Anonymous Referee #1
Received and published: 25 July 2017

The manuscript deals with the effect of land cover and/or land use on a watershed response functioning. The authors investigated the influence of forest and monoculture plantations (oil palm and rubber plantations) on rainfall partitioning to direct runoff and subsurface flow for a humid tropical watershed in Indonesia. The results are based on streamflow as simulated by a calibrated SWAT model and observations across several watersheds and subsequently derived the direct runoff coefficient (C) and the baseflow index (BFI). The study exhibits a statistically significant correlation of percentage of forest covers in a watershed with C (negatively) and BFI (positively). On the other hand, the rubber and oil palm plantations showed flow regulation behavior contrary to forest covers. Finally the study suggests the minimum forest cover requirement in the study area (i.e. 30%) for sustainable ecosystem services. The topic is of current scientific interest and several studies have also investigated previously.

However, the manuscript requires a substantial improvement of the methodology and, results and discussion to be publishable. Furthermore, the manuscript would benefit a lot with the inclusion of more discussions in the introduction section from previous similar studies in the tropical regions.

General comments

1. Given the previous several studies on the effect of land cover/use conversion on the hydrology of a watershed, the introductory section needs further literature review in this regard. It should also highlight the new contribution of this manuscript.

We appreciate the referee's suggestions, and have added more literature review on the effect of land cover/use conversion on the hydrology of a watershed in the introductory section. (Line 104-114) and highlight the new contribution of this manuscript (Line 119-124)

2. I think the organization of the methods section, in general, requires restructuring and further information. For example, there is no section that describes the general SWAT model and the SWAT model for the study area, which are important for general readers and non-SWAT users.

We agree with the referee's suggestions, and have re-structured the method section as follows:

2. Methods
2.1 Study area
2.2. SWAT model
2.2.1 Model setup
Crop parameters
a) Interception
b) ET
c) Infiltration and surface runoff
d) Litter fall
General Input data
2.2.2 Model validation and calibration
2.3 Simulated C and BFI values and the proportion of land use types in a watershed
2.4 Observed C values

The general SWAT model is described in Line 163- 182 and the SWAT model for the study area in Line 183-282

3. Section 3.2 and section 3.3 should be presented before section 3.1. Logically thinking, observation based model evaluations should be presented first and then results of analyses based on the model simulation.

We agree with the referee's suggestions, and have re-structured the discussion section as follows:

3. Results and Discussion

3.1 Measured C values (Line 331)
3.2 SWAT model Performance (Line 344)
3.3 Simulated C and BFI values (Line 362)

4. No information is provided in the manuscript about the SWAT parameters, particularly the ones that control the surface runoff and the baseflow process. I think information about some of the sensitive parameters would give a good discussion points on the flow regulation behavior of different Landover/use in the study area. What was your observation on the calibrated SWAT parameters such as CN2, SOL_AWC, ALPHA_BF and CANMX among other?

We agree with the referee's suggestions, and have added detail information about mentioned SWAT parameters (Line 189-257).

5. The calibration and validation strategy are not clearly stated, albeit its importance in interpreting simulation outputs from SWAT. The calibration and validation period need to be explicitly stated. Which automatic calibration algorithm was used in SWAT-CUP? It is also essential use multiple evaluation criteria.

We agree with the referee's suggestions, and have described in detail the calibration and validation strategy and period (Line 283-305)

6. I encourage the authors to explicitly discuss the SWAT model simulation results are mainly arising due to changes in land cover not by wrong parameterization. SWAT is a highly parameterized model, therefore we might get the expected patterns for the wrong reason. This could be addressed by referring the calibrated SWAT parameters.

We appreciate very much the referee's concerns, and have explicitly discussed the SWAT model simulation to ensure that the results are mainly arising due to changes in land cover not by wrong parameterization. (Line 176-262).

Specific comments

1) Lines 1-2: I suggest to check the title. i) Since it is an application in tropical region in Indonesia, it needs to be specific. ii) It seems to me some action words are missing. You could simply add, for instance, "requirement" that reads as "Minimum forest cover requirement for sustainable water flow regulation: A case study in a watershed under rapid expansion of oil palm and rubber plantations in Indonesia"

We appreciate the referee's suggestion. The title has been adjusted.

