetting" on Vegetation Diversity in Transition Zones Adjacent to Cotton Fields Along a Distance Gradient

Abstract

This study investigates the ecological impact of the "sowing and wetting" irrigation technique on the plant community structure and species diversity within the

transition zones adjacent to cotton fields. By establishing sampling transects at varying distances from the field edge, we analyzed the spatial distribution of vegetation and the shifts in diversity indices. Our findings indicate that the influence of agricultural moisture runoff significantly alters the botanical composition of the transition zone, with a pronounced effect observed in the immediate vicinity of the cotton fields. As the distance from the field increases, the anthropogenic influence diminishes, leading to a transition toward native desert-steppe vegetation. This research provides critical insights into the ecological footprint of intensive irrigation practices on neighboring uncultivated land.

1. Introduction

In arid and semi-arid regions, the expansion of irrigated agriculture has profound effects on the surrounding natural ecosystems. The "sowing and wetting" method, a common practice in cotton cultivation, involves intensive early-season irrigation to ensure seed germination and seedling establishment. However, the lateral seepage and runoff from these fields often penetrate the adjacent transition zones, creating a moisture gradient that can fundamentally reshape local plant communities. Understanding how vegetation diversity responds to this gradient is essential for assessing the environmental sustainability of large-scale cotton production and for developing strategies to preserve regional biodiversity.

2. Materials and Methods

2.1 Study Area The research was conducted in a representative cotton-growing region characterized by an arid climate and high dependence on irrigation. The transition zones selected for study are situated between stabilized cotton fields and the surrounding natural desert landscape.

2.2 Sampling Design To quantify the impact of the "sowing and wetting" process, we established several sampling transects perpendicular to the boundary of the cotton fields. Vegetation surveys were conducted at fixed intervals (e.g., 5m, 10m, 20m, 50m, and 100m) from the field edge. At each sampling point, we recorded species richness, plant density, and canopy cover within standardized quadrats.

2.3 Data Analysis Species diversity was evaluated using the Shannon-Wiener index (H'), Pielou' s evenness index (J), and the Simpson dominance index (D). The mathematical expressions for these indices are as follows:

1 Description of monitoring points

The soil available phosphorus content was determined, and the soil available potassium was measured using the flame photometry method [**?**].

1.3.1 "Vegetation Diversity-Distance Relationship" Model

To analyze the "dryness-vegetation diversity-distance relationship" model, we···

79°32$ '3.25'' $E

79°33$ '19.10'' $E

39°57$ '12.29' '*N*79°33' 35.39'' $E

1.2.2 植被调查由于 2024 年 7 月为植被生长较为

During the peak growth period, this time was selected for the vegetation sampling survey. Within each sample plot, three quadrats were randomly established, each measuring 50 m × 50 m.

50 m. Within this area, four tree and shrub quadrats were established at 25 m intervals. Each quadrat measured 25 m × 25 m, and the species and density of all trees and shrubs within each plot were recorded in detail. Additionally, four 5 m × 5 m quadrats were established within the study area to···

We established 5 m × 5 m herbaceous quadrats, recording the species composition, coverage, and height of all herbaceous plants within each plot. Using GPS positioning equipment, we meticulously documented the geographic coordinates and environmental characteristics of each sampling site to ensure spatial accuracy for subsequent data analysis.

The elevation, latitude, and longitude of the sample plots were recorded to facilitate subsequent data analysis.

To account for recent changes, this study employs a "distance-decay" model to evaluate the relationship between vegetation diversity variations and the distance to cropland. The geographical distance (m) from the cotton fields can be calculated using the `Geosphere` package. The `Geosphere` package is an R language tool designed for calculating distances and areas on a spherical earth, providing high precision for spatial ecological modeling.

The toolkit used for processing geospatial data (e.g., calculating geographic distances, azimuths, and other georeferenced computations); specifically, the "vegdist" function from the **vegan** package in the R language, which is dedicated to community ecology analysis.

Calculate vegetation diversity. The change in slope reflects the variation in vegetation diversity relative to the distance from farmland. To further explore the relationship between soil water-salt content, nutrients, and the distance from farmland, the soil physicochemical property data were first normalized. Geographic distance (m) based on longitude and latitude was calculated using the `Geosphere` package in R, while soil distance [?] was calculated using the Euclidean distance method.

1.3.2 物种多样性的计算物种多样性的计算参照

Following the methods of Margalef [?] and Whittaker [?], we calculated the Importance Value (IV), Margalef richness index (R), Simpson dominance index (D), Shannon-Wiener diversity index (H), and Pielou evenness index (J_{sw}) for the plant species at each monitoring site.

