Research advances on driving mechanism of nitrogen and phosphorus loss in sloping fields

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Abstract: Slope runoff and its associated soil nutrient loss are affected by precipitation, topography, underlying surface conditions and soil physical and chemical properties. The loss of nitrogen and phosphorus in slopes is an important cause of soil quality degradation and eutrophication of water bodies. Therefore, based on the study of rainfall runoff, the loss of soil nutrients and the change of runoff quality in the process of runoff can be further analyzed, which can provide reference for controlling nutrient loss and revealing the mechanism of nutrient loss. In this paper, the current situation of the study on the loss of nitrogen and phosphorus in sloping fields at home and abroad is analyzed from five aspects of precipitation characteristics, topography and vegetation conditions, so as to provide ideas for more systematic study on the loss mechanism of nitrogen and phosphorus in sloping fields.

1. Introduction
Nitrogen and phosphorus migration and transformation is an associated chemical process of slope-channel and surface-soil-underground three-dimensional water cycle [1]. Recipitation causes soil erosion, which leads to the loss of soil nutrients [2]. The lost nutrients, such as nitrogen and phosphorus, enter the water body along with the production/confluence of slope, forming non-point source pollution [3, 4]. If it exceeds the self-purification capacity of water environment, water pollution events such as rivers and lakes (reservoirs) are easy to break out [5, 6]. Therefore, the loss of nitrogen and phosphorus in slope has become one of the hot issues in hydrology, ecology and environment. The hilly area accounts for about two-thirds of the land area in China, and the soil erosion and nutrient loss in the mountainous area are important factors affecting the ecological environment [7]. In recent years, scholars at home and abroad have conducted a lot of research on the nitrogen and phosphorus loss in sloping fields by means of indoor simulation experiment, field prototype observation experiment and...
software simulation, etc. In this paper, the research progress of the driving mechanism of nitrogen and phosphorus loss in sloping fields is reviewed and summarized.

2. Factors of influencing the loss of nitrogen and phosphorus in slope land

The process of nitrogen and phosphorus migration and transformation in soil is very complicated. Fertilization, atmospheric deposition and rock weathering can increase the concentration of nitrogen and phosphorus in soil. Rainfall is the driving factor of nitrogen and phosphorus loss from slopes. Topographical conditions change the flow rate and flow pattern of runoff and thus affect the type of soil erosion; Soil characteristics affect the loss patterns and pathways of nitrogen and phosphorus; Vegetation affects soil nitrogen and phosphorus content and runoff, which affect slope nitrogen and phosphorus loss. Human activities will affect the above factors, and then affect the loss of nitrogen and phosphorus [8]. In the process of nitrogen and phosphorus loss in slope land, the content of soil nitrogen and phosphorus plays a decisive role in the loss of nitrogen and phosphorus. Precipitation, topography, soil characteristics, vegetation and human activities affect the runoff and sediment production processes, and then affect the loss of nitrogen [9].

2.1 influence of precipitation characteristics on nitrogen and phosphorus loss from sloping fields

The essence of slope nitrogen and phosphorus loss is the interaction between slope soil nitrogen and phosphorus and rainfall and runoff [10, 11]. Rainfall characteristics such as rainfall intensity, rainfall, and rain pattern affect the loss of nitrogen and phosphorus by affecting the degree of surface soil damage, soil erosion, and runoff [12]. The loss of nitrogen and phosphorus in light rain intensity is mainly in dissolved state. With the increase of rain intensity, the loss of nitrogen and phosphorus is affected by three aspects: (1) The runoff increases with the increase of rain intensity, resulting in the increase of nitrogen and phosphorus loss [13, 14]. (2) Increased rainfall intensifies soil erosion, resulting in increased nitrogen and phosphorus loss [15]. With the increase of raindrop kinetic energy, large soil particles are destroyed, which is easier to lose with runoff. (3) Tainfall intensity will affect the flow rate and flow pattern of runoff, and then affect the loss of nitrogen and phosphorus. With the increase of rain intensity, the flow turbulence increases, which leads to the increase of shear stress of runoff erosion and the increase of nitrogen and phosphorus loss in adsorption state [16]. At the same time, the soluble nitrogen and phosphorus content released from soil to runoff also increased.

