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Nitrogen export by runoff and sediment under different types of land use in West Tiaoxi catchment

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Five typical land covers in West Tiaoxi catchment of China, including mulberry garden, bamboo forest, pinery, vegetable plot and paddy field, were studied on nitrogen loss in artificial rainstorm runoff and sediment. Triple duplication experiments have been carried out under the artificial rain condition with an intensity of 2 mm.min-1 and lasting 32 minutes in 3 m2 field. Export of various species of nitrogen in runoff and sediment were investigated. The results show that nitrogen loss amount and rate are quite different among five kinds of land covers. The loss of total nitrogen in runoff of mulberry is the largest and that of paddy field is the smallest. Particle nitrogen accounts for 70-90% of total nitrogen in runoff of various kinds of land covers. Loss of dissolved nitrogen in pinery is much higher than in other kinds of land covers, which are similar among them. More detailed species of dissolved nitrogen show their respective features among various land covers. Total amounts of nitrogen loss from the top 10 cm layer of 5 kinds of soils are estimated as high as 4.66-9.40 g.m-2, of which nitrogen loss through sediment of runoff accounts for more than 90%. The rate of total nitrogen losses are ranged in 2.68-14.48 mg.m-2.min-1 in runoff, which is much lower than that of 100.01-172.67 mg.m-2.min-1 in sediment of runoff.

LIANG Tao1, ZHANG Xiumei1, ZHANG Shen1, YU Xingxiu2, WANG Hao3 (1. Inst. of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China; 2. Nanjing Institute of Geography and Limnology, CAS, Nanjing 210008, China; 3. Institute of Resources Science, Beijing Normal University, Beijing 100875, China) 1 Introduction As the main topic of global environmental change, researches on land use/cover change (LUCC) were carried out extensively (Li, 1996). Effects of land use/land cover changes on regional ecological environment were one of the great concerns recently (Guo et al., 1999). By affecting regional material cycling and energy flows, LUCC has profound impact on regional climate, soil, rainfall, and water quality. The study of influences of LUCC on regional environment, especially on process and flux of nutrient elements in catchment scale, is significant to assess eco-environmental effect, and raise and draw up land use polices in accord with sustainable development strategies. Research results pointed out that the primary approach of LUCC affecting elements transportation is by non-point source pollution, i.e., pollutants leaching from soil to surface water by rainfall and subsequently reducing water quality (Novotry et al., 1993). The loss of nitrogen and phosphorous can not only degrade the soil fertility, but also cause eutrophication of surface water. Therefore, the characteristics and quantification of non-point source pollution were well documented (Ma et al., 1992; Zhu et al., 2000; Shen et al., 1995). It is generally done through investigating the transportation process of pollutants with runoff, simulating three main links of surface runoff, soil erosion and pollutant transportation, and evaluating the flux of nutrients on a regional scale (Zhu et al., 1985). As it is well known that rainstorm runoff plays an essential role in non-point source pollution. Most of the nutrient loss happened during the few rainstorm events. How to accurately quantify the loss under different land-use conditions still needs to be coped with. Many models were used to try to solve this problem, however, valid parameters are not easy to be acquired. In general, there are two ways used in the studies. One is based on long-term in-situ observations and quantitive analysis to create correlative relationship between volume of runoff and concentration of elements (Mander et al., 2000; Yan et al., 1998). Another method depends on field or lab artificial rainfall experiments to get parameters and carry out quantitive studies (Chen et al., 1991; Zhang et al., 1995; Huang et al., 2001). The latter method is easier to quantify because of its tractability. Previous studies about nitrogen export on single factor, such as vegetation coverage (Zhang et al., 2

