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Analysis of nitrogen and phosphorus loss of typical economic forests in Zhejiang Province

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Abstract. The quantitative relationship between accumulated rainfall and accumulated total nitrogen and total phosphorus loss was analyzed by setting up economic forest experimental sites in typical regions of Zhejiang Province, and the response efficiency of accumulated total phosphorus and total nitrogen loss in different economic forests to rainfall was compared The results showed that there was a significant linear relationship between accumulated rainfall and accumulated total nitrogen and total phosphorus loss. The total nitrogen and total phosphorus loss rate of *Castanea mollissima Blum* economic forest was higher than that of *Phyllostachys edulis* forest and *nursery* > *Morella rubra* > *Camellia sinensis* > *Phyllostachys edulis*. Man-made disturbance of economic forest will accelerate the loss of total nitrogen and total phosphorus, and its loss rate is 1.5~4 times that of natural economic forest. The total nitrogen loss rate of 28% and total phosphorus loss rate of 47% can be reduced by planting shrubs or herbs under the in the *Phyllostachys edulis* forest. The purification efficiency of total phosphorus and total nitrogen of different economic forests is affected by economic forest types, ecological restoration, rainfall, and the purification efficiency varies between 30% and 70%.

Keywords: Nitrogen and phosphorus loss, Economic forest land, Vegetation restoration, Cumulative rainfall, Red soil region in southern China.

1. Introduction

The soil erosion and nutrient loss of economic forests are very serious, which not only seriously threaten the security of soil resources, but also have a negative impact on food security [1]. At the same time, it pollutes the water quality of nearby rivers, resulting in low fertilizer utilization rate and poor economic benefits. According to the research results of Ma YH et al. [2] on the nitrogen and phosphorus loss in the runoff of tea plantation, mulberry plantation and grapery, the total nitrogen loss in mulberry and grapery is significantly greater than that in tea plantation, and the total phosphorus loss in grapery is significantly greater than that in mulberry plantation and tea plantation. Ammonium nitrogen and nitrate nitrogen are the main forms of nitrogen loss in runoff of orchard, accounting for 58% of total nitrogen. Most of the phosphorus in orchard is mainly lost in the form of soluble phosphorus, but only 30% of the phosphorus in the mulberry plantation is lost in the form of soluble phosphorus. Different fertilization patterns have different effects on nitrogen and phosphorus loss in tea plantation. Wang LM et al. [3] through the study of six fertilization patterns in tea gardens, concluded that the amount of nitrogen and phosphorus loss carried by runoff in the treatment of total organic fertilizer was high. The treatment of half amount of chemical fertilizer+half amount of organic fertilizer+legume green fertilizer has a good effect on reducing and controlling water and soil loss and nitrogen and phosphorus loss in tea plantation. The problem of agricultural non-point source pollution has been highly concerned by all countries [4, 5]. The extensive use of chemical fertilizers and pesticides in orchards has directly led to a series of environmental pollution problems such as soil texture degradation, soil and groundwater pollution, and soil acidification [6]. Huang HX et al. [7] have continuously monitored and analyzed the surface runoff generated by five different utilization patterns in farming area, tea plantation, citrus plantation, degraded area, and restoration area in the red soil area of southern China throughout the year. The results show that the tea plantation is second only to the farming area in terms of runoff and nitrogen and phosphorus loss. Unscientific fertilization and inadequate of soil and water conservation measures are the main factors causing nitrogen and phosphorus loss in tea gardens. In

