

Interactive comment on “Towards quantifying the increase of rainfall interception during secondary forest succession” by B. Zimmermann et al.

Anonymous Referee #2

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This is an important, well-written, and timely paper on the hydrologic impacts of tropical forest succession, an increasingly important land-change pathway, and one for which there is currently limited hydrologic understanding. Zimmermann et al. use throughfall measurements coupled with forest inventory data and a variety of statistical approaches to explore the effects of forest structure on rainfall interception across a fragmented forest landscape in lowland Panama. Two significant results emerge from their analysis.

First, the authors show that rainfall interception values differ between young and old forests only within the first 10 years of forest regeneration. This finding establishes a benchmark for the time changes in canopy interception can be expected to persist following secondary forest succession. Moreover, this time frame is shorter than what

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has been determined in other studies. For example, in Mexico, measured interception losses were 8% in a ~20-year-old tropical forest compared to 16% in a mature forest (Holwerda et al. 2010), suggesting that in this montane environment changes in canopy interception occur more slowly than in lowland Panama. In their paper, the authors also suggest that effects of secondary succession on streamflow generation are likely to be greatest during early successional stages due to the combined influence of change in canopy interception and altered soil permeability. Research on tree plantation impacts on water yield has also shown that these are greatest during the early stages (first 20 years) of plantation development (Farley et al. 2005). These examples demonstrate how the information provided by Zimmermann et al. enables comparisons of forest hydrologic cycling among study regions and also distinct forest transitions.

Second, a relatively simple regression approach and a novel index of canopy structure, basal area ratio, were sufficient to predict relative throughfall rates across the study area. Although the accuracy of the predictions was not optimal, determining such relationships is crucial for modeling forest hydrologic processes at landscape scales. Understanding the mechanisms that underlie landscape-scale variation in water input to soil is also key for predicting nutrient fluxes to the forest floor and thus of importance in studies of forest biogeochemistry.

Specific comments

In a future study, it would be interesting to compare data derived from hemispherical photos and a LiCOR Plant Canopy Analyzer as the latter might provide a more accurate measure of canopy structure (Moser et al. 2007), and hence improved throughfall predictions.

The authors mention that this forest is semi-deciduous. It would be interesting to consider how changes in phenology over the course of a year influence estimated interception losses at both plot and landscape scales. Here, one might expect species composition to influence interception loss.

Technical Corrections

Title: I suggest the authors consider changing the title. I think the manuscript does more than what the title suggests (i.e., quantifying the increase in rainfall interception). A few possible titles are “Forest structure influence on rainfall interception along a secondary succession gradient in lowland Panama” or “Changes in rainfall interception (or throughfall) along a secondary succession gradient in a tropical forest region of Panama.”

Abstract Line 1 - Include a hyphen in “Large-scale”. Line 2 - “land-cover dynamics” Make sure to hyphenate two words that make a single descriptor (e.g., land-cover change or land-cover dynamics, or large-scale growth etcetera. . .) unless one of the words is an adverb (e.g., highly motivated). Line 3 - “the relationship between forest” Line 9 - “Regrowing” is redundant and “natural” is unnecessary. Edit and use past tense “The investigated gradient comprised 20 forest patches 3 to 130 years old”. Line 11 - “two-month period in 2011 that had . . .” Line 11 - “We acquired forest inventory data collected in 2011? and derived forest structural attributes for the sampled locations”. I am not sure what “the same time” refers to. Were the data collected during the two-month sample period or during the year in which data were collected? Line 14 - “the vegetation parameters that had the strongest influence on the variation in canopy interception” Line 15 - “Our analyses yielded three main findings” Line 23 - “Our results suggest that where entire catchments are undergoing forest regrowth, initial stages of succession . . .”. Can you be a bit more specific here. What does undesirable effects mean? Do you mean that the initial stages of succession may result in substantial decreases in streamflow generation due to associated interception losses? Line 25 - “We further highlight the need to study changes in hydrology? Interception? throughfall? during all stages of forest succession.”