000), gradient (Wu et al., 1996) and raininess (Kang et al., 1999), have been explored a lot. However, former studies are usually lack of necessary duplication due to its large rainfall area and uneven raininess. The precision could hardly meet the model´s requirement. So far, studies on comparison of effects on different land-use types to nitrogen transportation based on duplications are still rare. In this study, self-designed minitype artificial rainfall equipment was used. West Tiaoxi agricultural catchment (Figure 1) with complex land-use types and highly intensive farming was selected as study field. Based on three duplicated in-situ experiments, the main objectives of this study are: (1) to compare the different nitrogen loss processes under different land-use types; and (2) to evaluate the flux rate and transportation characteristics of different formd of nitrogen from runoff and sediment under different land-use labd cover types. 2 Materials and methods 2.1 Artificial rainfall equipment The artificial rainfall equipment consists of four main parts, which include water supply bucket, float flow meter, rain sprayer and water collection groove (Figure 2). The area of rainfall is 3 m2, which is 2 m long and 1.5 m wide. The rain sprayer is made of 1.5 m long copal pipe with plastic muzzles. It could spray raindrop in 0.7 mm diameter upwards evenly. Rainfall intensity is controlled by rainfall intensity adjuster and float flow meter. Water stop boards are used to keep rainfall and mud inside. Surface runoffs during rainfall will be collected through water collection groove and then its volume be measured. The advantages of this equipment lie in its compactness, even rainfall and rainfall intensity tractability. Therefore, duplicated experiments are easy to be carried out in-situ in favor of reducing the experimental error. 2.2 Field experiment The agricultural catchment, locally named West Tiaoxi, is located in the upper reaches of Taihu Lake, one of the largest lakes in China. The drainage area of West Tiaoxi catchment is 2,240 km2, where intensive agriculture is practiced. Five most typeical types of land use were selected, including bamboo forest, mulberry garden, pinery, vegetable plot and paddy field. Table 1 supplied the basic physiochemical information on the experimental field. The field experiment was carried out at Mushan village in Biannan town of Huzhou city on September 22-27 in 2001. Three parallel artificial rainfall experiments were conducted in every land type under the same condition for the sake of increasing data reliability. Based on the local rainfall database, rainfall intensity was set to 2 mm.min-1 in simulating the rainstorm level. Duration of every rainfall event is 32 minutes excluding runoff-generation time. After runoff-generation, samples were collected every 4 minutes in turn (labeled with T1 to T8). When rainfall stopped, the remaining runoff was also collected (labeled with T9). Volume of runoff in every period was measured respectively. Runoff samples were deposited for 3 hours and then the upper 1000 ml of liquid was taken for water phase analysis, while sediments were collected at the same time for determination of sediment phase. Because the volume of sediment is small when runoff is initially generated, the first two periods were combined into one sediment sample and labeled with S1, other sediment samples were labeled with S2 to S8 in turn. Soils were also collected before and after each rainfall event. Rain water was taken as contrast. Samples of surface runoff were separated into two parts. One part was used to analyze total nitrogen, while the other was filtered by 0.45 ?滋m membrane for analysis of dissolved nitrogen. Total nitrogen and dissolved nitrogen were determined by UV meter after oxidation with potassium persulphate. Dissolved ammonia nitrogen was determined with colorimetry in Nashi reagent. Nitrite nitrogen was determined in colorimetry in ?琢-naphthylamine. Nitrate nitrogen was determined with colorimetry by phenol bi-sulfonic acid. Dissolved nitrates and nitrites was the sum of nitrite nitrogen and nitrate nitrogen. Particulate nitrogen and dissolved organic nitrogen could be calculated by the above data. Nitrogen contents in sediment and soil were determined with kjeldahl method after air-dried. Quality assurance was under the standard samples supplied by Standard Analysis Center of China. 3 Results and discussion Under artificial rainstorm conditions, nitrogen release in soil involves two processes, horizontal convection, which occurs in the bottom region of the source, and vertical convective diffusion and/or dispersion from the upper region of the source. Generally, the ratio of vertical diffusion is low and makes little contribution to surface water, so horizontal convection of nitrogen is the main concern in this study. Horizontal convection also includes two parts. One part is taken through runoff, which reflects the dissolved nitrogen and suspended thin particle nitrogen. The other part goes with sediment, which represents the thick particle nitrogen loss through sand. Under the same rainstorm intensity (2 mm.min-1), the times duration of runoff generation was different under various land use type conditions because of the difference of their slopes and physiochemical properties. The time duration of runoff generation in vegetable plot was the longest (average 10 min.), however, it was shorter in other land use types (average 2.5-5 min.). After the generation of runoff, various species of nitrogen in soil began to transport through runoff and sediment. Comparison of the results of three parallel experiments showed that the relative error of nitrogen loss was between 7% and 12% under the same kind of land use type. Therefore, the average values of three parallel experiments were used in the following discussion, which compared the features of nitrogen losses in runoff and sediment under different land use types. 