terms of total loss, the more fertilizer is applied, the more serious the loss is. The amount of nitrogen and phosphorus loss is significantly positively correlated with the amount of fertilizer application [8, 9]. The nutrient loss of economic forest land is different under different conditions. Intensive soil management measures with fertilization, reclamation, weeding as the core have been applied more and more widely in the process of *Phyllostachys edulis* forest cultivation. Although these artificial measures have improved economic benefits, they have had a greater impact on the runoff pollution of Phyllostachys edulis forest. The loss of nitrate nitrogen in the runoff of Phyllostachys edulis forest is relatively common, and the loss of nitrogen and phosphorus in the intensive management of *Phyllostachys edulis* forest increased by 80.68% and 47.62% respectively compared with the extensive management [10]. Other studies have pointed out that there are obvious differences in nitrogen and phosphorus loss under different topographical conditions of slope top, convex slope and concave slope, and grass cover has obvious effect on reducing nitrogen and phosphorus loss of economic forest [11-13]. Therefore, the research on the regulation and control of runoff pollution in typical economic forests can provide scientific basis for the ecological management of economic forests, provide technical support for improving the quality of regional ecological environment construction and speeding up the comprehensive control of water and soil loss in economic forests, and provide scientific technology and method system for optimizing the ecological construction pattern of water and soil conservation.

2. Materials and Methods

2.1 Overview of the experimental site

Based on the investigation and analysis of the utilization of economic forests in different regions of Zhejiang Province, typical experimental areas and sites were selected, and field experimental observation sites of different types of economic forests were set up. According to the actual situation, economic forest pattern of five types (*Phyllostachys edulis*, *Castanea mollissima Blume*, *Camellia sinensis*, *Morella rubra* and *Nursery*) in three states (natural type, disturbed type, and restored type) were set up in Anji County and Yuyao City of Zhejiang Province. And table 1 shows various types of economic forest lands.

Table 1. Test sites of different economic forest lands

Regional location	State	Scientific name of plant	Pattern	Description
Anji county	Natural	Phyllostachys edulis	ANP	Natural growth without human disturbance
		Castanea mollissima Blume	ANC	
	Restored	Phyllostachys edulis + shrub	ARP-S	High-density planting shrub in contour strips
		Phyllostachys edulis + shrub and herb	ARP-SH	Scattered planting of shrubs, and planting of herbs in contour strips
		Castanea mollissima Blume + shrub and herb	ARC-SH	Scattered planting of shrubs, and natural growing herbs
Yuyao city	Natural	Phyllostachys edulis	YNP	Natural growth without human disturbance
		Morella rubra	YNM	
		Camellia sinensis(Tea)	YNT	
		Acer palmatum Thunb(nursery)	YNA	
		Prunus yedoensis(nursery)	YNY	
	Disturbed	Phyllostachys edulis	YDP	Regularly digging shoots, weeding and

				applying fertilizer
		Morella rubra	YDM	Regularly digging root soil, weeding, and applying fertilizer

2.2 Data monitoring and calculation

The runoff pool is used to collect the runoff generated from the economic forest slope plot, and the rainfall data is observed by installing a rain gauge or a remote rain gauge. The total nitrogen (TN) and total phosphorus (TP) of runoff were determined by ultraviolet spectrophotometry and by molybdenum antimony anti-spectrophotometry, respectively. The calculation formula of nitrogen and phosphorus loss per rainfall is as follows:

$$TN = (A_1H_1C_{N1}+5A_2H_2C_{N2})/A \quad (1)$$

$$TP = (A_1H_1C_{P1}+5A_2H_2C_{P2})/A \quad (2)$$

Where A is the area of the experimental site. A_1 and A_2 are the area of the primary and secondary runoff pool respectively. H_1 and H_2 are the observed water depth respectively. C_{N1} and C_{N2} are the average concentrations of total nitrogen respectively. C_{P1} and C_{P2} are the average concentrations of total phosphorus respectively.