2) Lines 9-32: The abstract could be shortened to a certain extent by reducing the seemingly redundant sentences on flow regulation functioning and benefits, keep the most important points only.

We agree with the referee's suggestions, and have improved the abstract accordingly (Line 11-34).

3) Lines 14-15: It is a bit confusing sentence, please improve the language.

The referee appears to be correct. We have removed the confusing sentence from the abstract.

4) Line 40 " Lele, 200" please add 0 (

We thank the referee for the correction (Line 76)

5) Line 40 "Functional water flow regulation reduces flood peaks by moderating direct runoff." It would be nice to add some references here.

We have provided the relevant reference (Line 77)

6) Line: 46:"base flow" remove space

Revision made; we inserted the space (Line 80)

7) Line 46: ")]" remove the square bracket

Revision made; we removed the square bracket (Line 80)

8) Lines: 69-71: Please improve the language

We thank the referee for pointing this out; we have improved the language Line 70-72.

9) Lines 72-73: Improve the language, for instance, "Distributed hydrologic models such as the Soil and Water Assessment Tool (SWAT) are useful to understand the effects of land use changes on watershed flow regulation: : :: : :."

We thank the referee for pointing this out; we adapted the sentences suggested by the referees. (Line 97-98)

10) Lines 104-105: ": : :: : : is the direct runoff ratio of to rainfall." should be "is the ratio of direct runoff to rainfall"

We thank the referee for the correction. We have revised the sentence (Lines 164)

11) Line 88: Please add the size of the study area and perhaps the location coordinates.

We have added the size of the study area (Line 140) and the location coordinates (Line 127).

12) Lines 88-93: It would be informative to add information on the historical land cover change in the study area.

We thank the referee for the suggestion. We have added more information on the historical land cover change in the study area. (Line 128-137).

13) Lines 94-98. I think the methodology description should not be included in study site description. I suggest to move this part to appropriate subsection in the methodology.

We thank the referee for the suggestion. We have removed this part.

14) Line 99: Replace "&" with and

Revision made; we replaced "&" with "and" (Line 306)

15) Line 101: "C & BFI" it should be "C and BFI" like in the abstract section and it should be consistent throughout the manuscript.

Revision made; we replaced "&" with "and"

16) Lines 102-104: Please improve the language. And it is somewhat similar with Lines 109-110

We thank the referee for pointing this out; we have removed the duplication.

17) Lines 104-109: This is confusing! This describes the general SWAT model and I would rather expect a separate subsection for it. This should also tell how SWAT computes surface runoff, baseflow: : :...See the comments in the general comment.

We thank the referee for the suggestion. We have added subsection 2.2 under which we have described the general SWAT model and the model setup (Line 163- 282)

18) Line 114: I would prefer the areas in km2.

Revision made; we have replaced "ha" with "km^2" (Line 140)

19) Line 118-121: Describes the SWAT model setup for the study area. Therefore, I would expect to get this information before describing section 2.2 (Simulated C and BFI) values.

We thank the referee for the suggestion. We have described the SWAT model setup in sub-section 2.2.1 (Line 183)

20) Line 122: Add SWAT-CUP reference

Revision made; we have added the SWAT-CUP reference (Line 289-290)

21) Lines 121-129: This part tries to elaborate the model calibration and evaluation part. SWAT-CUP provides several options for model calibration, which one did you use in this study? Please be specific. When is your calibration and validation periods? I suggest separate subsection for model calibration and evaluation approach.

We thank the referee for pointing this out. We have elaborated the model calibration and validation in subsection 2.2.2 (Line 283).

22) Line 128: As demonstrated in several studies, NSE is sensitive to peak flows. You calibrated and evaluated your model using only NSE. How do you justify this? I think it would be good to add a few more performance indices in the evaluation so that the reader would have a better feel on the reliability of the model simulation outputs.

We thank the referee for the suggestion. We have added one more indices, i.e. Percent bias (PBIAS) for the evaluation. Percent bias measures the average tendency of the simulated data to be larger or smaller than the observations. The optimum value is zero, where low magnitude values indicate better simulations. Positive values of

PBIAS indicate model underestimation and negative values indicate model over estimation (Line 296-305)

23) Line 130: Again "&" remove throughout the manuscript.