Introduction - page 8001 Line 1 - Delete “proportions” Line 3 - “rural-to-urban” Line 6 - Change “spreading” to “expanding” Line 7 - “In addition, there is evidence that” Line 10 - “Most often, regrowing forests are found alongside. . . and thus they are part of”

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Line 16 - Do not use “original” as this would be hard to ascertain. Instead use “mature” Line 17 - “secondary forest hydrology” and “former agricultural areas” Line 20 - “rate of mature forests” and “the high rainfall interception storage Line 25 - “rainfall interception in forest hydrology, reliable”

Page 8002 Line 1 - A definition of recovery time would be good here as you use this term throughout the paper. . . In fact, I wonder if forest age wouldn't be clearer? Line 1 - Delete successional trajectories” “that influence forest structure and composition” Line 1 - “For instance, regrowth stage”, “the composition of the regrowing forest” (e.g., invasive versus native plants) Line 3 - “e.g., pasture versus “shifting cultivation”. Slash-and-burn has a negative connotation in the social sciences whereas shifting cultivation does not. Line 7 - Cut “it should be evident” and “forests of different ages and . . . age class are needed to describe” Line 9 - From here forward, edit “change in interception” rather than “change of interception Line 10. Cut “it would thus be desirable if we could” and begin “Ideally, forest inventory data could be used to predict the change IN interception Line 15 - “relate canopy interception to secondary forest succession?” or rather to “forest structure along a secondary succession gradient” Line 17 “forest structural” Line 23 - Cut “At the end of the article”

Page 8003 Line 1 - “loss along” Line 5 - Delete “a”, “have steep”. Line 6 - Delete “a”, “with high drainage densities”. Line 7 - “mainland” one word. Line 7 “after the Chagres River was dammed to form Lake Gatun” Line 10 - Delete “the”. “to Soberanía National Park” Line 16 - “Data courtesy of” Line 17 - “. . . Republic of Panama). Mean daily temperature. . .” Line 20 - Break into 2 sentences. This vegetation type covers all of BCI. Line 22 - forests in varying stages of recovery Line 25 - “For our study, we”

Page 8004 “Sampling design? Rather than scheme? Line 3 - “to forest structure using a regression-type” Line 5 - “we optimized site selection by 5 spreading the range of succession stages as far as possible and by sampling the distribution of potentially important predictor variables as evenly as possible”. This sentence is unclear. Perhaps you can cut this sentence and combine with the following sentence, which is very clear.

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My suggestion is to rewrite as follows: “we optimized site selection by including very young forests (i.e., 3 yrs old) as well as sites in the mature secondary forest of BCI. We chose. . .” Line 15 – Why did plot sizes differ? Line 20 – “of our forest plots through interviews” Line 22 – “in the stage of forest succession” Line 23 – “(e.g., by cattle treading) Line 24 – “downslope” Line 25 – Delete “of course”. How does streamside influence secondary succession? Does it speed it up, slow it down? By encouraging dispersal, for example? Line 25 – “For this reason, recovery time is considered . . . and is not used”

Page 8005 Line 5 – Delete “of all stems” “species with a dbh. . .” Line 7 – “Delete “the same was done”. “In every other quadrant, individuals with dbh . . . were identified and measured”. Line 13 – “2-L” Line 17 – “between each throughfall and the closest rainfall site” Line 18 “760 m maximum”. Line 23 – “decline in canopy openness” Line 26 – “size of 36 collectors” Line 26 – “collector surface area of 113 . . .” Line 28 – “limits of estimated mean”

Page 8006 Line 10 – “Data from the other. . .” Line 12 – “Stemflow measured at” Line 14 – “report similarly low” Delete “of”; “Calculation of relative throughfall and interception loss” Line 19 – Delete “First”. “At each site, we added measured throughfall and rainfall values over the entire measurement period. I suggest you delete “to obtain long-term data (i.e. throughfall and rainfall during several months)”. Line 21 – “we calculate relative..”