3. Results and Analysis

3.1 Correlation between rainfall and TN/TP

It can be seen from figure 1 that the Pearson correlation coefficient between the successive cumulative rainfall and cumulative the total nitrogen and total phosphorus loss in different economic forest lands is relatively high. The average value, maximum value, and minimum value of correlation coefficient between cumulative total nitrogen and total phosphorus loss and cumulative rainfall are 0.995, 0.999 and 0.982. The variation coefficients of correlation coefficient were 0.006 and 0.005 respectively. The correlation coefficients were significant at 0.01 level. This shows that the total nitrogen and phosphorus loss is closely related to natural rainfall. From the analysis of economic forest lands in different states, the correlation coefficients of natural and restored states are very good, ranging from 0.996 to 0.998, while the correlation coefficient of disturbed state is about 0.985. Human disturbance of economic forest lands has an impact on the relationship between rainfall and total nitrogen and total phosphorus loss and has led to the weakening of this relationship.

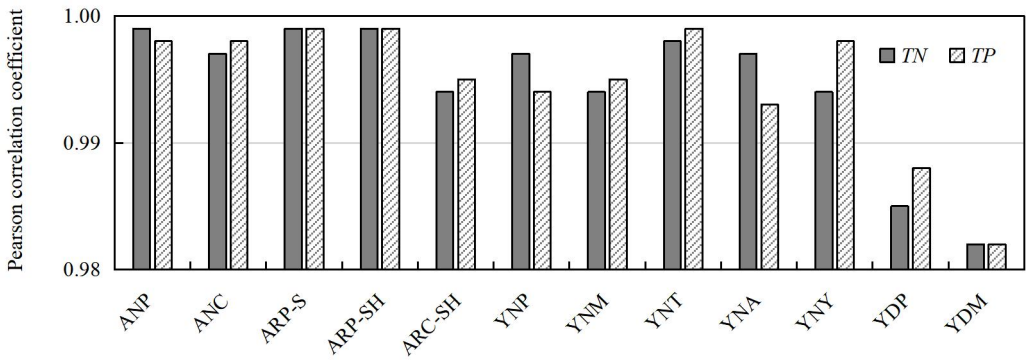

Fig. 1 Correlation coefficient between cumulative rainfall and cumulative TN/TP of different economic forest lands

3.2 Relationship between rainfall and TN/T

The relationship between rainfall and total nitrogen and total phosphorus is affected by statistical time scales and methods. The statistical relationship under the sub-rainfall scale is unstable and can't be used for prediction and analysis. Through sorting out the data, it is found that there is a good correlation between cumulative rainfall and cumulative loss, and the statistical relationship is very stable. The quantitative relationship between cumulative rainfall and cumulative total nitrogen and total phosphorus loss is of great significance for predicting total nitrogen and total phosphorus transport in a large time scale. Table 2 shows the statistical relationship between cumulative rainfall and cumulative total nitrogen and total phosphorus loss in different economic forest lands.

Table 2. Statistical equations between cumulative rainfall(P) and cumulative TN/TP

Pattern	Relationship	
ANP	TN = 0.005175P - 0.294292 (R2=0.999)	TP = 0.000137P - 0.022490 (R2=0.995)
ANC	TN = 0.500597P - 34.61851(R2=0.995)	TP = 0.457665P - 21.75237(R2=0.996)
ARP-S	TN = 0.003711P - 0.169549(R2=0.999)	TP = 0.000072P - 0.009186(R2=0.997)
ARP-SH	TN = 0.002728P - 0.160240(R2=0.998)	TP = 0.000060P - 0.003535(R2=0.998)
ARC-SH	TN = 0.267028P - 18.20125(R2=0.988)	TP = 0.191962P - 11.12881(R2=0.990)
YNP	TN = 0.008216P - 0.280372(R2=0.985)	TP = 0.000232P - 0.007064(R2=0.988)
YNM	TN = 0.242549P - 12.53830(R2=0.989)	TP = 0.389903P - 16.57798(R2=0.991)
YNT	TN = 0.011115P - 0.710331(R2=0.973)	TP = 0.000290P - 0.010115(R2=0.974)
YNA	TN = 0.356816P + 3.015234(R2=0.994)	TP = 0.204767P + 8.061101(R2=0.985)
YNY	TN = 0.382248P + 9.678313(R2=0.989)	TP = 0.191730P - 3.804148(R2=0.996)
YDP	TN = 0.016115P - 0.660918(R2=0.946)	TP = 0.000851P - 0.020029(R2=0.945)
YDM	TN = 0.359225P - 2.079547(R2=0.935)	TP = 0.585373P + 2.165418(R2=0.948)

