

## ***Interactive comment on “Temporal variation of nitrate and phosphate transport in headwater catchments: the hydrological controls and landuse alteration” by T.-Y. Lee et al.***

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### General comments

This paper focused on the export of DIN and DIP from three small catchments contrasting in cultivation impacts in Taiwan. The study captured two years of data and included three typhoon events enabling an investigation of seasonal (dry vs. wet), events, and landuse effects on nutrient export from these catchments. The results of this work are significant and useful to the readership of Biogeosciences and the watershed biogeochemistry field at large because the work captures these fluxes for (1) a globally significant region (Oceania) where exports for large rivers are known to be significant

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and increasing, (2) smaller catchments which represent lotic environments that are the most vulnerable to landuse activities while at the same time critical to our understanding of source inputs to larger river systems, and (3) typhoon events of varying strength enabling some assessment of how fluxes behave during these events which are likely to continue to change with climate variation.

Overall, I believe the approaches used are sound though there are critical details missing from the methods section that make it a bit difficult to determine this absolutely (see detailed comments below). I found, however, that the results and discussion sections were not distinct enough which contributed to a lack of development of the contributions this dataset provides regarding the points listed above. I have made some suggestions below on reorganization, however, it is important to emphasize that a clearer discussion of the mechanisms responsible for the differences in how DIN and DIP behaved in relationship to landuse and hydrology (seasonal and event driven) is sorely needed. If the mechanisms were provided with a clear linkage to the findings the final conceptual figure would be put to better use (after corrections of course). For example, by the time one gets to the discussion of Fig. 9 it is not abundantly evident why the patterns of soil/deeper versus surface NO<sub>3</sub><sup>-</sup> and PO<sub>4</sub><sup>2-</sup> concentrations or DIN:DIP loading would be as provided in that figure. Further details on the discussion points and conclusions are provided below.

Detailed comments by section. Abstract. Authors should consider points made in the Conclusion section when editing their abstract. Some major points are provided in that section that really belong in the abstract as that conclusion section reads just like an abstract. Line 32. Provide the units for yields to clarify what is being presented there. Line 33. An easier comparison among the catchments could be made by providing these ratios in terms of whole numbers such as 24, 104, and 79, respectively. Then state high DIN yields were in fact observed in all three and comparable to intensively disturbed rivers around the world. Line 39. Need to clarify the difference in the DIN and DIP ratios reported here and more clearly describe what they mean in terms of

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the cultivation gradient. Line 41. What other evidence supports this statement of N saturation in these watersheds. Line 42. “fundamental clues” is a bit too vague. There are some important conclusions provided in the conclusion section that belong here in the abstract. Also please consider the main three important aspects listed above in the general comments when revising the abstract.

Introduction. Line 55. Replace “the increase of DIN and DIP” with “this increase..” Line 59. The word emission makes me think of releases to the atmosphere. Consider export or loading. Line 59. Be sure to clarify form of N and P being discussed here and specify the phrase “deteriorating the ecosystem”. That phrase is vague and not informative. Lines 60-62. End the sentence after the (Howarth et al. 1996; Elser et al. 2009). Start new sentence omitting “that is,” with “For example,” and omit the word ratios and add more information on these impacts such as distribution of phototrophs (benthic to more pelagic), harmful algal blooms. Here there needs to be a stronger argument regarding the impact of N:P. I certainly agree there is but this could be stronger in the introduction. Line 63. It would be helpful to very briefly define the Oceania River region here so clear for rest of the paper. Line 65. Place Seitzinger et al ref at end of sentence. Line 66. Rewrite – suggest “Moreover, tropical cyclones, which induce. . .” Line 68. Rewrite – suggest “abundant nutrients may also disturb in-stream and coastal ecosystems that are associated with nutrient uptake (references).” Line 76. Suggest “a pristine, moderately. . .” Line 77 Suggest “catchments were monitored during a 3-day. . .” Line 80 suggest “12-month period and the significance of typhoons in altering this pattern; and. . .”

Study site. Line 90. Need to refer to Table 1 and clearly define these “levels” of cultivation. For example, don’t see reference to cultivated lands other than orchard in Fig. 1 but do see small % in Table 1. Seems secondary forest is really the component that differs among the watersheds. This point needs to be clarified so as to understand the relevance of the differences in these catchments both regionally and internationally. Line. 93. Suggest rewording “75% of the precipitation falls during the wet season

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(may to Oct), primarily due to typhoons.” Line. 94. How was discharge measured by these two gauges? Line 95. Suggest rewording “The discharge for the pristine watershed (Gaoshan Creek) was derived from that of the . . .” Line 96. Need to clearly justify this approach of using the larger Chichianwan to predict the Gaoshan. This is particularly important for interpreting the loads among these catchments. What is the point of providing the average daily discharge for Chichiawan and Yusheng? How was the discharge of Yikawan determined? Line 105-106. What does “similar environmental background” mean? Line 107. Need to provide a bit more clarity and/or evidence to support this last statement that these creeks are good sites for revealing the relationship between nutrient export and landuse.

