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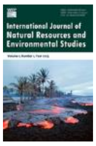

The Calculation of Agricultural Non-Point Source Pollution Load in High Standard Farmland Construction Area

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ABSTRACT

This paper utilized field monitoring, model simulation, and theoretical analysis methods to study the agricultural non-point source pollution monitoring and load quantification under the construction of high-standard farmland, focusing on the demonstration project (Fengxiang area) implemented by the group. The calculated nitrogen and phosphorus loss coefficients for the high-standard farmland in the Fengxiang area were lower. The construction of high-standard farmland effectively controlled the loss of nutrients such as nitrogen and phosphorus. The agricultural non-point source pollution load for the Fengxiang area during a normal water year was determined to be 422.688 t (TN) and 447.576 t (TP). The research results can significantly reduce the cost of water pollution control caused by agricultural non-point source pollution, enhance the utilization of land resources, greatly mitigate the direct and indirect economic losses due to agricultural non-point source pollution, and provide valuable insights for sustainable agricultural development and ecological environment protection..

KEYWORDS

Agricultural Non-Point Source Pollution; High-Standard Farmland; Load; Nitrogen And Phosphorus.

1. INTRODUCTION

"The Central Document No. 1 of 2021 requires the 'implementation of a new round of high-standard farmland construction planning' and has accordingly developed the 'National High-Standard Farmland Construction Plan (2021-2030).' However, as the level of agricultural production intensification in China continues to rise and the new type of urbanization in rural areas rapidly spreads, the issue of agricultural non-point source environmental pollution in China has become increasingly prominent[1-2]. According to the 'Second National Pollution Source Census Bulletin' published in 2020, the total nitrogen emissions from farmland runoff reached 719,500 tons, and total phosphorus emissions reached 76,000 tons, accounting for 51.2% of the total nitrogen emissions and 35.4% of the total phosphorus emissions from agricultural sources[3-4]. The 'National High-Standard Farmland Construction Plan (2021-2030)' emphasizes that the construction of high-standard farmland should improve the agricultural ecological environment, particularly in terms of reducing agricultural non-point source pollution[5]. Based on this, the paper employs field monitoring, model simulation, and theoretical analysis methods, focusing on the ongoing high-standard farmland construction demonstration project (Fengxiang area), to explore the changes in agricultural non-point source pollution load from the perspective of high-standard farmland construction, clarifying whether the construction objectives have been met and whether agricultural non-point source pollution loads have been reduced."

2. STUDY AREA

This paper focuses on the Fengxiang District of Baoji City, Shaanxi Province, located in the western part of the Guanzhong Plain. Fengxiang is situated at a complex site where the Qinling Mountains run north-south and intersect with the Qi, Lu, and He mountains, forming a unique topography with hills, rivers, and plateaus. The area has a warm temperate continental monsoon climate, characterized by a semi-humid and semi-arid climate. The average annual temperature is 11.4°C, with an average annual precipitation of 625 mm. The area experiences distinct four seasons, with long winters and summers but short springs and autumns. Rainfall is concentrated from July to September, with annual runoff patterns closely following the distribution of rainfall throughout the year. The average annual runoff depth in Fengxiang District is 68.5 mm, with an increasing trend from southeast to northwest, ranging from 50 to 100 mm. The highest runoff values are found in hilly areas, reaching up to 100 mm.

The high-standard farmland demonstration construction project (Fengxiang area) includes 10 villages such as Beidoufang Village and Caiyangshan Village in Liulin Town, Chencun Town, and Changqing Town, with a total construction scale of 2.83 million mu (approximately 188,667 hectares). Upon completion, the average application rate of fertilizer per unit area in the Fengxiang area, calculated based on fertilizer application levels in different regions, is 1590 kg/hm2.

3. RAINFALL EVENT MONITORING

Rainfall event monitoring was conducted in the project area, during which six rainfall events were recorded from 2023 to 2024. The dates of these rainfall events are June 27, 2023; September 17, 2023; March 24, 2024; April 29, 2024; June 8, 2024; and June 18, 2024. The duration and rainfall amount of each event are as shown in Table 1.

