Hydrol. Earth Syst. Sci. Discuss., 7, C5238–C5248, 2011
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Hydrology and Earth System Sciences Discussions

Interactive comment on "The nitrate export in subtropical mountainous catchment: implication for land use change impact" *by* J.-C. Huang et al.

J.-C. Huang et al.

riverhuang@ntu.edu.tw

Received and published: 11 March 2011

1.This paper investigates the impacts of landuse change on the nitrate transportation pattern at a tropical mountainous watershed. The analysis is mainly data-driven and supplemented by a hydrologic model. The different behavior of the subcatchments with various levels of cultivation implies the highly sensitivity of nitrate loading to agricultural activities. I found that the methodology is generally appropriate, and the results are interesting. However, I hope the authors pay substantial attention to the representation, or writing. Although the general organization is ok, sometimes the interpretation is not presented with smooth logic. English grammar can also be improved, but in a secondary manner.

Reply: Thanks for reviewer's comment. Below we provide a point-to-point reply. We believed the writing in this revision was improved significantly.

2.Moreover, the authors could be challenged further to highlight the distinct features of their study area and the corresponding impacts. There are two major features distinguishing this catchment from the others around the world. The first is the abundant precipitation and typhoon season, and the second is that the farm land is mainly located at the riparian areas. This provides the authors a unique opportunity to understand how these features lead to the nitrate transportation patterns distinct from those in the other regions. The authors may not have to add extra comparative analysis into this paper, but there could be more in-depth discussion along this direction. For example, at an agricultural catchment in Midwest USA, featured by very flat topography and extensive tile drains, the nitrate loading into the stream is mainly carried by tile drainage. And it was found there is a carry-over of nitrate storage in the soil from dry years to wet years, which leads to relatively constant mean annual nitrate concentration. Similarly a question could be asked for this study area: What are the dominant runoff generation mechanisms in the study area of this paper, and how do they affect the spatio-temporal pattern of nitrate?

Reply: To highlight two features in our study area and reveal the merit of paper, we give a more straightforward title "Landuse effect and hydrological control on nitrate yield in subtropical mountainous watershed". Of course, we added more illustration about hydrological effects on nitrate export. The study area is a complex with various proportions in landuse types due to limitation of arable land, available water for irrigation and natural vegetation cover. The purpose of this paper is to pin down each individual landuse type associated nitrate yield through observational network and deconvolution computation. The numbers of yield factor for each landuse category were given with reasonable uncertainties benefiting future model use and management. Details in runoff generation mechanism and its control on spatio-temporal pattern of nitrate export/concentration are not the scope of this paper; however, we add two new panels

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in old Figure 3 (see Figure 1 below) for event chemical hydrograph and one new figure (Figure 2 below) to illustrate potential hydrological control and answer reviewer's question about "carry-over nitrate storage". Some photos were pooled together in Appendix (will be in the revised version; now at the bottom of reply) for readers to know what study sites look like. In our case, it is very difficult to separate riparian output from underground storage. By using observation in two flood event cases (Fig. 1), we inferred potential runoff mechanism. At cultivated Y1 station, one single data point of high nitrate concentration appears at the hydrograph rising limb in each flood case. This high concentration is very likely caused by infiltration excess runoff that washed over cultivated area. This phenomenon was not observed at K1, which is relatively pristine. During the two flood events, both cultivated and natural sub-watersheds exhibit similar pattern that the peak concentration followed the peak discharge by a few hours. The 3 hour lag time between discharge and concentration peaks might indicate the predominance of nitrate-replete water from groundwater discharge during recession, including those flowing through the cultivated riparian zones. Similar to previous studies in chemical hydrograph separation, the subterranean old water was pushed out rapidly. In fact, if we go into detail the two flood cases reveal a drop in discharge around the peak, meanwhile, nitrate concentration jumps up synchronously. Such synchroneity reflects a fast decrease in fractional contribution from surface component with nitrate-deplete water. Overall speaking, the concentration of nitrate was lower in the second flood that occurred two months later with greater discharge. Dilution by larger surface runoff is one possibility; alternatively, the storage had been diminished by antecedent events. The cumulative discharge and event total nitrate export for the two floods was shown for comparison (new panels). Interestingly, the nitrate export of the second event is significantly larger than the first flood regardless of cultivated or pristine conditions. In terms of event total export, it seems that supply-limited situation had not occurred. Whether the higher export in the second event is due to "carry-over" is not known, however, concentrations is not a useful index for "carry-over" phenomenon in our study system. Previous studies indicated that only when the rainfall intensity exceeds 60 mm/hr the