The calculation methods for these indices are as follows:

Importance Value (IV):

× 100% R f = i × 100%

To evaluate the physical and chemical properties of the soil, a stratified sampling method was employed. Soil samples were collected from five specific depths: 0–20 cm, 20–40 cm, 40–60 cm, 60–80 cm, and 80–100 cm. The soil moisture content of each layer was determined using the oven-drying method to characterize the hydrological status of the soil profile.

Foreign materials and debris were removed from the samples to ensure the accuracy of subsequent analytical procedures. The soil samples were then processed through 1 mm and 0.25 mm mesh sieves to prepare them for the determination of soil nutrients, salinity, and other physicochemical properties.

1.2.4 Measurement of Indicators

Soil water content was determined using the oven-drying method [?]. Total soil salinity was measured using the water bath evaporation method [?] with a water-to-soil ratio of 5:1.

1.2.3 样品采集在植被调查样地内，为了准确评

∑A × 100%

Margalef Richness Index (R): $R = \frac{S-1}{\ln N}$ Simpson Dominance Index (D): $D = 1 - \sum P_i^2$

Li Fangfang et al.: Effects of “Dry Sowing and Wet Emergence” on Vegetation Diversity and Soil Nutrients in the Oasis-Desert Ecotone

D = 1 -∑P i2

H = -∑P i lnP i

The Shannon-Wiener diversity index (H) and the Pielou evenness index (J_{SW}) are defined as follows:

The Shannon-Wiener diversity index (H) is calculated using the formula:

$$H = -\sum_{i=1}^{S} P_i \ln P_i$$

where S represents the total number of species in the community, and P_i denotes the proportion of individuals belonging to the i-th species relative to the total number of individuals in the sample.

The Pielou evenness index (J_{SW}) is derived from the Shannon-Wiener index and is calculated as:

$$J_{SW} = \frac{H}{H_{max}} = \frac{H}{\ln S}$$

In this equation, H is the observed Shannon-Wiener diversity index, and H_{max} represents the maximum possible diversity for a community with S species, which occurs when all species are equally abundant.

2.1 绿洲-荒漠过渡带植被优势种分析

The eight monitoring sample sites contain five typical vegetation species belonging to three families and five genera.

The Shannon-Wiener diversity index is calculated as $J_{SW} = H$. In this formula, R_d, R_f, and R_c represent the relative density, relative frequency, and relative coverage, respectively.

The importance values of the species were calculated and are presented in .

In these equations, S represents the total number of species within the quadrat, and P_i denotes the relative abundance of the i-th species.

This species was present in all sample sites, with an average importance value of 63.92%, whereas *Glycyrrhiza inflata* was found only in specific locations.

The relative abundance is defined as the ratio of the number of individuals of a species to the total number of individuals (N_i/N), where N is the total number of individuals of all species within the quadrat and N_i is the number of individuals of the i-th species. Furthermore, S_i represents the frequency of occurrence of the i-th species across the quadrats, and A_i denotes the coverage of the i-th species.

1.3.3 数据处理采用 Excel 2016 统计数据，采用

One-way analysis of variance (ANOVA) was performed using the SPSS 23.0 biostatistical software package. Significant differences between groups were determined using Duncan’ s multiple range test, with the threshold for statistical significance set at $P < 0.05$. All experimental data are presented as “mean ± standard deviation” (mean ± SD).

One-way analysis of variance (ANOVA) and Pearson correlation analysis were performed, followed by Duncan’ s multiple range test to determine the significance of differences. All statistical visualizations were generated using Origin 2021.

Among the species identified, *Alhagi sparsifolia* and *Tamarix chinensis* were present across all five monitoring sites, with average importance values of 65.13% and 64.79%, respectively. *Lycium ruthenicum* was recorded at seven monitoring sites, while another species appeared at two monitoring sites with an average importance value of 47.07%. Additionally, *Populus euphratica*···

Populus euphratica appeared in four monitoring sample sites, with an average importance value of 94.87%. At monitoring site A, *Tamarix chinensis* was the dominant species, while *Alhagi sparsifolia* and *Lycium ruthenicum* exhibited the highest frequency of occurrence. At monitoring site B, *Populus euphratica*···

The importance values of multiple sampling points approach or reach 100%, demonstrating a clear ecological dominance at point B.

2.2 植被多样性分析

Statistical analysis and graphing were performed using the software. Results are expressed as "Mean ± Standard Error of the Mean (Mean ± SEM)." A value of $P < 0.05$ was considered to indicate a statistically significant difference.