From Table 2, it can be found that the optimal equations for the quantitative relationship between the cumulative rainfall of different economic forest lands and total nitrogen and total phosphorus loss are all linear equations, the R2 of which is above 0.9, and more than 80% of the decision coefficient is greater than 0.95. The optimized linear equation can well reflect the internal law between them. The change rate of total nitrogen and total phosphorus loss with rainfall in different economic forest lands is very different. The total nitrogen and total phosphorus loss rate of ANC pattern and ARC-SH pattern in Anji county with rainfall change is about 100 times of that of ANP, ARP-S and ARP-SH patterns. Compared with the ANP pattern, the loss rate of total nitrogen and total phosphorus in the restored economic forest lands (ARP-S and ARP-SH) decreased by 28% and 47% respectively.

The gradings of total nitrogen and total phosphorus loss rate of different economic forest lands are obvious in Yuyao city. The total nitrogen and total phosphorus loss rate of YNY, YNA and YNM patterns is tens to hundreds of times that of YNT and YNP patterns. The total nitrogen and total phosphorus loss rate of YDP pattern is 2-4 times that of YNP pattern. In the Morella rubra economic forest lands, that of YDM pattern is 1.5 times of YNM pattern. In the same condition, *Morella rubra*, *Acer palmatum Thunb* (*nursey*), *Prunus yedoensis* (*nursey*) economic forest lands are more prone to total nitrogen and total phosphorus loss.

3.3 Analysis of total nitrogen loss

From the analysis of accumulated total nitrogen loss caused by accumulated rainfall, there is a consistent relationship between the accumulated total nitrogen loss of different economic forest lands in Anji County (in table 3) as ANC > ARC > ANP > ARP-S > ARP-SH. Compared with the natural type(ANP/ANC), the average total nitrogen purification efficiency of ARP-S pattern is 28%, and the purification efficiency increases with the increase of accumulated rainfall, and The average total nitrogen purification efficiency of ARP-SH pattern is 47%, but its purification efficiency declines with the increase of accumulated rainfall. Similarly, the average total nitrogen purification efficiency of ARC-SH pattern is 47%, and its purification efficiency increases with the increase of

accumulated rainfall. The total nitrogen loss of different economic forest lands is different. The total nitrogen loss of ANC pattern is 96 times that of ANP pattern, and ARC-SH pattern is 97 times that of ARP-S and ARP-SH patterns.

There is also an obvious relationship between the cumulative total nitrogen loss of different economic forest lands in Yuyao city (in table 3), which is manifested as YNY > YNA > YDM > YNM > YDP > YNT > YNP. Compared with the disturbed type (YDP/YDM), the average total nitrogen purification efficiency of YNP pattern is 49%, and the purification efficiency increases with the increase of accumulated rainfall, and the average total nitrogen purification efficiency of YNM pattern is 35%, and the purification efficiency shows a downward trend with the increase of accumulated rainfall. For different economic forest lands, the total nitrogen loss of YNM pattern is 29 times that of YNM pattern, and the total nitrogen loss of YDM pattern is 23 times that of YDP pattern.