Correction made

24) Line 158 "didn't" should be "did not"

Correction made

25)Lines 162-163 repetition see line 121

We thank the referee for pointing this out. We have removed the repetition

26)Line 163-164: Add more statistics

Revision made; we have added more statistics, namely percent bias (PBIAS). The PBIAS measures the average tendency of the simulated data to be larger or smaller than the observations. The optimum value is zero, and low magnitude values indicate better simulations. Positive values of PBIAS indicate model underestimation and negative values indicate model overestimation. (Line 296-305)

27)Lines 165-167: what did you obtain from the comparison? How much they agree? What statistical measures did you use?

We thank the referee for pointing this out. We explained the comparison in Line 333-336. It was just a simple arithmetic comparison.

28)Lines 168-173: More suitable in the methodology section.

We agree with the referee suggestion. We have moved the sentences to the methods section (Line 310-314)

29)Lines 180-184 Too long sentence, it is better to follow simple sentences. Improve the language as well.

Revision made. We have improved the language (Line 367-369)

30)Line 182: Oil palm harvest and oil palm circle are equal (i.e. 3 cm h-1).

Revision made. We have improved the language

31)Lines 185-188: I'm puzzled by this conclusion. Is the rainfall distribution similar throughout the basin? Because if there is a spatial variation in rainfall magnitude, the effects of forest conversion on the flow regulation would vary accordingly.

We thank the referee for raising this question. We agree that there is always spatial variation in rainfall magnitude throughout the basin from one event to another event. Both watersheds in our study were partitioned into 48 sub-watershed, which reduce the degree of rainfall spatial variability in the watersheds.

32)In Figure 4a, I see a C value less than 0.35 for forest cover about 20%, what do you think about this?

We thank the referee for raising this question. We have explained the reason in Line 370-373.

33)Line 207: please improve the language

We have omitted this particular paragraph due to the lack of field sample data to construct the graph statistically sufficient.

34)Lines 207-214. I think this need more discussion. SWAT has a known limitations in simulating the low flow regime and that would have an effect on the BFI, as also mentioned by the authors. See the recent study for further discussion: Pfannerstill, M., B. Guse, and N. Fohrer, 2014a. A Multi-Storage Groundwater Concept for the SWAT Model to Emphasize Non- linear Groundwater Dynamics in Lowland Catchments. Hydro- logical Processes 28:5599-5612, DOI: 10.1002/hyp.10062

We agree with the referee, the SWAT version used in this study has limitation to model the groundwater component of the streamflow. We have enriched the discussion on BFI with the suggested literature (Line 395-401).

35)Line 344: ": : :MT(b,: : :"

Revision made. We thank you the referee for the correction

36)Line 376: Table 3, In MT watershed sub.wat.nr 23 has a 100% forest cover but the BFI is low, meaning low baseflow contribution from the groundwater. Justify this in the discussion.

We thank the referee for raising this question. We have explained the reason in Line 373-377

37)Line 379 Table 4, Please recheck the numbers and the calculations.

We have re-checked and corrected the errors. The total average of the C values of 0.59 remains unaffected.

Anonymous Referee #2

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General comments:
I found the topic and results described in this manuscript to be quite interesting. There is very limited information available in the literature to date regarding the potential effects of expanded production of rubber or oil palm trees, using SWAT model or any other modeling approach. Thus I think that the information reported in this manuscript will ultimately prove to be a useful contribution to Hydrology and Earth System Sciences (HESS) and the existing literature in general. However, I believe that the current manuscript suffers from several deficiencies including inadequate review of existing literature, insufficient description of SWAT and key input parameters (including coefficients used for rubber tree and oil palm tree in the crop parameter file), lack of in-depth description of SWAT calibration and validation results, and an inadequate description of the simulated watersheds. Specific comments regarding these issues are provided below.

We appreciate the referee's concerns. We have addressed all referees' concern in the respective comments below including: a) more comprehensive review of existing literature, b) in depth description of key crop parameters and c) adequate description of the simulated watersheds

Specific comments

1) Abstract: The Abstract needs to be considerably revised to reflect more of the actual quantitative results of the study versus the "general discussion" that dominates much of the abstract between lines 9 to 24. The revised abstract should include a summary of the baseline calibration and validation results.

We agree with the referee's suggestions. We have shortened the "general discussion". We have also included more quantitative results (Line 28) and summary of the baseline calibration and validation results (Line 23-25).