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infiltration excess runoff may occur. In dry season, which is the dormant season, most of the fertilizer in cultivated land or recycled nutrients in forest will be carried by infiltration. Therefore, storage of nitrate occurs. In wet season, which is also the growing season, the nutrients will be uptake by vegetation; however, typhoon brings torrential rain to flush out essential nutrients. In both monitoring years we found significant positive relationships between cumulative nitrate flux and cumulative runoff depth (Fig. 2 below) over entire network stations with various landuse combinations. Such consistency among all stations again emphasizes the overwhelming hydrological control on nitrate dynamics in subtropical mountainous watersheds. Since the water discharge is lower in the second monitoring year (blue curve in Figure 2 below) our case does not allow us to prove the carry-over of storage from antecedent drought year. Yet, we cannot deny its potential. On the other hand, our inter-event comparison reveals that the storage seems to be very large to support frequent flush-out export, thus, the storage might not be sensitive to the additional input via "carry-over" process.

Specific comments 1. The title is somehow confusing and does not read well. Please reword. Reply: See reply above.

2. P9294. A bit more details of the methodology should be included. The conclusions could be organized in a more logic way. The number "5.2%" is given here and later in the conclusion section, so one would take it as a very important number. But there is no other description about this number, i.e., how was it estimated. Is it the fraction of the catchment (as a whole) subject to agricultural activities? Reply: Yes, reviewer is correct. The number is the average fraction of the catchment subject to agricultural activities, however, not specifically to a single type. It includes orchard, active and inactive farms. In this version, however, we decided to remove this number since giving an average of three divergent yielding numbers is less meaningful (yield of active farm is extremely high). The abstract and conclusions have been revised in the latest manuscript.

3. P9295, Line 27. "It is also recognized that this island ecosystem is relatively vulnera-

ble in such environmental settings". Reference please. Reply: The following two references have expounded the vulnerability of island ecosystem to environmental changes due to its geographically isolated feature. However, we removed this sentence because we think this sentence is not essential in this study.

Davies, P. M.: Climate change implications for river restoration in global biodiversity hotspots. Restoration Ecology, 18, 261-268, 2010. Huang, P.H., Tsai, J.S., Lin, W.T.: Using multiple-criteria decision-making techniques for eco-environmental vulnerability assessmet: a case study on the Chi-Jia-Wan Stream watershed, Taiwan, Environ Monit Assess, 168: 141-158, 2010.

4. P9296, Line 22. Reference for the global mean annual precipitation? Reply: A highly-cited paper is referred and listed in reference. Legates, D.R., 1995: Global and terrestrial precipitation: A comparative assessment of existing climatologies. Int. J. Climatol., 15, 237-258.

5. P9296, Line 24-25. This sentence could be rephrased as "The mean daily discharges averaged within the total study period are 7.94 m3/s for Chi-Chia-Wan and 2.41 m3/s for You-Sheng Creek, and those averaged within the wet season are 11.80m3/s and 4.07m3/s respectively." This is just one example that the authors could make their representation more clear. Reply: Thanks for the comment. We've modified the sentence accordingly.

6. P9297, Line 1-2. Again, not clear. 15.8oC within what period? Reply: We've changed the statement as "The annual average air temperature is 15.8 âĎČ, and the monthly average air temperatures in January and July are 4 âĎČ and 23 âĎČ during 2000-2009."