Table 3. Cumulative TN and TP loss in different economic forest lands ($kg \cdot hm^{-2}$)

Index	TN			TP		
Cumulative rainfall /mm	1200	1500	1800	1200	1500	1800
ANP	5.92	7.47	9.02	0.14	0.18	0.22
ANC	566.1	716.28	866.46	527.45	664.75	802.04
ARP-S	4.28	5.4	6.51	0.08	0.1	0.12
ARP-SH	3.11	3.93	4.75	0.07	0.09	0.1
ARC-SH	302.23	382.34	462.45	219.23	276.81	334.4
YNP	9.58	12.04	14.51	0.27	0.34	0.41
YNM	278.52	351.29	424.05	451.31	568.28	685.25
YNT	12.63	15.96	19.3	0.34	0.42	0.51
YNA	431.19	538.24	645.28	253.78	315.21	376.64
YNY	468.38	583.05	697.72	226.27	283.79	341.31
YDP	18.68	23.51	28.35	1	1.26	1.51
YDM	428.99	536.76	644.53	704.61	880.22	1055.84

3.4 Analysis of total phosphorus loss

According to the data in Table 3, from the perspective of cumulative total phosphorus loss, the relationship order of cumulative total phosphorus loss of different economic forest lands in Anji county is ANC > ARC-SH > ANP > ARP-S > ARP-SH. Compared with the natural type (ANP/ANC), the average total phosphorus purification efficiency of ARP-S and ARP-SH patterns is 44% and 52% respectively. The purification efficiency of the two patterns increases with the increase of accumulated rainfall; The average total phosphorus purification efficiency of ARC-SH pattern is 58%, and its purification efficiency decreases with the increase of accumulated rainfall. The total phosphorus loss of ANC pattern is thousands of times that of ANP, ARC and ARP-SH patterns are also thousands of times different.

The relationship between cumulative total phosphorus loss of different economic forest lands in Yuyao city is YDM > YNM > YNA > YNY > YDP > YNT > YNP. Compared with the disturbed type (YDP/YDM), the average total phosphorus purification efficiency of YNP pattern is 73%, and the purification efficiency of YNM pattern is 35%. At the same time, with the increase of accumulated rainfall, the purification efficiency of the two economic forest lands shows a downward trend. There are great differences in total phosphorus loss in different economic forest lands. The total phosphorus loss of YNM pattern is more than thousand times of YNP pattern, and YDM pattern is hundreds of times of YDP pattern.

4. Summary

Based on the statistics of the quantitative relationship between accumulated rainfall and accumulated total nitrogen and total phosphorus loss in different economic forests, this paper compares and analyzes the total nitrogen and total phosphorus loss rate and total nitrogen and total phosphorus purification efficiency in different economic forests. The main conclusions are as follows: the correlation between cumulative rainfall and cumulative total nitrogen and total phosphorus loss of different economic forests is very good, and the fitted linear equation R2 is above 0.95. The response of total nitrogen and total phosphorus loss to rainfall can be characterized by the optimized linear equation. Through comparison, it can be concluded that the total nitrogen and total phosphorus loss rate of different economic forests is different in order of magnitude, especially in *Castanea mollissima Blumet* forest, *Morella rubra* forest, and *nursery* land, the total nitrogen and total phosphorus loss rate is very high, and it is necessary to prevent and control nutrient loss. The loss of total nitrogen and total phosphorus in economic forests is affected by economic forest types, human disturbance, and rainfall factors. Through comparison and analysis, it is found that reducing human disturbance and implementing understory vegetation restoration can significantly reduce the total nitrogen and total phosphorus loss rate. The gradual transformation of artificial disturbance economic forest into near-natural economic forest will control loss of nitrogen and phosphorus and produce 30%~70% nitrogen and phosphorus purification benefits. At the same time, the shrub and herb vegetation restoration under the Phyllostachys edulis economic forest and the reduction of artificial disturbance can reduce the total nitrogen loss rate by 28% and the total phosphorus loss rate by 47%.

This study is mainly based on the data monitoring under the present patterns, and carries out classification discussion on the data. It lacks in-depth analysis of the specific pattern, and needs further improvement in the monitoring indicator system and other aspects. In terms of the benefits of the economic forest management pattern, the management of nitrogen and phosphorus loss in the economic forest will improve the ecological environment of the forest land, but how much the economic benefits of this improvement are and how to evaluate the ecological and economic synergetic benefit of the economic forest management need further study.

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