Hydrol. Earth Syst. Sci. Discuss., 12, C2381–C2388, 2015
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Hydrology and Earth System Sciences
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Discussions



# *Interactive comment on* "Long-term effects of climate and land cover change on freshwater provision in the tropical Andes" *by* A. Molina et al.

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Received and published: 3 July 2015

### General Comments ###

This paper provides an analysis of the relationship between vegetation cover and streamflow in the tropical Andean Pangor catchment, which has experienced a unique land conversion trajectory that includes conversion of natural vegetation to agriculture as well as exotic afforestation. The authors use long-term hydroclimate data and a data-adaptive time series decomposition technique to evaluate trends in hydroclimate data relative to the land use change trajectory. The timing in hydroclimate trends is paired with timing in land conversion to infer impacts of land cover change on the water budget of the catchment. I appreciate the data-based (not modeling) focus of the



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analysis, as well as the analysis of 'real' (instead of extreme experimental) land use change. The complexity of the analysis methods is appropriately suited to the data used.

Overall, I greatly enjoyed reading this paper! Most of the comments below make suggestions that are intended to aid in clarifying explanations of the methods and results. The abstract needs some work to provide clarity on the study design and data. By the end of the Introduction and Methods sections, I'm still not entirely clear on the focus of the analyses - what questions are asked and answered, and which methods are used for specific parts of the analysis. This becomes clear in the Results section, where the headers point out that the analysis is two-fold: analysis of land use change, and then analysis of hydroclimate trends. The descriptions of the methods used are mostly clear, but I lacked that guiding framework/outline of the analysis when reading them. The Methods section in particular could be clarified with improved introductory sentences for each paragraph. Detailed comments below.

### Specific Comments ###

Page 5221, Line 3-5: This paragraph could be supplemented with additional literature.

Page 5221, Line 15 and 26: The citations following these statements could be supplemented with additional and/or more recent literature.

Page 5225, Line 10-11: Can you state why it is necessary to gap-fill the data?

Page 5225, Line 19-21: By the "observed relationship" do you mean a linear relationship, or something else?

Page 5225, Line 26: Can you state how you did this (like in the caption for Table 3)?

Page 5226, Line 11: Can you state here briefly that you can neglect change in storage at annual time scales in this region (you provide a discussion of this on Page 5228, but would be nice to mention it here.)



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Page 5226, Line 20: Consider adding "at annual time scales." to the end of this sentence, and then describe how the annual time scale quality check relates to the usability of the data at monthly time scales (the time scale at which you decompose the data).

Page 5227, Line 14-23: This paragraph could be written more clearly, and the first sentence could be rewritten to summarize it's purpose. Is this paragraph intended to summarize the EEMD procedure, or to describe processes additional to the EEMD that are specific to this analysis? I remain confused about what the "non-significant trends" (Line 15) actually are (assuming simulated P and WD), or if you are saying the process described is the means by which the significance of P and WD trends is evaluated. It remains unclear in what capacity the actual P and WD data are used, and in what capacity simulations/samples of those data are used.

Page 5227, Line 17: With respect to "were randomly distributed" - does this mean the monthly values "are" randomly distributed according to some test, or does this mean that a random sample was generated using statistics of the monthly data (I'm assuming the latter)? If so, using samples from what distribution, or simply by randomly sampling the empirical distribution (the data)?

Page 5227, Line 20: what type of "perturbation" - Gaussian white noise?

Page 5228, Line 13-23: The purpose of the explained procedure is not entirely clear and could be improved. Why was a chi-squared test used, and why is it necessary for establishing the partial water balance, or is this related to another component of the analysis?

Page 5228, Line 19-20: "reconstructed based on linear interpolation of existing land cover distributions" - is there precedent for this method, any references where this method was also used?

Page 5231, Line 4-10: The reporting of these very interesting findings and their significance could be improved. Perhaps it would be appropriate to change "climate change"



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(Line 5, and also the Abstract at Page 5234 Line 8, and title) to "precipitation change" because climate is not fully accounted for in this analysis; solar radiation and/or temperature data are not used. ET change (and therefore flow change) result from a combination of energy/temperature variability and vegetation cover - only vegetation cover is discussed. Additionally, from Figure 6, it is clear that the decomposed rainfall trend moves gradually upwards while the flow trend moves gradually downwards over the same time period - and that these changes correspond to a snapshot record of land cover over a long period of time. Stronger statements might not be warranted unless further discussion is provided. The use of the words "remarkable decrease", "increased sharply", and "decreased notably" either do not represent the findings according to Fig. 6, or obscure reporting of the nature and significance of the findings. Is there a quantitative measure of the significance in the trend change for both? Do you have any information on the degree to which measurement error does or does not affect interpretation of the trend or its significance?

Page 5232, Line 4-5: re-state some numbers from Table 3 instead of saying "major".

Line 9-12: this statement seems strong ("as a result of [land change]") given that no energy or temperature data was used in the analysis - same comment as above.

Page 5233, Line 16-18: citation for this, or is this a finding from this study?