Page 8007 Lines 3-5 – You compared throughfall to the nearest rainfall site both at BCI and ASP, and this makes sense, hence I wonder if this text is necessary. Line 7 – “forest inventory data” Line 9-10 – “abbreviated with BA1 etcetera. This is awkward and perhaps not necessary here but rather in the table? Line 10 – “For dbh-class 2, we had. . .for all plots. Therefore, we calculated. . .” Line 11 – “hereafter diversity” Line 12 – no hyphen with dbh-classes Line 13 – “we defined as the ratio” Line 15 – I think it is important here to include a sentence here, which explains how basal area of the smaller trees is related to that of canopy trees given its importance in the study. Line

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19 – Cut “The” before openness. Line 21 – “most strongly” instead of “strongest” Line 25 – “rough terrain” and “We derived these”

Page 8008 Line 14 - “was designed to examine whether the inclusion” Line 15 – “would improve predictive” Line 16 – “parameters was best suited to” Line 20 – “on a weighted average of all of them”

Page 8009 Line 23 – “summarize, for example, with the posterior mean and standard deviation”

Page 8010 Line 2 – “age-class dependent” Line 3 – cut “finally” Line 5 – “throughfall across different age” Line 6 – “data for the years” Line 8 – “year, which we” Line 9 – “landscape-scale estimates” Line 9 – “relative throughfall input to the secondary forests” Line 17 – “to a maximum” Line 21 – Cut “natural” Line 23 – “had a low skewness” Line 24 – “showed a skewness . . . due to the influence of single. . .”

Page 8011 Line 8 – Cut “at all” Line 17 – “models using the variables most strongly related to relative throughfall as predictors” Line 21 - “Using the BAratio as an explanatory. . .”

Page 8012 Line 2 - “also in multivariate space: it has” Line 5 – “In addition, in almost all models, the BA ratio is positively. . .” Line 8 – “over the course of forest” Line 23 – “to predict relative throughfall at the landscape scale. In a first step, . . .”

Page 8013 Line 3 – “a next step, . . . throughfall input to all secondary. . .” Please fix “changes of canopy interception” to “Changes in canopy interception” throughout. Line 13 – “after land abandonment” Line 15 – “early succession as is reflected . . .” Line 16 - “increase in basal area” “decrease in the ratio of . . .” and so forth. Line 19 – For clarity, I suggest rewriting the sentence as follows. “The large scatter in relative throughfall amounts within a given period (Table 1, Fig. 4a) reflects the tremendous spatial variation in forest structure, and the underlying factors that influence secondary forest regrowth, including the intensity of past land use, landscape features, and nu-

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trient availability (Guariguata and Ostertag, 2001; Hölscher et al., 2005). Line 23 – “two important implications?” rather than consequences? Line 25 – “interception at landscape scales” Line 26 – “forests . . . early successional stages”

Page 8014 Line 14 – “are likely difficult to detect.” Line 19 – “succession was less efficient” Line 21 – “to relate more strongly to the development of canopy structure during forest succession” Line 27 – “its potential to explain . . . amounts and longer-term data”.

Page 8015 Line 10 – Are you suggesting that empirical relationships should not be used? If so, I am not sure I agree that interception modeling alone is the way forward. Line 18 – “for predicting interception”. You may consider citing Weathers et al. 2006 who have similarly suggested the potential application of LiDAR for capturing fine-scale variability in throughfall deposition. Line 19 – “exhaustive?” Do you mean it has good spatial coverage? Also, hyphenate here “landscape-scale”.

Page 8016 Line 3 – “during tropical? Forest succession” Line 5 – “mature tropical forests” Line 9 – “are often correlated with . . .” Line 12 – “collinearity, and, hence, . . .” Line 13 – “to model canopy interception than multiple regression” Line 14 – “small and large stem basal area, . . . predictions in this study”

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 7999, 2013.

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