

Postprint: Ecological Risk Assessment of Non-point Source Pollution from Cultivated Land in Xinjiang Hotan Region

Authors: Tian Fengshou, Liu Xinping, Weipeng Yuan, Liu Xinping

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Abstract

With excessive application of chemical fertilizers, agricultural plastic films, and other agricultural inputs in agricultural production, the severity of farmland non-point source pollution has intensified accordingly. This study selects the Hotan region in the upper reaches of the Tarim River Basin as the research area, constructs an ecological risk assessment indicator system for farmland non-point source pollution in Hotan based on the P-S-R framework theory, incorporates soil physicochemical data, and employs an ecological risk assessment model to evaluate the ecological risk status of farmland non-point source pollution in Hotan for the years 1980 and 2016. The spatiotemporal differentiation of farmland non-point source pollution in Hotan is analyzed using the farmland ecological risk model, ecological risk transition matrix, and ArcGIS analysis. The research conclusions are as follows: In 1980, farmland ecological risk levels in Hotan were all classified as Level II or Level III, exhibiting a “high in the middle, low on both sides” distribution pattern; in 2016, farmland ecological risk levels escalated to Level IV or Level V, displaying an “inverted W-shaped” distribution pattern. The degree of farmland non-point source pollution in all counties increased substantially compared to 1980, with Moyu County and Yutian County reaching the highest Level V in 2016, while Minfeng County also warrants heightened attention due to its strong ecological environmental vulnerability. According to the principle of “controlling pollution at the source” for non-point source pollution, practical measures should be implemented to advance the protection and governance of the farmland ecological environment in Hotan, enhance government prioritization, strengthen technical guidance, initiate pilot projects, and ameliorate the current status of farmland non-point source pollution in Hotan.

Full Text

Ecological Risk Assessment of Cultivated Land Non-Point Source Pollution in Hetan Prefecture, Xinjiang

Abstract

With the excessive application of chemical fertilizers and agricultural films in agricultural production, non-point source pollution in cultivated land has become increasingly severe. This study selects Hetan Prefecture in the lower reaches of the Tarim River Basin, Xinjiang, China as the research area. Based on the PSR (Pressure-State-Response) framework and the “input-output” principle of economics, a physicochemical data indicator for cultivated land is incorporated as a status indicator to construct an ecological risk assessment index system for non-point source pollution. Using ArcGIS software, the spatial and temporal differentiation of ecological risk levels for cultivated land non-point source pollution in Hetan Prefecture is analyzed for 1980 and 2016. The results demonstrate that the ecological risk level of non-point source pollution in Hetan Prefecture increased significantly from 1980 to 2016. Specifically, the ecological risk in Moyu County and Yutian County reached the highest Level V, while Minfeng County exhibited vulnerability due to its ecological environment. These three counties can serve as pilot areas for promoting non-point source pollution control. The research findings provide a reference for exploring the construction of non-point source pollution ecological risk assessment systems and guiding differentiated pollution control strategies according to regional characteristics.

Keywords: Ecological risk assessment; Spatial and temporal differentiation; PSR framework; Surface land source pollution; Hetan Prefecture

1. Introduction

Non-point source pollution from agricultural activities has emerged as a critical environmental challenge, particularly in arid regions where intensive cultivation practices coincide with fragile ecosystems. The application of chemical fertilizers and agricultural films has intensified pollution loads, necessitating comprehensive risk assessment frameworks.

2. Materials and Methods

2.1 Study Area

Hetan Prefecture, located in the lower Tarim River Basin of Xinjiang, represents a typical arid agricultural region characterized by intensive land use and sensitive ecological conditions.

2.2 Data Sources

The assessment integrates multi-source data from 1980 and 2016, including: - Land use and land cover data - Agricultural input statistics (fertilizers, pesticides, agricultural film) - Soil physicochemical properties - Socioeconomic indicators

Data processing was conducted using ArcGIS software for spatial analysis and interpolation.

2.3 PSR Model Framework

The Pressure-State-Response (P-S-R) model was employed as the theoretical framework. This model captures: - **Pressure:** Anthropogenic stressors (fertilizer application, cultivation intensity) - **State:** Environmental conditions (soil nutrient content, pH, organic matter) - **Response:** Ecosystem vulnerability and resilience indicators

2.4 Indicator System and Weights

An ecological risk assessment indicator system was constructed (Table 1). Indicator weights were determined using an objective weighting method based on data variability and expert consultation.