Page 5233, Line 25-27: Is this referring to Figure 8 instead of Figure 7 (where peak mean monthly flows are the same between periods, but peak baseflow is different)? Are you attributing the increased flashiness to reduced soil water infiltration, or just proposing that reduced infiltration as a possible cause? It doesn't seem like enough evidence is provided to say that the flashiness is from reduced infiltration - increased rainfall could induce surface runoff in the period during which you also saw land use change, even if soil infiltration remained the same.

### Technical Corrections ###



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# Abstract

Page 5220, Line 1: "role to supply" is awkward. Suggestion: "Andean headwater catchments are an important source of fresh water for downstream water users."

Page 5220, Line 3: Suggestion for clarity: add "in these catchments." on the end of the sentence ending in "flow regimes."

Page 5220, Line 5: "freshwater provision" is vague. Does this term refer to provision of water to downstream users, or does it refer to in-stream flow?

Page 5220, Line 6: Is time period listed for the hydrometeorological data (1974-2008) also the same as the "multi-decadal" period of the study? This might be assumed, but it's not stated.

Page 5220, Line 6-7: include the name of the basin in the abstract.

Page 5220, Lines 7-11: With respect to the list of land cover change trajectories: do these changes refer to net change over the study period, or end-year change relative to a baseline year, or some other specification? It would help to include this information in or directly after the previous sentence.

Page 5220, Line 8-9: the use of "∼" is potentially confusing. If it means approximately, use "approximately" instead. Additionally, 'decline' is an unclear category relative to the other categories; consider "transition of native vegetation to another land cover type". Lastly, define/describe páramo.

Page 5220, Line 9: The meaning of (2) is unclear. Does this mean that agricultural land increased by an area equal to 14% of the basin area?

Page 5220, Line 15: use ", which" instead of "that"

Page 5220, Line 16-17: it is not clear if this sentence means that flow changes likely result 'from direct anthropogenic disturbances evident in land cover change', or literally - from anthropogenic disturbances that occur "after land cover change" (meaning the



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disturbances are different from the land cover change itself)? (This comment also applies to the Conclusion - Page 5234, Line 10)

Page 5220, Line 19: colonization by what? does this refer to the land use change trajectory (1) or (2)? If so, it would help to use similar language.

# Introduction

Page 5220, Line 22: same comment as Line 1.

Page 5221, Line 2: "has" instead of "have"

Page 5221, Line 4-5: does "demographic" just mean "population"? If so, use "population". The meanings of "internal and external migration" and "land reform programs" are unclear. Can you provide brief additional descriptions of these?

Page 5222, Line 14: does "commonly associated to" mean "commonly associated with" or "commonly attributed to" instead?

Page 5222, Line 25: change to "of the Ecuadorian Andes" (added "the")

Page 5222, Line 25: combined present tense ("is rapid") and past tense ("resulted in") reads awkwardly. Additionally, by what standard is this rapid? a 20% change over 46 years might not be considered rapid. (Same comment on use of rapid in Page 5223, Line 20.)

# Regional Setting

Page 5223, Line 1: delete "at"

# Materials and Methods

Page 5225, Line 5-6: the statement following the semicolon needs to be a complete sentence, consider "...; daily streamflow data was obtained from the Pangor AJ Chimbo gauging station (Fig. 1)"

Page 5225, Line 12: is "either" correct? Mora and Willems (2012) says both are esti-



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mated.

Page 5226, Line 2: "aggregated to monthly" (replace "at")

Page 5226, Line 23: "was used" instead of "was here used"

Page 5226, Line 27: "until" instead of "till"

Page 5227, Line 16-17: "used" instead of "here proposed".

Page 5228, Line 8: delete "here" (in general, "here" is used frequently in this context throughout the paper, and it's not necessary)

Page 5228, Line 10: what is meant by "narrow(ing)" - does this imply that the cloud forest is narrowing over the time of the study and this means something for interception? If it doesn't have anything to do with the interception assumption, maybe delete.

Page 5228, Line 18: "the partial" (add "the")

Page 5229, Line 11-12: This is already stated in a previous section, delete. And, include the subsequent sentence (Line 13-14) in the first mention of the definition of P and WD, and delete here.

# Results

Page 5230, Line 3-4: Same question as before: expansion equal to 14% of basin area, or 14% of previous agricultural land?

Page 5230, Line 3-6: Aside from the question above, this summary (and the rest of the paragraph) is much clearer than what is provided in the abstract - consider using this wording in the abstract instead.

Page 5230, Line 23 - Page 5231, Line 2. These two sentences ("Given" to "trend") belong (also) in the Methods section. They're very clear, and motivate and introduce the use of EEMD. There's also a period missing after "(Fig. 5)".

Page 5231, Line 10: insert "in streamflow and baseflow" between "change" and "de-



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creased", otherwise it could be misinterpreted as referring to rainfall.

Page 5231, Line 28: "contributed" should be "attributed".

# Figures

Figure 1: Make symbols, map inset, and labels all larger.

Figure 3: Make the river line larger and/or a different color because it's hard to see.

Figure 7: Include the time scale of the WD values (daily) in the caption.

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Cheers!

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 5219, 2015.