Materials and methods. Line 118. Is this month/day, looks to be that way but it might be better to clarify this. Line 122. How was nitrite and ammonium determined and what were the detection limits? Line 125. What colorimetric method was used in the flow injection analysis conducted? How was total suspended matter determined? How was temperature monitored? Lines 131-132. “Flux estimations are often essential. . .” sentence is awkward and difficult to follow – suggest clarify. Line 136. Define C-Q first time used. Line 140. Suggest clarify what is meant by flow-weight method. Define the term “Load” used in equation 1 so distinct from “Load” in equation 2. These need distinct and descriptive terms that should be maintained throughout the paper. This was difficult to follow here and in the paper itself. Line 142. Provide the units for the conversion factor. Where does it come from? That is not provide here and should be. Line 160. “could be as much as three” Was it or not? Should clearly state actual results, wording like this is a bit confusing. Lines 162-164. Last sentence here sounds like part of the methods not the results. Line 170. Here is an example of different terms used for the events associated with the typhoons. In this case “rainstorm”. Upon first read I found it difficult to follow the paper because I was not sure if events or rainstorms coincided with the typhoons or not – so I was always trying to figure this out. Might help to stick with one term for these perhaps typhoon rain events. Lines 173-183. This entire section reads like discussion material should be moved and integrated into a

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reorganized discussion. Line 181. Clarify the sources of these different N pools in the surface and subsurface. This is an issue when it comes to understanding the mechanisms behind differences found in these datasets by element, catchment, and flow regime. Line 185-187. Suggest rewording “ The irregular application of fertilizer likely caused a decoupling between nitrate concentration and discharge noted in this watershed (fig. 5).” This, however, doesn’t necessarily fit here unless a reorganization of the results is made based upon NO<sub>3</sub><sup>-</sup> which includes both the fluxes in addition to the relationships with discharge. So either move this or integrate the discharge relationships into this section. This would reduce redundancy in the results section. Line 189. Example of terminology associated with the typhoon events. Here the term “flood period” is used. Line 190. Suggest reword – “In the intensively cultivated watershed. . .” Line 191. Looks like NO<sub>3</sub><sup>-</sup> levels are actually higher than 10 ppm. Lines 192-194. Looks like discussion not results. Line 198. Clarify phrase “have insignificant seasonality” should this read “did not vary with season or seasonally?” Lines 199- Discussion material. Lines 200-202. Repetitive, consider integrating these statements into one. Line 203. Suggest reword – “Increasing phosphate concentration, however, accompanied the increase in discharge, congruent with the hydrologic controls on the enhancement of phosphate concentration in other watersheds (refs; Fig 5). Again this is a bit like discussion material. . . Lines 206-207. Discussion material to be moved. Lines 208-211 Starting with “In a year, the phosphate . . .” and ending with (Green and Finlay, 2010) reads like material for discussion. Should consider integrating with discussion. Lines 211-214. Starting with “The scattered phosphate..” Need to state more clearly as results and compare with the nitrate. Line 216. If keep separate section “Hydrological controls” need to remove reference to relationships to discharge in the proceeding sections to avoid repetition. In this section it would helpful to first provide the basic results (1) what were the relationships between NO<sub>3</sub><sup>-</sup> and discharge; (2) How did this relationship vary among catchments; (3) How did this also vary between nontyphoon and typhoon periods? Repeat this line of organization for PO<sub>4</sub><sup>3-</sup> so can clearly state the differences. Lines 225-226. “is that the source area of the phosphate is propor-

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tional to the. . .” this line of discussion is a bit unclear and I think this issue may be analogous to that highlighted above for line 181. Getting this information including any evidence for sources is important to the later interpretation of these results. Line 226-227. Sentence starting “From those concentration and discharge..” This sentence needs to more clearly explain the patterns by N then by P then state the differences. Lines 228-229. This last sentence is the kind of basic results material that belongs up front in this section.

Discussion. Overall there is a great deal of results provided in this discussion section which made it difficult to wade through. One telling example of this are the discussion section titles which read much more like results sections and less like actual findings and/or their interpretation. I tried here to identify many of the examples of the results in this section so can see what could be moved/reorganized. I also wonder if the authors would consider organizing this section using titles such as: (5.1) Hydrologic controls different for DIN and DIP. In this section the differences in how DIN and DIP concentrations and loading could be discussed using the different levels of hydrology investigated (e.g. seasonal and event driven). So first focus on flux and export. Then yield and discuss the mechanisms likely responsible for DIN versus DIP. (5.2) Importance of landuse activity on nutrient export and differences in their proportions from Oceania streams. (5.3) Differing mechanisms for DIN and DIP export, potential mechanisms and consequences. I would suggest starting of the section with a paragraph that introduces the pathway of this discussion and with this sort of organization and the ending focused on the conceptual model the conclusion section would not likely be needed. Lines 234-239. This whole section contains results that were not provided in the results section. Lines 239-243 Suggest rewording “Although the nitrate concentration was diluted during the typhoons, the increase in discharge by three orders of magnitude compensated for the dilution effect and led to the transport of more nitrogen during these periods as compared with the low flow period on an annual basis.” Line 242. Is the phrase “directly proportional to the discharge magnitude” accurate? I did not see any direct tests of this in the results but perhaps I missed something. Line 244.