Table 1. Duration and amount of rainfall for 6 monitored events

Rainfall events	2013-06-27	2013-09-17	2024-03-24	2024-04-29	2024-06-08	2024-06-18
Duration (h)	20	40	10	36	4	12
Rainfall Amount(mm)	54	45.5	15.2	20.4	2	9.6
Rainfall level a	rainstorm	heavy	moderate	moderate	light	light

Note: a The rainfall levels are classified by the national meteorological department based on the 24-hour rainfall amount, ranging from light rain (0.1-10 mm), moderate rain (10-25 mm), heavy rain (25-50 mm), rainstorm (50-100 mm), heavy rainstorm (100-250 mm), to super heavy rainstorm (250 mm and above).

3.1. Typical rainfall monitoring point runoff process

An analysis was conducted on the single rainfall event on June 27-28, 2023, indicating that the rainfall amount reached 54 mm, categorized as a rainstorm. By analyzing water data from each monitoring point, the runoff process at each monitoring point during this event can be obtained, as shown in Fig. 1.

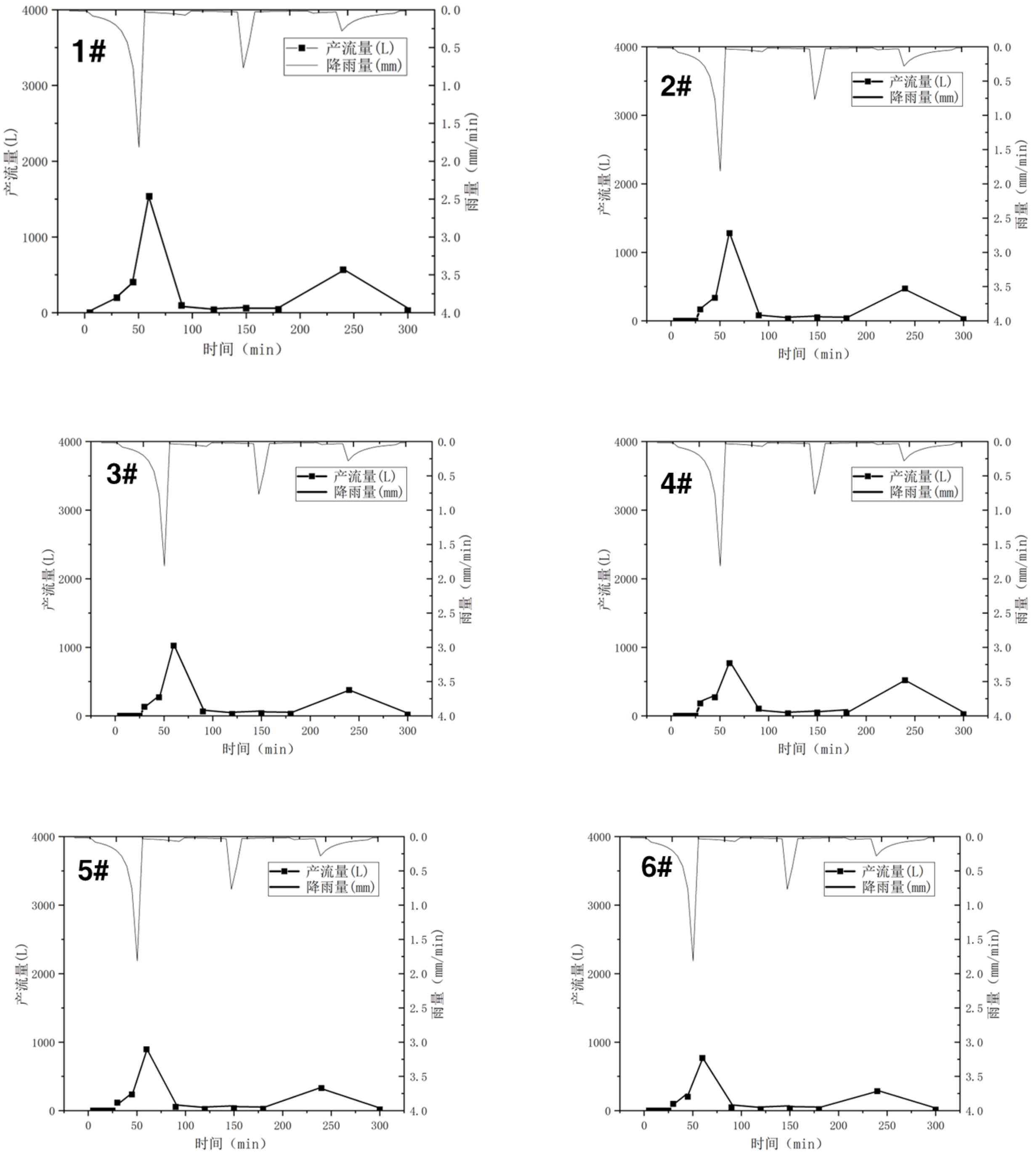

Fig.1 Runoff process at 6 monitoring points for the typical rainfall on 2023-06-27.

3.2. Calculation of pollutant concentration for rainfall events

By collecting rainfall water samples at multiple locations and conducting tests, the average concentration (EMC) of pollutants for a single rainfall event is calculated. The calculation formula is as follows:

$$C = \frac{W_L}{W_A} \tag{1}$$

Where: C is the average concentration of pollutants during the rainstorm; WL is the pollutant load carried by the rainstorm (g), $W_L = \sum_{i-1}^{n}(Q_{Ti}C_i - Q_{Bi}C_{Bi})\Delta t_i$; WA is the runoff generated by the rainstorm (m³), $W_A = \sum_{i-1}^{n}(Q_{Ti} - Q_{Bi})\Delta t_i$.