7. P9297, Line 8. Are you implying that in American and Europe the cultivated land occupy other zones? Then what are they? References? Actually this could an important point to convince the novelty and uniqueness of your work. Reply: We rewrote the sentences to highlight the difference in spatial allocation of cultivated land. "Unlike the

land use patterns in large watershed in America and Europe (Mayer et al., 2002; Rode et al., 2009; Rose et al., 2001), in the small mountainous catchment those cultivated land are almost confined in the riparian zones (Figure 1(b)) due to wide cover of steep hill slopes and the convenience of water intake.

8. P9297, Line 20-21. How "rationally" is this assumption? Does elevation matter here? Are the observed rainfall data from the three rain gauges showing spatial homogeneity across different temporal scales? Reply: The original idea of this assumption is to emphasize landuse rather than atmospheric nitrogen deposition is the main cause for derived spatial heterogeneity in nitrate yield. The assumption of homogenous concentration of N in air mass is quite reasonable, particularly, in high mountain. If the thickness of airshed is uniform over the watershed and wash-out efficiency is 100%, then, the atmospheric N deposition (per area) will be equal everywhere not being determined by rainfall amount . However, according to the previous study in adjacent area by Kao et al. (2004) a very large fraction of input nitrogen is retained in watershed via biotic and/or abiotic processes. Here in the new version, we eliminate relevant descriptions about atmospheric deposition since in this paper we focus on land use impact on N output over spatial scale rather than internal cycling/transformation and budget of nitrate.

9. P9298, Section 2.2. How about sedimentation here? It might also bring some particulate nitrogen into the stream. Reply: The N export from agricultural land is mainly nitrate due to its mobilization feature. NH4 was measured, yet, almost all samples were below detection limit, and therefore, NH4 was ignored when comparing with nitrate concentration. As for particle-associated nitrogen (PN), agriculture activity may enhance particulate nitrogen yield, which might be important in mountainous region with high rainfall. However, we can hardly separate agriculture-associated PN from extraordinarily high sediment export sourced from typhoon-triggered landslide (Hilton et al., 2008). Since the sediment export is $\sim$4 orders of magnitude higher in high flow when comparing to low flow periods (Kao et al., 2008). Besides, high stream power washes out

almost all organic and fine grained detritus (except large wood debris) leaving gravel and rock on the riverbed. The limited organic debris remaining on the channel has less contribution to N export. We add two extra references, some photos at different locations and more descriptions into revised version letting readers know the situation. Meanwhile, the entire story remains the same aiming on nitrate, the predominant dissolved species of N export. (See Figure 3)

10. P9298, Line 24. The word "elemental flux" is too vague here. "nitrate flux" will just do. Reply: corrected.

11. P9299, Line 1-2. Please add some description of the model here. The original TOPMODEL does not consider fast subsurface flow (preferential flow, or macro-pore flow), which is typical in mountainous forest areas. Is your model including this? Reply: This model had been successfully applied in other mountainous watersheds in Taiwan. Details of the model were shown in our previous modeling works (Huang et al., 2009; 2011). [P9299, Line 2]. As requested by reviewer, we still add more descriptions as below in section 2-3 in this newer version. "The model divides the vertical soil column into three layers: upper layer, middle layer and bottom layer. Five hydrological processes and three runoff routings are considered, including precipitation, interception, infiltration, percolation, and evaportranspiration. Based on the saturation state in the three layers, the surface flow can be routed by diffusion wave approach and the inter flow and base flow can be routed by soil moisture deficit."

12. P9302, Line 7-9. I could not follow the logic. I could understand that the selected yield factors minimize RMSE values, but how do they reduce the annual variation and the landscape heterogeneity effect? The annual variation and the landscape heterogeneity effect are something we try to understand and gain physical insight into, not to reduce by parameter calibration. Reply: We changed the sentence into "Since the eight landuse-specific yield factors are constrained by using the monitoring networks composing of wide landuse patterns the optimal solution we derived should approximate the representative yield of each landuse category over spatial and temporal scale."

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13. P9302, Line 21-23. My understanding is that Irrigation, complementary to precipitation, usually leads to higher low flow. Why the authors got the opposite conclusion? Does your model include irrigation? Reply: No, our model does not include irrigation. Unlike the irrigation on large river floodplain that water is extracted from groundwater/impoundment, water is withdrawn directly from stream resulting in a lower water level in low flow simulation. In revised version, we added two sentences to describe such discrepancy.