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What is meant by the phrase “recovery of nitrogen is fast.” Lines 245-246. Report these in the results. Lines 247- The mechanism vaguely eluded to here is really interesting an important but not quite clear enough I am afraid. In this first section I found three typhoon events were referred to but not always as in some places only two were reported on. Need to clarify this. Overall need to discuss potential mechanisms for increase in nutrients with frequency of events. Why is this not simply due to greater discharge in later events. How can size of events be separated from frequency in these data in order to make such statements? Line 254 Suggest rewrite as “The nutrient fluxes were converted into yields to illustrate the export rate of DIN and DIP per unit watershed area. . .(here more specifically state why). “ Also given that this is a topic sentence in the discussion should indicate what this suggests. Line 257. Add “captured by these catchments” after “cultivation gradient. . .” Line 258. Place (Caraco and Cole) reference at end of sentence. Lines 259-262. What evidence is there specific to the watersheds investigated in this study? Line 260. In this phrase “High nitrogen yields were also noticed in China “ provide information on type of system. Lines 263-264. Belongs in results. Line 264. Suggest rewrite “Phosphate yields in these streams were also larger than most. . .” and include other examples – that is compare to other systems in addition to Changjiang River. Overall there needs to be some clarity on how to compare these smaller tributaries to the larger rivers systems we typically have more information on. This is an important point that would be helpful to clarify in this discussion but is currently not included. Lines 272-275. Example of where the small vs. larger river comparisons should be made. Line 280. Need to clarify what evidence is derived from this study then back up with interpretation of the data using evidence from elsewhere. The section above this is difficult to follow I think because of the lack of clarity on what was found here and how other work relates and helps to interpret these new findings. What evidence is here for N saturation (this phenomenon?).? Lines 282-285. Good example of where the argument gets lost in the writing and needs clarification. Lines 286-289. Material that needs to go into the results and taken out of discussion. Lines 289-292. Indeed the seasonal and event driven hydrology forcing on the NP ratio is

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really important but need to make a better link with the dataset. What are the different mechanisms at play here? Lines 292-294. Clarify the terms used here (i.e. immediately recovered, responds quickly) in terms of catchment, the pristine and intermediate cultivation catchments response was not so obvious from what I could tell whereas the intense cultivation catchment see a longer recovery 6-7 months (See Fig. 7). Line 297. Be sure to clearly define N:P ratio throughout the paper. Some reminder of this when first used in the discussion is important. Is this load based or concentration? This also needs to be rewritten to provide the major point of this section of the discussion. Lines 298-300. Results material here that needs to be removed. Lines 300-302. Don't see this in Fig. 8 where the lower N:P is shown in (d) which is the most cultivated catchment and largest variation in the most pristine catchment (b). Line 303. Were the N:P vs. PO<sub>4</sub><sup>2-</sup> concentration relationships similar among the three catchments? I don't agree with that. Line 303 Suggest reword “ In dry season, the N:P ratios were maintained around the annual average” Again these lines read like results and less like discussion. What are the likely mechanisms? Lines 305-307 Very important finding. What is the significance?? That needs to be included here. Lines 313-314. The information stated in sentence starting “However, the surface flow had abundant. . .” is not what is depicted in the conceptual figure. Which is correct? Line 315. Suggest reword by eliminating “most nitrates depleted and adding “is depleted in nitrate” after “the surface runoff,” Line 316. How are ratios diluted? Need to clarify this. Line 318. Not sure if I follow this high N:P during the typhoon events? Wasn't it actually lower? What is the role of the deeper soil water contributions during such events. This is just an example of the need for clarity around the relationship between the findings of this study and the most plausible mechanisms to explain them.

Conclusion. Reads too much like an abstract. In fact there are elements in this section that should be considered for the abstract. Here in this section I noted very important statements on the role of hydrology and the potential role of land use in regulating nutrient export. These should be used in constructing a new organization for the discussion. One really important finding that I think is lost in this discussion and that needs

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to float to the top is the differences in the N:P exported by these smaller catchments (in both value and variation) as compared to larger rivers where these values are so well constrained. Figure 1. Define K1, C2, and Y1 here. Figure 2. Need to include what the solid circles and triangles represent (baseflow vs. typhoon). Nitrate values presented as running means where  $n=5$  (if that is correct need to add to caption as well). Figure 3. Why is log scale used in (d)? Need explanation in caption. Figure 4. Need to include statistics for the least-square linear regression provided. This is a real problem in the paper overall where results of these are not really provided. Figure 5. Same issue as above Figure 7. Define the N:P ratio here along with what the shaded boxes represent (in the caption). Indicate that this is a box-whisker plot and what the "x" and bars refer to. Figure 8. Define N:P ratio here. Figure 9. Need to go over these trends as I found some inconsistencies with the text. For example the little  $\text{NO}_3^-$  and high  $\text{PO}_4^{2-}$  doesn't agree with text. Table 2. These are average values for what period/frequency. Provide n.

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