The average pollutant concentrations at different monitoring points under each rainfall event are shown in Table 2.

Table 2 Rainfall monitoring indicators and data (mg/L)

Rainfall events	Sites	COD	TN	TP	NO3-N
2013-06-27	1#	177.2	2.1	0.8	0.7
	2#	87.8	2.0	0.6	0.7
	3#	118.3	1.5	0.6	0.5
	4#	106.1	1.5	0.4	0.6
	5#	130.1	2.0	0.8	0.2
	6#	117.0	2.0	0.5	0.6
2013-09-17	1#	213.6	2.1	0.8	0.2
	2#	114.3	1.6	0.2	0.1
	3#	140.5	1.8	0.4	0.3
	4#	72.8	2.0	0.7	0.1
	5#	177.4	1.4	0.6	0.1
	6#	96.1	1.9	0.4	0.1
2024-03-24	1#	81.3	1.7	0.8	0.2
	2#	152.4	1.5	0.6	0.4
	3#	125.8	1.7	0.4	0.3
	4#	145.1	1.9	0.6	0.5
	5#	105.6	1.4	0.4	0.2
	6#	95.0	2.0	0.6	0.6
2024-04-29	1#	142.6	1.7	0.7	0.4
	2#	74.6	1.9	0.4	0.3
	3#	138.7	1.8	0.6	0.5
	4#	130.6	1.6	0.8	0.6
	5#	90.0	1.9	0.7	0.5
	6#	125.4	1.7	0.6	0.4
2024-06-08	1#	123.5	1.7	0.4	0.6
	2#	151.7	1.7	0.8	0.3
	3#	101.1	1.6	0.3	0.6
	4#	144.1	1.8	0.4	0.4
	5#	155.6	2.1	0.3	0.7
	6#	139.5	1.7	0.3	0.6
2024-06-18	1#	110.4	1.9	0.3	0.5
	2#	73.4	1.7	0.8	0.2
	3#	172.7	1.5	0.2	0.6
	4#	175.1	1.8	0.8	0.1
	5#	171.3	1.9	0.4	0.6
	6#	72.1	1.4	0.2	0.1

4. RESULTS OF SOIL NITROGEN AND PHOSPHORUS LOSS AND NON-POINT SOURCE POLLUTION ANNUAL LOAD

4.1. Soil nitrogen and phosphorus loss

Soil monitoring can reveal changes in nitrogen and phosphorus content in the soil, as well as their loss characteristics under conditions such as runoff erosion and leaching. Soil samples were collected from six monitoring points before and after rainfall monitoring, and total nitrogen, total phosphorus, and other indicators were measured. The results are shown in Table 3.

