Hydrol. Earth Syst. Sci. Discuss., 12, C2934–C2940, 2015
www.hydrol-earth-syst-sci-discuss.net/12/C2934/2015/

Hydrology and Earth System Sciences
Discussions
Open Access

Interactive comment on "Effects of mountain agriculture on nutrient cycling at upstream watersheds" *by* T.-C. Lin et al.

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Received and published: 2 August 2015

The authors have carried out a study to examine the effects of agriculture on watershed nutrient cycling in a mountainous area of northern Taiwan. Ion concentrations (NO3-, K+, SO42-, Ca2+, Mg2+) were measured in stream water and precipitation every 2 weeks in four subwatersheds representing a gradient of agricultural activity (0.4% agricultural to 22% agricultural). The authors explore the relationship between agricultural activity and nutrient retention across this gradient.

Although the authors have compiled an interesting dataset and ask interesting questions regarding the impact of agriculture on watershed nutrient cycling, the manuscript is significantly weakened by the lack of a coherent and detailed presentation of

watershed-scale mass balance data. In particular, all discussion of input-output ratios in Section 3.3 is presented out of context, with no discussion of how inputs and outputs are calculated. To make the paper suitable for publication, the authors must work to provide a clear accounting of relevant nutrient inputs and outputs, provided details regarding their methodology in the methods section, and then place their discussion in the context of this quantitative analysis.

Reply:

In the revision we added substantially more information on how we did the calculations of element fluxes. We removed the comparisons of output-input ratio between agriculture and forested watersheds for all elements except N. This is because the inputs for elements other than N and phosphorus (P) are not well understood, and the output of P lacks information on particulate P. Therefore, only N allows for a clear accounting. By providing more details in flux calculations and limiting the analyses to elements with the potential for clear accounting, we believe that the inferences made in the revised manuscript are greatly strengthened from the earlier draft.

Other issues to address:

p. 4786, line 15 Is it a novel finding that a dilution effect would occur when a nonagricultural watershed with low nitrate concentrations is present downstream from a high nitrate-yielding agricultural catchment? You may want to qualify this discussion, saying "As expected: : :" Yes, we have modified the sentence to say "As expected. . ."

p. 4786, lines 18-20 Your estimate of nitrate contributed from agricultural land (400 kg/ha-y) is indeed high, but so are the fertilizer N input values that you give later in the paper. You may find it useful to place this analysis in terms of a NANI-style analysis (see Howarth et al. 2011, Hong et al. 2013, Boyer et al. 2002), where you analyze the relationship between riverine N output and your calculated net N inputs.

Reply:

The suggestion raised by the reviewer is also what we want to present in this study. Indeed, the mass balance approach, like NANI, is a good way to understanding the nitrogen cycling in the watershed. In this revision, we added an equation (equation 1) to quantitatively describe the inputs and outputs. Furthermore, we added information on riverine output ratios and discussed how they might reveal the characteristics of nitrogen retention in our mountainous watershed with tea plantations.

p. 4787, line 6 Can you clarify your point about the impact of agriculture on ecosystem services? Because we did not examine ecosystem services in this study per se, we removed this sentence to give more room to address other issues raised by the reviewers.

p. 4787, lines 10-11 You say that the impacts of agriculture are "likely" exacerbated by steep slopes and high precipitation, but give no references. Can you give more context and literature support to your hypothesis that the impacts of agriculture have unique impacts on the surrounding ecosystem in a mountain environment?

Reply:

We rephrased this sentence with additional citations as follows: "The impacts are likely exacerbated by steep slopes and high precipitations as leaching potential is maximized under such conditions (Brouwer and Powell 1998; Tokuchi et al., 1999)"

0. 4787, line 18 You make the point here about the impact of nutrients on atmospheric deposition. In general, your treatment of the atmospheric deposition portion of the analysis in the paper is weaker than the analysis of stream data. You make the point, for example, that most NH3, for example, is "scavenged by precipitation" and then redeposited. If what is going up (NH4+) simply comes down again, what do we actually learn from this analysis of the deposition data?

Reply:

Although what goes up will eventually come down, different chemicals come down at

different distances, which has management implications at larger spatial scale. For example, SOx and NOx can travel much greater distances than NH4+ which mostly deposited in adjacent ecosystems.

p. 4788, lines 11-12 You refer to heavy use of fertilizers, but don't give a range. The input values are crucial here, so it is important to give real numbers. We added the numbers of fertilizer inputs (425 to 2373 kg N ha-1 yr-1 and 99 to 551 kg P ha-1 yr-1) and added a new citation (Water Resources Agency 2010).

p. 4788, line 21 You say that agriculture will have a negative effect on nutrient retention, but how are you defining this retention? Are you talking about a percent retention or absolute magnitude? And for N, for example, what constitutes retention? If N is being denitrified, is this included in the retention term?