Runoff is positively correlated with rainfall [17]. The concentration of nitrogen and phosphorus in runoff decreases with runoff production process, and the peak value of adsorbed nitrogen and phosphorus may appear again in the later period of runoff production due to soil erosion [18]. Early high-intensity rainfall may cause the most severe soil erosion and nutrient loss [10, 19]. Wen Leilei studied the soil erosion of slope farmland under different rain conditions, and found that the total amount of soil erosion was weakened> uniform type> delayed type> peak type. [20, 21].

2.2 influence of topographic conditions on nitrogen and phosphorus loss from sloping field

The topographical conditions that affect the loss of nitrogen and phosphorus on slope land mainly include slope, slope length, and slope shape. These topographic factors ultimately affect the loss of soil nutrients by affecting the splashing of raindrops and the erosion of surface runoff [22, 23].

(1) Slope affects nitrogen and phosphorus loss by affecting runoff process and soil particle loss [24, 25]. The flow energy of small slope is relatively small, and the deposition of sediment particles may block soil pores, form crusts, enhance soil shear resistance and reduce the loss of adsorbed nitrogen and phosphorus [26]. With the increase of slope, the stability of soil decreases, and the small particle soil on the slope is easier to be scoured, which is lost with runoff. When the slope continues to increase, rill erosion may occur on the slope surface, which will aggravate the loss of nitrogen and phosphorus [27-29].

(2) Slope length affects nitrogen and phosphorus loss by affecting runoff yield and the distribution of surface runoff and interflow [30]. The increase of slope length provides a larger buffer for the water from the upper part, which makes the water from the upper part infiltrate again, reduce the runoff yield
coefficient, and increases the amount of dissolved nitrogen and phosphorus leaching [31, 32]. At the same time, the flow resistance coefficient decreases with the increase of slope length, the flow pattern gradually changes from subcritical flow to supercritical flow, the shear force on the slope increases, the sediment loss increases with the increase of slope length, and the sediment adsorption nitrogen and phosphorus loss also increases [33-35].

(3) Slope type affects the loss of nitrogen and phosphorus by affecting flow velocity and erosion type. The slope type can be divided into straight slope, convex slope, concave slope and mixed slope. Rieke-Zapp et al. found that the linear slope and convex slope produced more sediments than the concave slope, and it can be inferred that the nitrogen and phosphorus loss in the concave slope may be smaller than that in the convex slope and linear slope [36]. However, Liu Qiao et al. showed that the loss intensity of nitrogen and phosphorus in the concave slope of red soil economic forest was greater than that in the convex slope [37]. At present, there are few studies on the influence of slope shape on nitrogen and phosphorus loss, and the mechanism of the influence is still to be further studied.

2.3 influence of soil characteristics on nitrogen and phosphorus loss from sloping field
Soil is a storehouse for storing nutrients needed by plants, the supply and loss of nutrients are closely related to soil characteristics [38, 39]. Soil bulk density, aggregate type, PH value, organic matter content and other characteristics affect the adsorption of nitrogen and phosphorus, the flow-producing process and the amount of soil loss [40-42].

(1) Soil bulk density affects nitrogen and phosphorus loss. Soil bulk density is an important factor affecting solute migration and runoff and sediment production in sloping field. Some studies have shown that the loss of nitrogen and phosphorus increases with the increase of bulk density at the initial stage of land flow on black soil slope, but with the increase of runoff, the soil erosion on loose slope increases, and the loss of particulate phosphorus decreases with the increase of soil bulk density [43].

(2) PH value affects the adsorption and release of nitrogen and phosphorus ions by soil colloids. Theoretically, the soil colloid has negative charge, so it can adsorb ammonia nitrogen with positive charge [44]. Under the influence of PH value, the soil colloidal surface absorbs ions or releases ions into the solution [45]. With the increase of PH value, the fixation amount of ammonia nitrogen in the soil will also increase, thus slowing down the loss of ammonia nitrogen. When the PH value is lower than the zero point of colloid charge, the electrostatic adsorption of phosphorus can occur to reduce the loss of phosphorus [46].