Table 3 Soil monitoring indicators and data

Monitor time	Sites	TN (g/kg)	TP (g/kg)
2022.04	1#	1.03	1.39
	2#	1.08	1.55
	3#	1.01	2.45
	4#	0.99	2.33
	5#	1.02	1.03
	6#	1.03	1.13
2024.09	1#	0.93	0.71
	2#	0.96	0.88
	3#	1.03	0.59
	4#	1.16	0.94
	5#	0.89	0.63
	6#	1.02	0.76

The nitrogen and phosphorus loss coefficients for the high-standard farmland in the Fengxiang area were calculated using the average concentration method. The specific calculation method is as follows:

$$P = \frac{\sum_{i=1}^{n} C_i \times V_i}{10^6} \times \frac{10000}{S} \tag{2}$$

Where: P is the nitrogen (phosphorus) pollutant loss, in kg/(hm^2·a); Ci is the concentration of nitrogen or phosphorus in the i-th runoff water sample, mg/L; Vi is the volume of runoff water from the i-th monitoring plot, L;； S is the area of the monitoring plot, m2. The nitrogen (phosphorus) loss coefficient (R) is calculated as:

$$R = \frac{P - P_{CK}}{W} \tag{3}$$

Where: R is the nitrogen (phosphorus) loss coefficient, %; P s the nitrogen (phosphorus) pollutant loss, kg/(hm2·a); PCK is the nitrogen (phosphorus) pollutant loss in the control area. kg/(hm2·a); W s the fertilizer nitrogen (phosphorus) application rate, kg/(hm2·a).

After calculations, the nitrogen and phosphorus loss coefficients for the high-standard farmland in the Fengxiang area were found to 0.13~0.20% for nitrogen, and 0.18~0.25% for phosphorus. Compared to related literature on the Guanzhong Plain and Loess Plateau, where the nitrogen and phosphorus loss coefficients are generally in the range of 0.19%-0.28% (TN) and 0.24%-0.32% (TP), it can be concluded that the construction of high-standard farmland has effectively suppressed the loss of nutrients such as nitrogen and phosphorus[6-7].

4.2. Non-point source pollution annual load

The rainfall data for Baoji City over the past fifty years were used to determine typical years through the method of least squares and the P-III curve, and hydrological years were classified accordingly. In the Fengxiang area, a design rainfall exceeding 644.5mm is considered an abundant water year, rainfall between 562.5 and 644.5mm is considered a normal water year, and rainfall less than 562.5mm is considered a dry water year.Based on the calculated average pollutant concentrations and runoff volume, the non-point source pollution load for the high-standard farmland in the Fengxiang area during different hydrological years is calculated. Assuming that the average concentration of surface runoff over the year is approximately equal to the weighted average concentration of multiple rainstorms, the annual non-point source pollution load (Wn) is given by:

$$W_n = \sum_{i=1}^{12} C_{ni} Q_{ni} \tag{4}$$

Incorporating the load carried by the dry season runoff, the total annual load is obtained:

$$W = W_n + W_B \tag{5}$$

By calculation, the agricultural non-point source pollution load for the Fengxiang area in different hydrological years of the high-standard farmland is shown in Table 4.

Table 4 Non-point source pollution load in different hydrological years for Fengxiang Area

Typical Year	Indicator	Annual non-point source pollution load (t)
Abundant Water Year	TN	730.6
	TP	567.3
Normal Water Year	TN	422.7
	TP	447.6
Dry Water Year	TN	195.7
	TP	313.2

5. SUMMARY

The construction of high-standard farmland has effectively inhibited the loss of nitrogen and phosphorus from farmland. Calculations reveal that the nitrogen and phosphorus loss coefficients for the high-standard farmland in the Fengxiang area are 0.13~0.20% for nitrogen, and 0.18~0.25% for phosphorus. For the established high-standard farmland in the Fengxiang area, the agricultural non-point source pollution load during a normal water year is 422.688 t (TN) and 447.576 t (TP). The construction of high-standard farmland has effectively reduced the agricultural non-point source pollution load in the area.

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