Reply:

Here we focus on the retention of nutrients especially N and P relative (proportional) to inputs so it is a percent retention. In our calculation all input that did not leave the watershed either through streamflow or harvest was considered retained within the watershed. Although denitrification was not included in the calculation (as we did not have the data) we considered denitrified N as a form of output and discussed its influences on N retention in the revised manuscript.

p. 4789, line 20 Again, you say fertilizers are heavily applied, but don't give values. Please quantify.

Reply:

We added the following information in the revision: "..the amount of fertilizer used is assumed to be close to 786 kg N ha-1 yr-1 and 171 kg P ha-1 yr-1, values taken from a case study in which the management practices (e.g. applications of fertilizers and pesticides, time and yield of harvests) were carefully recorded by a farmer in the same region as the current study (Tsai and Tsai, 2008). Although only one farmer was involved in the case study, the values are consistent to those reported by FAO and very close to the mean values across 10 tea plantations in our study area (743 kg N ha-1 yr-1 ranging from 425 to 2373 kg N ha-1 yr-1, and 179 kg P ha-1 yr-1 ranging from 99 to 550 kg P ha-1 yr-1; Water Resources Agency 2010).

Food and Agriculture Organization: Fertilizer use by crop in Taiwan Province of China, Rome, 2002.

p. 4791, line 13 You say that you use a paired t-test to establish whether there is a statistically significant difference between watersheds. Is there a reason that you used a paired test? It seems that an unpaired t-test might be more appropriate here.

Reply:

Because samples were taken weekly in the two locations with close spatial proximity, their precipitation data were likely influenced by the same temporal patterns in the air masses. Therefore, we used a paired t-test to address the shared temporal pattern between the two locations. Nonetheless based on the comment we also did un-paired tests and the results (statistical significance) were basically the same although the p values changed.

p. 4792, section 3.3 This section regarding output-input ratios needs more explanation. You are reporting results regarding these ratios, but there is nothing here that tells the reader how you have obtained these results. You should consider adding a section to Materials and Methods which details the methodology for whatever calculations you have done.

Reply:

We removed the output-input ratios for all elements except N in the revised manuscript. For N, we added more details to the Method to clarify the calculations.

Line 4796, section 4.5 Your calculations here need to be better explained. You say that you subtract nutrient output at F1 from that at A1 to estimate the N and P output from

agriculture at A1, but the logic behind this isn't clear. It would be helpful here to have a table of your calculated inputs and outputs for each watershed.

Reply:

We rephrased the sentence to clarify the logic behind our calculations: "Using nutrient output through streamflow at F2 as the background output from forested watersheds, the per unit area difference in nutrient output between A1 and F2 could be attributed to agriculture at A1." In the revised manuscript we used A1 and F2 for the comparison because we believe this is a more direct comparison as we do not have precipitation data of F1. We also provided a table of inputs and outputs of N and P for A1 and F2 (Table 3).

Line 4800, lines7-10 In your conclusion you describe the effects of agriculture on these mountain watersheds, and conclude that "agriculture activities have a more pervasive impact on watershed nutrient cycling than previously recognized." There is a very large body of literature detailing the impacts of agriculture on watershed nutrient cycling, so this statement seems unwarranted.

Reply:

We rephrased the statement to: "The result illustrates that agriculture activities can have pervasive impacts on watershed nutrient cycling through both streamwater and rainfall, and that mountain watersheds may be particularly vulnerable to agriculture expansion."

p. 4800, lines 19-21 You report that agricultural lands in your study are contributing 400 kg/ha-y N, and comment on the uniqueness of the finding. You don't, however, provide the context for these outputs (very high fertilizer inputs, >700 kg/ha-y). You also don't fully explain how you can estimate rates of P output (260 kg/ha-y) that are more than three times the estimated inputs (75 kg/ha-y). Again, spending more time on developing and explaining your nutrient mass balance for the watershed would strengthen your conclusions. This may also involve explaining the unique fertilizer requirements of a tea plantation and the typically very large fertilizer inputs.

Reply:

We added more details on the derivation of nutrient fluxes in the Method. We also added information on the effect of high fertilizer input on streamwater element output in the discussion. We excluded P from the construction of element fluxes because it was not correctly calculated in our original manuscript. After the recalculation the output was not nearly as large so the discussion on P was removed in the revised manuscript. We added information about over-fertilization on tea plantations by citing a study in Japan (Oh et al. 2006). Oh, K., Kato, T., Li, Z. P., Li, F. Y.: Environmental problems from tea cultivation in Japan and a control measure using calcium cyanamide, Pedosphere, 16(6), 770-777, 2006.

Although the paper is generally well written, there are some problems with grammar that should be corrected. Some examples include: "high precipitations" (p. 4787, line 10) "scarifying socioeconomic benefits" (p. 4787, line 25) "is characterized with high rainfall" (p. 4788, line 10) "without any preserves" (p. 4790, line 27)

Reply:

We changed these to "is characterized by high precipitation", "sacrificing socioeconomic benefits: and "without any preservatives". We also carefully checked through the manuscript for language issues and had an ecologist, Dr. Craig E. Martin, at the University of Kansas proofread the manuscript.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 4785, 2015.