3.1 Loss process of total nitrogen in runoff under different land uses The conc entration of total nitrogen in runoff under 5 kinds of land use types was described in detail (Figure 3). The curves showed that concentrations of total nitrogen in runoff decreased with duration and the speed was fast at first then slow in the end, besides the curve of vegetable plot fluctuated slightly. In addition, the descending order of loss amount of total nitrogen in runoff was mulberry garden > vegetable plot > bamboo forest > pinery > paddy field. The loss amount of total nitrogen in mulberry garden was almost five times higher than that in paddy field. One possible reason would be the difference of fertilization intensity, which caused the content of nitrogen in mulberry garden relatively high. On the other hand, there was a certain slope in mulberry garden, while it is flat in paddy field that made the nitrogen difficult to lose. Although the slope of pinery was large (average over 10o), its loss amount of total nitrogen was relatively low because it was almost immanured. Lots of farm manure was dressed in vegetable plot, so the loss amount of total nitrogen in runoff was relatively high. Moreover, the amount of manure dressed in bamboo forest was very little, the loss amount of total nitrogen was similar with it in pinery. It can be seen that the loss amount of total nitrogen in runoff under the same rainfall intensity and similar coverage mainly depended on three factors, including the content of nitrogen in soil related with fertilization intensity, the surface slope and the physiochemical property of the soil. 3.2 Loss process of nitrogen in various species in runoff under different land uses The significance of nitrogen in different species was quite different for agricultural non-point source pollution. Their loss characteristics were diverse. To further compare the loss of nitrogen in different species, particle nitrogen (PN), dissolved nitrogen (DN), dissolved inorganic nitrogen (DIN), dissolved organic nitrogen (DON), dissolved nitrates and nitrites (DNN) and dissolved ammonia (DHN) were selected for discussion (Figures 4, 5 and 6). From the trend of PN and DN (Figure 4), it can be seen that the loss amounts of PN were much higher than that of DN in whatever land use type, which occupied 70-90% of total nitrogen. It indicated that only the thin topsoil interacted with rain and little dissolved nitrogen leached out after runoff generation. Comparatively, the thin particle matters (diameter ≥ 0.45 ?滋m) in runoff were the main carrier of nitrogen. PN was the primary form in the loss of nitrogen in runoff. In addition, the features of PN under different land use types were basically the same as those of TN, because PN was the main part of TN. However, the features of DN were quite different with those of PN and TN. DN loss amount in pinery was obviously higher than the other 4 land use types and it decreased fast with the elapse of time. Moreover, DN loss amounts in mulberry, paddy and bamboo were similar and decreased slowly with the duration. DN in runoff included inorganic ammonia, nitrate and part of organic nitrogen, of which the first two parts were available to plant. Comparison of features of two DN species in Figure 5, contents of DON and DIN were similar between pinery and mulberry. Contents of DIN were much higher than DON in bamboo forest, while it was on the contrary in vegetable plot and paddy field. Furthermore, the descend order of contents of DON was pinery ≈vegetable > paddy > mulberry > bamboo. The descending order of contents of DIN was pinery, vegetable, mulberry ≈ paddy ≈bamboo. Obviously, contents of various species of DN in runoff was closely related with content of nitrogen in topsoil, soil component and its character. Loss amounts of DON and DIN in mulberry and paddy were similar because both of them were yellow brown soil, in despite of the difference of contents of nitrogen in topsoil. However, human disurbance was strong and moisture content was high in vegetable plot and paddy filed, absorptions of DIN were relatively high and loss amount of DIN was