An analysis of the vegetation diversity across different zones of the oasis-desert ecotone in the Xiaohaizi irrigation area (Table 3) revealed that the "small shrub + herb" community results were significantly

2 Relative importance values of key species in the oasis-desert transition zone

Relative frequency/%

Relative density/%

Relative coverage/%

Importance value/%

Monitoring site A

Monitoring site B

Arid region

3 Comparative analysis of vegetation diversity indices in the oasis-desert ecotone Margalef

Shannon-Winner

0.41$±$0.08a

0.91$±$0.13b

Monitoring Point A: Small Shrubs and Herbaceous Vegetation

A1(150 m)

0.43$±$0.12a

A3(2100 m)

0.14$±$0.04c

Monitoring Point B: Trees + Shrubs + Herbs

A2(1200 m) A4(3000 m)

0.29$±$0.11b

B1(350 m)

0.43$±$0.11a

B2(1500 m)

0.38$±$0.12a

B3(2200 m)

0.21$±$0.05b

B4(3000 m)

0.22$±$0.08b

Pielou

Simpson

1.25$±$0.10a

0.90$±$0.04a

0.69$±$0.33a

0.69$±$0.13c

1.00$±$0.14a

0.50$±$0.11b

0.66$±$0.15b

0.51$±$0.07d

0.47$±$0.09c

0.74$±$0.03a

0.71$±$0.10b

0.64$±$0.17b

0.84$±$0.18a

0.62$±$0.15b

0.97$±$0.22a

0.50$±$0.10c

0.72$±$0.08b

0.48$±0.10b0.27±0.12c0.50±0.06a0.54±0.10a0.48±$0.19a

0.32$±$0.02b

Note: Values in the table represent the mean ± standard error. Different lowercase letters indicate significant differences (P < 0.05) between monitoring points at varying distances from the cotton field for the same vegetation diversity index. Margalef refers to the

richness index; Shannon-Wiener refers to the diversity index; Pielou refers to the evenness index; and Simpson refers to the dominance index.

The results indicate that the Margalef richness indices at points A1 and A2, which are closer to the cotton field, were significantly higher than those at A3 and A4 (P < 0.05). The Shannon-Wiener

diversity index showed significant differences among the monitoring points, exhibiting a clear decreasing trend with distance (A1 > A2 > A3 > A4, P < 0.05). This suggests that human activities play a positive role in maintaining the diversity of proximal vegetation. The Pielou

evenness index results showed that point A3 reached the highest value (1.00 ± 14), which was not significantly different from A1 (0.90 ± 0.04), but was significantly higher than A2 and A4

(A2 > A4, P < 0.05), reflecting the distributional equilibrium of species in the middle region of the transition zone. The Simpson dominance index results showed that point A1

(0.69 ± 0.33) was significantly higher than the other points (P < 0.05), indicating the presence of clear dominant species in the area near the cotton field. Within the "Arbor + Shrub + Herb" community, the Margalef richness index

results showed that both B1 and B2 were significantly higher than B3 and B4 (P < 0.05). The Shannon-Wiener diversity index results showed that point B4 (0.50 ±

0.10) was significantly lower than all other points (P < 0.05), illustrating the negative impact of desertification pressure

on complex communities. The Pielou evenness index results showed that B2 and B3 were both significantly higher than B1 and B4 (P < 0.05).

2 Distance-decay curve of vegetation diversity

(Figure 3 [Figure 3: see original paper]). Within the "small shrub + herb" monitoring sites, the soil water content across all layers exhibited a consistent trend, following the order of A1 > A2 > A3 > A4. Furthermore, the differences in soil moisture between these monitoring points were statistically significant ($P < 0.05$). In the "tree + shrub + herb" monitoring sites⋯

…the stability of the equidistant community structure; the results of the Simpson dominance index…

…at the B1 point of the "tree + shrub + herb" monitoring site, which is located closest to the cotton field, the soil water content in the 0–100 cm layer…

…($P < 0.05$), further confirming the decline in community dominance at the desert margin.

At the B4 point, which is furthest from the cotton field, the water content was only 1.57%–4.45%.

…showed that point B4, located furthest from the cotton field, was significantly lower than the other points ($P < 0.05$).

2.3 基于距离的植被相似性衰减曲线

The "Bray-Curtis similarity [?]" was utilized to calculate the variation in diversity based on the absolute abundance differences of shared species between two monitoring sites. This analysis established the relationship between vegetation diversity at monitoring sites A and B and their geographic distance (referenced from the point nearest to the cotton field) [Figure 2: see original paper].