Table 1. Indicator system and weights for ecological risk assessment

Indicator Category	Specific Indicator	Weight
Pressure	Fertilizer application intensity	0.41
Pressure	Agricultural film usage	0.14
State	Soil organic matter content	0.31
State	Soil pH	0.06
Response	Vegetation coverage	0.22
Response	Agricultural output value	0.04

2.5 Assessment Method

The comprehensive ecological risk index (CER) was calculated using the formula:

$$CER_i = \sum_{j=1}^n p_{ij} \times w_j \quad (2)$$

where CER_i represents the comprehensive ecological risk index for evaluation unit i , p_{ij} is the standardized value of indicator j , and w_j is the weight of indicator j .

The grey relational analysis method was applied to calculate correlation coefficients between evaluation units and reference sequences. The distinguishing coefficient ρ was set to 0.5 based on standard practice.

3. Results

3.1 Spatial Distribution of Ecological Risk (1980 vs. 2016)

The ecological risk assessment results for 1980 and 2016 reveal significant spatial heterogeneity across Hetan Prefecture (Table 3). In 1980, the majority of cultivated land exhibited low to moderate risk levels (Class II and III), with risk values ranging from 0.1168 to 0.3089. The ecological risk pressure subsystem showed relatively uniform distribution across counties.

Table 3. Ecological risk assessment results for surface land source pollution in Hetan Prefecture

County	Pressure Index	State Index	Response Index	Comprehensive Risk
County 1	0.1603	0.1936	0.1264	0.1906
County 2	0.1392	0.1541	0.1168	1.2236
County 3	0.2980	0.2915	0.2765	0.3089
County 4	0.2720	0.2767	0.2204	2.0571
County 5	0.1350	0.1627	0.1595	0.1620
County 6	0.1883	0.1786	0.1515	1.1376
County 7	0.1711	0.2354	0.2340	0.1930

By 2016, dramatic changes occurred. The ecological risk status subsystem exhibited marked elevation, with comprehensive risk values increasing by 2-4 times in most counties. Moyu County and Yutian County showed the most severe degradation, reaching Level V risk classification (values > 0.5), indicating critical ecological stress.

3.2 Temporal Changes in Ecological Risk

Comparative analysis reveals that from 1980 to 2016: - **Pressure indicators** increased substantially, with fertilizer application intensity rising from 62.75 kg · hm⁻² to 452.68 kg · hm⁻² - **State indicators** showed declining trends, particularly

soil organic matter and pH levels - **Response indicators** reflected reduced ecosystem resilience

The grey relational degree analysis confirms significant temporal differentiation, with correlation coefficients between 1980 and 2016 risk patterns being consistently low ($\Delta < 0.5$), indicating fundamental shifts in the pollution regime.

3.3 Risk Subsystem Analysis

Pressure Subsystem (Fig. 4): The pressure distribution intensified dramatically, particularly in intensively cultivated areas where fertilizer and pesticide inputs exceeded environmental carrying capacity.

State Subsystem (Fig. 5): Soil degradation became widespread, with nutrient imbalance and salinization affecting over 60% of cultivated land by 2016.

Response Subsystem (Fig. 6): Ecosystem response capacity weakened significantly, with vegetation coverage declining and natural buffering functions compromised.

4. Discussion

The pronounced increase in ecological risk from 1980 to 2016 reflects the combined effects of agricultural intensification and inadequate environmental management. Several factors contributed to this trend:

1. **Excessive chemical inputs:** The eightfold increase in fertilizer application far exceeded crop absorption capacity, leading to nutrient accumulation and groundwater contamination.
2. **Agricultural film residue:** Plastic film usage, while improving water retention, introduced persistent microplastic pollution.
3. **Soil degradation:** Continuous monoculture and intensive tillage reduced soil organic matter by 30-40% in high-risk areas.
4. **Climate vulnerability:** The arid climate amplified pollution effects through limited leaching and high evaporation rates.

The spatial differentiation pattern suggests that counties with higher agricultural productivity and population density experienced greater risk accumulation, while remote areas with lower intensification maintained relatively stable conditions.

5. Conclusions

This study demonstrates the effectiveness of the PSR framework for assessing agricultural non-point source pollution ecological risk. Key findings include:

1. The ecological risk level of non-point source pollution in Hetan Prefecture increased significantly from 1980 to 2016, with comprehensive risk indices rising by 150-300% across most counties.
2. Spatial differentiation is marked: Moyu County and Yutian County reached the highest risk level (Level V), while Minfeng County shows vulnerability due to its fragile ecological environment.
3. The pressure subsystem (fertilizer and film inputs) contributed most to risk elevation, followed by degradation in the state subsystem (soil quality).
4. Targeted control measures should be prioritized in high-risk counties, including optimized fertilization practices, film recycling programs, and soil restoration initiatives.

The assessment framework and results provide a scientific basis for differentiated pollution control strategies and ecological restoration planning in similar arid agricultural regions.

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