(3) The contents of organic matters and mineral species in aggregates affect the process of nitrogen and phosphorus loss. Soil organic matter not only provides nutrients for plant growth, but also has a large surface area and surface energy. NH$_4^+$ and other positive nutrient ions can be adsorbed to avoid loss with water, and organic matter can improve soil permeability and water retention, and reduce the generation of runoff [47, 48]. The coordination adsorption of iron and aluminum oxides and other solid phase surfaces with phosphorus in the form of coordination bonds can reduce the content of dissolved phosphorus and the migration capacity of phosphorus, so as to reduce the loss of phosphorus [49].

(4) Soil water content affects the way of nitrogen and phosphorus loss. In the early stage, the soil moisture content was low, and the infiltration rate was high. A large amount of nitrogen and phosphorus elements were infiltrated and lost with rain, especially the most obvious impact on nitrate nitrogen [50, 51]. Li Deming found in his research on the nutrient loss law of black soil slope that when the initial soil water content was less than 25%, the nitrate nitrogen loss in black soil was mainly in the form of leaching. With the increase of soil water content in the early stage, the nitrate nitrogen loss ratio with runoff also increased [52].

2.4 effect of vegetation on nitrogen and phosphorus loss
Vegetation cover plays a protective role on topsoil, and vegetation type, density and growth state all affect the loss of nitrogen and phosphorus from slopes.

(1) Plant root growth and vegetation density affect soil aggregates and runoff process [53]. Cui Cheng's study on the effect of bamboo expansion on soil structure and composition found that the
proportion of large aggregates in bamboo forest was lower than that in broad-leaved forest [54]. The increase of the proportion of small aggregates will increase the loss of nitrogen and phosphorus in the adsorbed state. Li Xiaona studied the interception effect of vegetation on nitrogen and phosphorus. The results showed that plant growth could improve soil permeability and increase runoff infiltration rate, thus reducing surface runoff and nitrogen and phosphorus loss [55]. The larger the vegetation root diameter and vegetation density, the greater the resistance to runoff in the process of movement, and the amount of absorbed nitrogen and granular phosphorus carried by sediment will also decrease [56, 57].

(2) Vegetation coverage affects nitrogen and phosphorus loss by affecting runoff production [58]. The direct impact of rain will splash the fine soil particles in the surface soil, and the surface soil will become dispersed, the runoff and sediment loss will increase, and the nitrogen and phosphorus loss dissolved in the runoff and absorbed by the sediment will increase accordingly. The larger the vegetation coverage is, the more obvious the reduction of droplet kinetic energy is, and the less nitrogen and phosphorus loss is. Vegetation branches and leaves also have the function of retaining rainwater, which will reduce the runoff, so the total amount of nitrogen and phosphorus lost will also be reduced [59].

(3) Litter can reduce soil erosion, but will increase the total amount of soil nitrogen and phosphorus [60]. As the second barrier between rainfall and soil, litter covering can reduce the kinetic energy of raindrops and reduce the erosion and damage to soil caused by raindrops [61, 62]. Compared with the branches and leaves of vegetation, litter has a stronger ability to retain rain water and has a more obvious effect on reducing runoff. In addition, decomposition of litter will transport nutrients such as nitrogen and phosphorus to the soil, which may increase the amount of nitrogen and phosphorus lost [63]. In our last five rainfall observations, it was found that litter cover had little effect on the loss concentration of nitrogen and phosphorus, but litter cover could significantly reduce the runoff yield, thus reducing the total amount of nitrogen and phosphorus loss. (Figure 1)

Figure 1. TN loss concentration and TN loss amount. In boxplot, mean value, median value, and outliers are represented by red dots, blue horizontal line, and diamond mark, respectively, and different letters indicate significant differences (P<0.05).SR: Surface runoff of experimental field without litter cover; SRL: Surface runoff of the experimental field covered with litter; I: Interflow of experimental field without litter cover; IL: Interflow of the experimental field covered with litter.