The experimental results indicate that plant diversity at both monitoring sites exhibited a downward trend as the distance between the sampling points and the farmland increased.

Notably, the magnitude of this decline was more pronounced at site A.

(KA=-0.09，KB=-0.04)。

2.4 土壤水盐、养分的空间分布

The soil water content of different vegetation types decreases as the distance from the cotton field increases.

The water content ranged from 3.59% to 9.09%, which was significantly higher than that of the other sampling points ($P < 0.05$). Regarding soil salinity, the levels at points A1 and B1, which were closest to the cotton fields, were significantly higher than those at all other points ($P < 0.05$). At the points furthest from the cotton fields, A4 and B4, the soil salinity contents were 5.23–11.43 $g \cdot kg^{-1}$ and 5.85–9.07 $g \cdot kg^{-1}$, respectively.

Regarding soil nutrient content ([Figure 4: see original paper]), the various soil layers at different depths exhibit significant variations.

The average performance was highest at points A1 and B1, which were located closest to the cotton field, and lowest at the most distant points.

points A4 and B4 exhibit the lowest values. Specifically, at the "small shrub + herb" monitoring site, the soil alkali-hydrolyzable nitrogen content at point A1, which is closest to the cotton field, ranges from 19.68 to···

39.04 mg · kg^{-1}, available phosphorus ranged from 1.42 to 3.53 mg · kg^{-1}, and available potassium···

The concentrations ranged from 149.4 to 826.97 mg · kg^{-1}, while the organic matter content was between 3.82 and 12.11 g · kg^{-1}.

Impact of "Dry Sowing and Wet Emergence" on Vegetation Diversity and Soil Nutrients in the Oasis-Desert Ecotone

Abstract

The oasis-desert ecotone serves as a critical ecological barrier for maintaining the stability of oasis ecosystems. In recent years, the "dry sowing and wet emergence" (DSWE) irrigation technique has been widely adopted in arid regions to conserve water and ensure seedling establishment. However, its long-term impact on the surrounding natural vegetation and soil properties remains poorly understood. This study investigates the effects of DSWE on plant community composition, species diversity, and soil nutrient dynamics in the transition zone. Our results indicate that while DSWE optimizes water use efficiency for agricultural production, it induces significant shifts in the neighboring natural vegetation patterns. Specifically, the altered soil moisture and salt distribution patterns influence the competitive balance between dominant species. Furthermore, soil nutrient analysis reveals that the implementation of DSWE leads to a redistribution of organic matter, total nitrogen, and available phosphorus across the soil profile. These findings provide a theoretical basis for the sustainable management of water resources and the ecological restoration of oasis-desert ecotones under modern irrigation practices.

1. Introduction

The oasis-desert ecotone is a unique geographical unit characterized by high environmental sensitivity and fragile ecological balance. As the interface between the productive oasis and the surrounding arid desert, it plays a vital role in windbreak, sand fixation, and biodiversity conservation. In the context of global climate change and increasing anthropogenic pressure, the rational allocation of water resources has become the core challenge for regional ecological security.

"Dry sowing and wet emergence" (DSWE) is an innovative water-saving irrigation technology where seeds are sown in dry soil, followed by precise drip irrigation to trigger germination. While this method significantly reduces water consumption during the early growth stages of crops, its ecological footprint extends beyond the farmland boundaries. The lateral seepage and changes in the local microclimate associated with DSWE may alter the hydrological niche of native species in the ecotone. Despite its widespread application, there is a lack of comprehensive research on how this irrigation shift affects the structural integrity of natural plant communities and the underlying soil nutrient cycling.

2. Materials and Methods

2.1 Study Area Description The study was conducted in a typical oasis-desert ecotone located in the arid region of Northwest China. The climate is characterized by extreme aridity, high evaporation rates, and sparse precipitation. The natural vegetation is dominated by drought-tolerant shrubs and ephemeral herbs.

Different lowercase letters indicate significant differences in soil water and salt content at the same monitoring point and soil depth, relative to the distance from the cotton field ($P < 0.05$). The same convention applies below.

3 Variations in soil water and salt content dynamics in the ecotone at different distances from cotton fields

At a soil depth of 0-100 cm, these values were significantly higher than those at all other sampling points ($P < 0.05$).

The results were influenced by soil water content (SWC) and available potassium (AK), confirming the "water-potassium synergy" regulation model characteristic of irrigated agricultural regions.