2) Lines 43-45: I would suggest you rewrite this sentence to read something like: "This vertical movement of water in the soil determines how much water flows as direct runoff and how much percolates to the water table where it sustains baseflow or groundwater (references)."

We agree with the referee's suggestions, and have revised the sentence (Line 79-81).

3) Lines 49-68: Please include citation and discussion of some "big picture" studies regarding the impacts of Palm Oil and/or Rubber Trees in the southeast Asia region such as those listed immediately below.

We thank the referee for this suggestion. We have substantially enriched the citation and discussion of some studies regarding the impacts of palm oil and/or rubber trees in the Southeast Asia region (Line 46-64).

4) Lines 69-70: Please expand this discussion to provide a broader review of different modeling and other analysis methods, beyond the option of SWAT, available to assess the impacts of expanded rubber and oil palm plantations in the Southeast Asia region.

We thank the referee for this suggestion, and have expanded the discussion to provide a broader review of different modeling and other analysis methods, beyond the option of SWAT (Line 84-96).

5) The expanded paragraph noted in comment 3 should be followed by a specific paragraph about SWAT including relevant review studies about SWAT and a more in-depth review of how SWAT has been used for land use change analyses. Note that the Zhang et al. (2013) article you cite in line 76 is not a very good choice regarding reviews of SWAT studies; please instead cite one or more of the studies listed on the webpage at http://swat.tamu.edu/publications/special-issues/ or in the "SWAT Publications box" in http://swat.tamu.edu/. Please also cite some relevant SWAT "land use change studies" (see the SWAT Literature Database that can again be accessed on the SWAT model homepage) such as those listed here:

Babel, M.S., B. Shrestha and S.R. Perret. 2011. Hydrological impact of biofuel production: A case study of the Khlong Phlo Watershed in Thailand. Agricultural Water Management. 101(1): 8-26. DOI: 10.1016/j.agwat.2011.08.019.

Marhaento et al. 2017. Attribution of changes in the water balance of a tropical catchment to land use change using the SWAT model. Hydrological Processes. 31(11):2029–2040. DOI: 10.1002/hyp.11167.

Tan et al. 2015. Impacts of land-use and climate variability on hydrological components in the Johor River basin, Malaysia. Hydrological Sciences Journal. 60(5): 873-889. DOI: 10.1080/02626667.2014.967246.

Tarigan et al. 2016. Mitigation options for improving the ecosystem function of water flow regulation in a watershed with rapid expansion of oil palm plantations. Sustainability of Water Quality and Ecology . 8: 4-13. DOI: 10.1016/j.swaqe.2016.05.001.

Wangpimool et al. 2017. The impact of Para rubber expansion on streamflow and other water balance components of the Nam Loei River Basin, Thailand. Water. 9(1) DOI: 10.3390/w9010001.

We thank you the referee for suggestions. We have added specific paragraph about SWAT and a more in-depth review of how SWAT has been used for land use change analyses (Line 103-115).

6) Lines 71-73: These two current sentences have grammatical problems. As a part of comment 4, I suggest that you revise the text as follows: "A useful tool to answer this question is the Soil and Water Assessment Tool (SWAT) ecohydrological model (Arnold et al., 1998; 2012), which quantifies the water balance of a watershed on a daily basis (Neitsch et al., 2009) and has been recommended for the evaluation of hydrological ecosystem services of a watershed (Vigerstol et al., 2011)."

We agree with the referee's suggestions, and have improved the sentences accordingly (97-103).

7) Study area description: The two study watersheds should be described in depth in this subsection rather than being referenced later in subsection 2.2 (please describe the area of the watersheds in km2 rather than ha). More detailed land use information (percentages of each type of land use) for the two watersheds should be provided (rather than waiting until subsections 2.3.1 and 3.2 to describe some of that information), as well as more information about the natural vegetation, and rubber and oil palm plantations (growth cycles, management practices, time period of plantation development, etc.). Further details about the typical porosity and other characteristics of the soils in the study watersheds would also be useful.

We thank the referee for the suggestion. We have re-restructured and substantially improved the description of the whole subsections in the method section. We have described in depth the study watersheds and land use information (Line 127-148), more information about the natural vegetation, and rubber and oil palm plantations (Line 152-162) and characteristics of the soils (Line 142-143).