2.5 effects of human activities on nitrogen and phosphorus loss from sloping fields
Fertilization, ridge furrow, grazing and other human activities will affect the loss of nitrogen and phosphorus [64, 65]. Among them, fertilization increases the content of soil nutrients, which is the most fundamental factor affecting the loss of nitrogen and phosphorus on slopes; engineering measures such as ridges and ditches change the flow rate and flow path; grazing, fire and other engineering measures change the physical properties of soil and vegetation coverage, thus affecting the loss of nitrogen and phosphorus.

(1) Fertilizer increases the content of nitrogen and phosphorus in soil and becomes an artificial
"source" of nitrogen and phosphorus in soil. Factors such as fertilizer composition, fertilizer application method and fertilizer application amount can affect crop absorption [66, 67]. Improving crop utilization rate of fertilizer can reduce nutrient loss. The method of one-time fertilization, such as spraying, can not make the plants fully absorb, and the content of nitrogen and phosphorus in the soil increases rapidly. When runoff is generated, a large amount of fertilizer dissolves in the runoff [68]. The bag controlled-release fertilizer is to place the fertilizer in a bag according to a certain proportion, and slowly transport nutrients to the soil through the holes on the bag, so as to reduce the contact between the fertilizer and the soil, so as to reduce the loss of nutrients [69].

(2) Ridge cultivation and reverse-slope terrace and other farmland engineering measures slow down nitrogen and phosphorus loss by slowing down runoff velocity and increasing soil water storage capacity [70, 71]. Ridge cultivation can increase the active soil layer, reduce the soil bulk density, facilitate the rooting of plants, improve the infiltration capacity of precipitation, and reduce the loss of nitrogen and phosphorus [72]. Measures such as reverse-slope terrace and bamboo-type contour trench are the same as the principle of ridge ditches, which can reduce the flow velocity of surface runoff, increase infiltration and weaken the erosion of runoff on the surface. In addition, straw returning to the field will increase the surface coverage, weaken the impact of rainfall on the soil, and delay the formation of runoff. At the same time, straw rotting on the surface of the soil can improve the physical properties of the soil, promote the formation of aggregates, increase the adsorption of nitrogen and phosphorus to the soil, so as to reduce the loss of nitrogen and phosphorus.

(3) Farming, grazing and forest fire will increase the loss of nitrogen and phosphorus to some extent [73]. Tillage will destroy the structure of the topsoil. Grazing will destroy the surface vegetation and increase the exposure of the surface soil, resulting in the increase of sediment yield of runoff [74]. Forest fires increase the exposed area of the soil, and ash enters the soil, increasing the content of soil nitrogen and phosphorus [75]. At the same time, ash may block the soil pores, resulting in decreased soil infiltration capacity, increased surface runoff, and increased nitrogen and phosphorus loss.

3. Research prospects
On the basis of the above domestic and foreign research achievements, the possible research directions are proposed from three aspects of rainfall, slope and underlying surface conditions:

(1) Influence of rainfall on water quality: ①The difference in soil erosion under different rainfall patterns and the proportion of nitrogen and phosphorus loss in surface runoff and interflow under different rainfall patterns need to be further quantitatively studied. ② The effect of antecedent soil moisture content on the form of nitrogen and phosphorus loss needs to be analyzed in order to clarify the "background value" and "static transformation process" of soil nitrogen and phosphorus.

(2) slope influence: ①There are few studies on the influence of slope type on runoff generation and runoff flow pattern, especially the change of runoff flow pattern on compound slope is more complex, and its influence mechanism on nitrogen and phosphorus loss is unknown. ② It is worth exploring whether the slope change has an effect on the ratio of surface runoff to interflow.

(3) influence of underlying surface conditions: ①The hydrological influence of vegetation on rainfall is usually studied from the perspective of vegetation coverage, and the interception effect of vegetation leaf characteristics on rainfall is worth further study; ② Litter has a bidirectional effect on nitrogen and phosphorus loss from slopes, which not only releases nutrients to the soil, but also reduces nitrogen and phosphorus loss through its own water holding capacity. The comprehensive effect of litter decomposition on nitrogen and phosphorus loss in sloping fields needs to be further studied.

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