lower than DON significantly. There were lots of inorganic colloid and mineral particles in yellow brown soil, which were easy to combine with DON and difficult to move. This caused loss amount of DON lower than that of DIN. The loss amounts of DON and DIN were similar with DN under different kinds of land use types. Further comparison of DIN indicated that loss amount of DNN was much higher than that of DHN (Figure 6). Among the five land use types, loss amount in pinery was much higher than others. And loss amounts in the other four land use types were close, of which the lowest one was paddy. It could be concluded that the largest loss amount of total nitrogen and PN happened in mulberry garden. However, the largest loss amount of DN occurred in pinery, while this part was the important one of soil nutrient. 3.3 Loss process of nitrogen in sediment and soil under different land use types Loss processes of total nitrogen in soil and runoff sediment were described in Figure 7. Loss amounts of total nitrogen in topsoil were among 100-200 mg.mg-1 before and after rainfall, with the descending order being mulberry > vegetable ≈bamboo ≈paddy > pinery. Based on the soil density, it could be estimated that the loss amount of total nitrogen was among 4.66-9.40 g.m-2 in 10 cm topsoil per m2, which was far more larger than that in runoff (less than 0.5 g.m-2). Obviously, most of nitrogen in soil was taken with runoff through sediment, i.e., taken with sand leached by runoff. In addition, whichever land use types, the loss amount of nitrogen in sediment decreased significantly with elapse of the time duration. The rates of decrease were close among the five land use types. It can be deduced that the peak of nitrogen loss generally happened at the beginning of the rainfall, the loss amount of which in that period accounted for the majority of the total nitrogen loss in soil. 3.4 Flux rate estimation of nitrogen under different land use types While the approach used in this s tudy ignores the effect of gradient, coverage and rainfall intensity, the flux rate of nitrogen, phosphorous and heavy metals in runoff and sediment could be evaluated by volume of runoff or sediment and concentration of various elements. It can be expressed as: $V = C \times Q/(S \times T)$ where Vij is the average flux rate of j element under i land use type (mg.m-2.min-1), Ctij is the average concentration of j element in t time interval (t = 1...8) under i land use type (mg.L-1 or mg.g-1), Qti is the volume of runoff or sediment in t time interval under i land use type (L or g), S0 is the valid area of rainfall (m2), and T0 is the duration of the rainfall (min.). The loss rate of nitrogen in both runoff and sediment under different land use types with the same rainfall intensity were calculated based on the above formula. The ratios of loss amount in runoff and that in sediment were also computed (Figure 8). It was obvious that the average loss rate of nitrogen in mulberry was the biggest (14.48 mg.m-2.min-1) among the five land use types studied. Bamboo and paddy was in the next place and pinery and vegetable plot was the smallest (2.71 and 2.68 mg.m-2.min-1). As to the ratio of loss amount in runoff and sediment, the majority of nitrogen loss was through sediment of runoff (more than 90%). The ratio of vegetable plot was the largest, the next was pinery and paddy, and the ratio of mulberry was the smallest. Loss process and features of phosphorous and heavy metals would be discussed in the following section. 4 Conclusion The results of three parallel artificial rainstorm experiments under different types of land use showed that nitrogen loss amount and rate are quite different among five types of land covers under the same rainfall intensity. The loss of total nitrogen in runoff of mulberry is the largest and that of paddy field is the smallest. The loss amount of various species of nitrogen in runoff was diverse from each other. Thin particle nitrogen accounts for 70-90% of total nitrogen in runoff of various types of land covers. Loss of dissolved nitrogen in pinery is much higher than that in other kinds of land covers, which is similar among them. More detailed species of dissolved nitrogen show their respective features among various land covers. Total amounts of nitrogen loss from top 10 cm layer of 5 types of soils are estimated as high as 4.66-9.40 g.m-2, of which nitrogen loss through sediment of runoff accounts for more than 90%. Under the rainfall intensity of 2 mm.min-1 and area of 3 m2, if the slope and coverage were ignored, the rates of total nitrogen losses are ranged in 2.68-14.48 mg.m-2.min-1 in runoff, which is much lower than that of 100.01-172.67 mg.m-2.min-1 in sediment of runoff.

关键词： surface runoff; nitrogen export; artificial rainstorm; land use