The monitoring point featuring a "tree + shrub + herb" configuration was located closest to the cotton field.

The vegetation diversity at monitoring point B was significantly correlated with soil water content (SWC) and available phosphorus (AP).

Within the 0–100 cm soil layer, these parameters were significantly higher than those at all other monitoring points ($P < 0.05$).

These findings highlight the phosphorus-limited characteristics of the desert transition zone.

At monitoring point B1, the concentrations of soil alkali-hydrolyzable nitrogen, available phosphorus, available potassium, and organic matter were significantly higher than at other locations.

These values reached their maximums at 45.87 $mg \cdot kg^{-1}$, 3.85 $mg \cdot kg^{-1}$, and $P < 0.05$.

The maximum values recorded were 548.03 $mg \cdot kg^{-1}$ and 8.39 $g \cdot kg^{-1}$, respectively.

2.7 Impact of "Dry Sowing and Wet Emergence" on NDVI in the Transition Zone

Based on the monitoring data collected during the growing season before and after the implementation of the "dry sowing and wet emergence" technology.

2.5 基于距离的土壤水盐、养分衰减曲线

To further explore the characteristics of plant diversity within the context of "dry sowing and wet emergence" (DSWE), we analyzed the relationship between changes in the soil environment and the decay of plant diversity (DDRs) [Figure 5: see original paper]. Soil moisture, salinity, and nutrient data were standardized and transformed using Euclidean distance.

The transformed results were then subjected to regression analysis against vegetation diversity, using the sampling point closest to the cotton field as the baseline. This approach allowed us to investigate the relationship between soil physicochemical differences—relative to the distance from the farmland—and vegetation diversity. As shown in Figure 5, the results indicate a specific spatial pattern.

To further analyze the impact of implementing "dry sowing and wet emergence" technology on vegetation growth in the oasis-desert transition zone, we examined the changes in the NDVI index at the monitoring points [Figure 7: see original paper].

It can be observed that the monthly NDVI trends during the growing seasons from 2020 to 2022 were largely consistent, characterized by an initial increase followed by a decrease. Among the different years, monitoring point A exhibited the highest NDVI values in 2020, prior to the implementation of the "dry sowing and wet emergence" technology, with monthly NDVI values consistently higher than those in 2021 and 2022.

Similarly, the NDVI at monitoring point B showed a trend of increasing and then decreasing across different years, with the monthly NDVI values reaching their minimum in 2022. From these observations, it can be inferred that:

As the distance from the farmland increases, soil moisture, salinity, and nutrients exhibit a downward trend. This decay is more pronounced at monitoring point A ($K_A = -0.08$) compared to monitoring point B ($K_B = -0.02$).

The overall trend is characterized by a decline, indicating that the implementation of "dry sowing and wet emergence" has an impact on the oasis-desert transition zone.

The decay is more significant at monitoring point A ($K_A = -0.08$, $K_B = -0.02$).

The downward trend suggests that the implementation of "dry sowing and wet emergence" affects the oasis-desert transition zone.

2.6 土壤水盐、

Mantel Test Analysis of Nutrients and Vegetation Diversity

Results of the Mantel test. The color intensity in the heatmap represents the magnitude of the Pearson

correlation coefficient (r); a higher value indicates a stronger correlation.

Following the implementation of the "wet extraction" technology, the overall monthly mean NDVI at monitoring points A and B had a negative impact on vegetation growth in the desert transition zone.

3 讨论

The results indicate that a positive correlation exists between vegetation diversity and soil water-salt content, as well as other physicochemical properties.

Vegetation diversity serves as a critical indicator of the structural and functional complexity of plant communities.

Specifically, at monitoring site A, vegetation diversity is significantly influenced by soil moisture content.

Research into these indicators can reveal the stability of ecosystems and the dynamics of plant communities.

In arid regions,

4 Variations in soil nutrients in the ecotone at different distances from cotton fields

···successional stages and the spatial distribution patterns of species [?]. This study found that the "dry sowing and wet emergence" technique significantly influences the spatial distribution of soil water, salts, and nutrients.

relatively high (). Li Xia et al. [?] found that when plant communities

When the structure is relatively simple, its ability to resist external interference will be significantly weakened.

spatial distribution, which in turn significantly influences the vegetation within the oasis-desert transition zone.

weak; research by Wang Xinyuan et al. [?] demonstrates that the relationship between total vegetation coverage and species richness

diversity. At monitoring sites A and B, the distribution of *Tamarix chinensis* and *Populus euphrat

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv —Machine translation. Verify with original.