8) In relation to comment 7, some description of all six macro watersheds shown in Figure 1 should also be provided in the Study area description subsection. Who defined these six watersheds and why? It is clear that hydrologic data was collected for the watersheds but the current text is vague regarding the overall purpose of these six watersheds.

We included only 2 macro watersheds and two small watersheds in the analysis. The other four watersheds, which were previously used to analyze observed BFI value in a watershed scale, were excluded. The reason was that these four watersheds were considered insufficient statistically to represent the observed BFI value for the whole study area.

9) Also in relation to comment 7, please describe the "small watersheds" referenced in lines 144-145 and 195-196 and shown in Figure 1 in the study area subsection, rather than waiting to describe those in current section 2.3.1

(and that information does not need to be repeated at the start of section 3.2). What other hydrologic data were collected for those small watersheds besides the C values?

We agree with the referee's suggestions, and have described "small watersheds" in Line 144-148. Additional description of small watershed are provided in the methodology section of measured C values (Line 322-329).

10) Please rewrite "C&BFI" as "C and BFI" throughout the text.

Revision made

11) A SWAT Description subsection needs to be added to the manuscript. This should note the specific version of the model used for the study (including the Revision number) and provide a succinct overview of the model, especially regarding components that were particularly important for the study you conducted. A description of the crop parameters used for the rubber and oil palm trees, and other vegetation in the watersheds, should also be provided (those parameters could be described later in the methods if more appropriate). See the Wangpimool et al. article listed in comment 4 above regarding revised rubber tree crop parameters they used in their study.

We agree with the referee's suggestions, and have described the SWAT model and crop parameter in subsection 2.2 (Line 163-257).

a) An expanded description of the SWAT calibration and validation procedures is needed, which again should be in a separate subsection. This should include a description of the calibration parameters used in the study, including the default value (or initial value range) and the final calibrated values. Please also provide a description of any sensitivity analyses that was performed and provide a description of the specific baseflow separation techniques that were used in the calibration process. A description of measured baseflow data, or proxy baseflow data obtained via literature sources or expert opinion, is also important in relation to the use of the BFI indicator in your study.

We agree with the referee's suggestions, and have expanded the description of the SWAT calibration and validation procedures in the Section 2.2.2 (Line 283-.305). The default value (or initial value range) and the final calibrated values has been described in Line 350-352. The baseflow separation technique was described in Line 359-262.

b) I suggest you then introduce a third subsection that describes the specific C and BFI methods that were used in your analyses.

We agree with the referee's suggestions, and have added subsection 2.3 to describes the simulated C and BFI methods (Line 306-320).

13) Please expand on your discussion of the calibration and validation results. This should include showing hydrograph comparisons between the simulated and measured outputs and discussion of your results in the context of model evaluation criteria suggested in the two Moriasi et al. studies.

We agree with the referee's suggestions. We have expanded our discussion of the calibration and validation results including NSE and PBIAS as suggested in the two Moriasi et al. (2007, 2012). Moriasi et al. (2007, 2012) recommend three quantitative statistics, Nash-Sutcliffe efficiency (NSE), percent bias (PBIAS), and ratio of the root mean square error to the standard deviation of measured data (RSR) be used in model evaluation (Line 345-361)

14) Line 131: I think the word "was" should be "were". Why were simulated values that were within an "order of magnitude" of the measured values considered acceptable? It appears that the average measured and simulated C values reported in Tables 5 versus 6 were almost identical; that would indicate that the "order of magnitude" criteria is unnecessary?

We thank the referee for pointing this out. We have revised the entire sentence (Line 334-336).

15) Sentence in lines 184-185: The phrase "as acceptable for a good watershed service" in this sentence sounds odd. A suggested revision is: "The Ministry of Forestry of Indonesia considers C values < 0.35 to be adequate to support required ecosystem services for Indonesian watersheds (citation)."

We agree with the referee's suggestions, and have revised the sentence accordingly (Line 383-387).

16) Conclusions: Some expansion of your Conclusions section is warranted. Please include additional quantitative information from both the baseline testing results as well as the C and BFI analyses.

We agree with the referee's suggestions and have included additional quantitative information in the conclusion (Line 426-432).