14. P9303, Line 5. Should “0.35” be “3.5”? Reply: Yes. We corrected the value.

15. P9303, Line 15. To me the seasonality at K1 is just as significant as at Y1, in a relative sense, except for smaller magnitude. Reply: We agree with reviewer. The paragraph was rephrased.

16. P9303, Line 25. Does “fewer” here mean less illegal plantation, or “a few” ? Reply: We’ve changed it to “a few”.

17. P9307, Line 9-10. “We were not surprised. . .”. Not necessary. Could be removed. Reply: Removed.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 9293, 2010.

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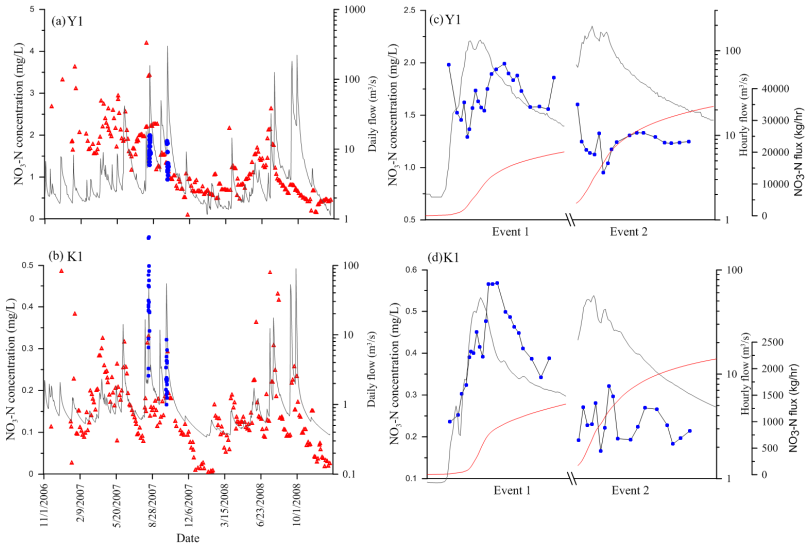

Figure 1. The daily flow and nitrate concentration for Y1 (a) and K1 (b). The nitrate concentrations during typhoon events are presented in (c) and (d). The red curves mean the accumulated export for each event.

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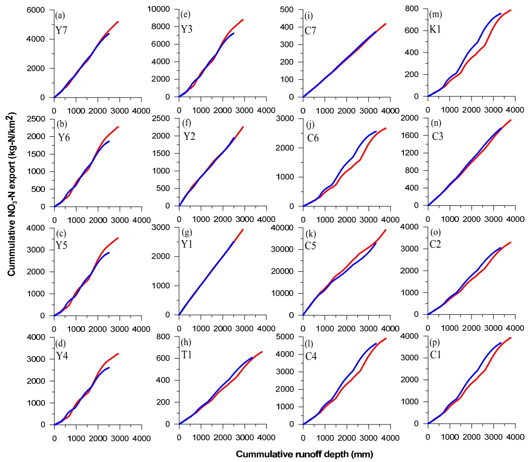

Figure 2. The Cumulative runoff depth and nitrate export for the all 16 sites. The red and blue curves represent the export during 2007 and 2008, respectively.

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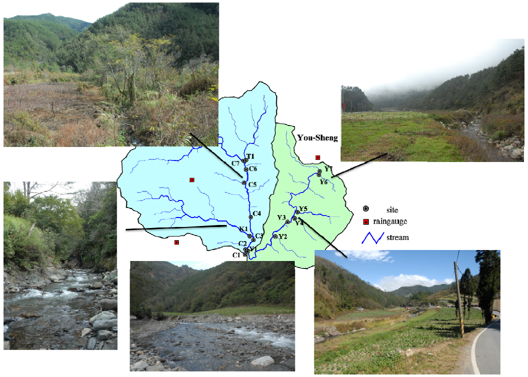

Figure 3. The photos and the locations in Chi-Chia-Wan Creek

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