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Interactive comment

Interactive comment on "Minimum forest cover for sustainable water flow regulation in a watershed under rapid expansion of oil palm and rubber plantations" *by* Suria Tarigan et al.

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Author responses to Anonymous Referee #1

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

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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. (See the description in the following paragraphs)

Line 53-58 (Oil palm and local water cycle) The impact of tropical rainforest conversion into plantations such as oil palm and rubber is not limited to the biodiversity loss, decreased carbon stock, and increased greenhouse gas emissions but also change local water cycle including increased transpiration (Roell et al., 2015; Hardanto et al., 2017), increased evapotranspiration (Babel et al., 2011; Meijide et al., 2017), decreased infiltration (Banabas et al., 2008; Tarigan, et al., 2016), increased flooding (Tarigan, 2016), decreased low flow (Yusop et al., 2007; Adnan and Atkinson, 2011; Comte et al., 2012; Merten et al., 2016) and water quality (Babel et al., 2011).The change of the water cycle will in turn affect water flow regulation function of a watershed.

Line 93-102 (Land use change and the SWAT model) Marhaento et al. (2017) used the SWAT model to simulate impact of forest cover and agriculture land use on the runoff coefficient and the ratio of base flow to stream flow in Java Island Indonesia and found that forest cover change from 48.7% to 16.9% resulted in the increased of the runoff coefficient (C) to 44.6% and decrease of the ratio of base flow to stream flow to 31.1% showing similar trend with that of our results. Meanwhile, Wangpimool et al., (2017) found that annual reduction of about 3% in the basin average water yield based on the SWAT model simulation due to the rubber expansion in Thailand from 2002 to 2009. Babel et al., (2011) simulated impact of oil palm expansion using SWAT in Thailand and reported increased nitrate loading (1.3 to 51.7%) to the surface water. The new contribution of our study is the establishment of quantitative relation between forest cover and flow indicators in a watershed, which can be used as a guide for spatial planners to determine the minimum proportion of forest conservation area to maintain a sustainable ecosystem service of water flow regulation in a watershed. Tarigan et al. (2016) used SWAT model to simulate impact of soil and water conservation practices on low flow in oil palm dominated watersheds in Jambi Provinces, Indonesia dominated watersheds in Jambi Provinces, Indonesia

Some newly added References:

Adnan, N. A., Atkinson, P. M. 2011. Exploring the impact of climate and land use changes on streamflow trends in a monsoon catchment. International Journal of Climatology 31, 815–831.

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.

Comte, I., Colin, F., Whalen, J.K., Gruenberger, O., Calliman, J.P., 2012. Agricultural Practices in Oil Palm Plantations and Their Impact on Hydrological Changes, Nutrient Fluxes and Water Quality in Indonesia: A Review. Advances in Agronomy, Volume 116, 2012 Elsevier Inc. ISSN 0065-2113.

Hardanto A, Röll A, Furong N, Meijide A, Hendrayanto, Hölscher D (2017) Oil palm and rubber tree water use patterns - effects of topography and flooding. Frontiers in Plant Science 8: 452 http://journal.frontiersin.org/article/10.3389/fpls.2017.00452/full

Hardanto A, Röll A, Hendrayanto, Hölscher D (2017) Tree soil water uptake and transpiration in mono-cultural and jungle rubber stands of Sumatra. Forest Ecology and Management 397: 67-77 http://www.sciencedirect.com/science/article/pii/S0378112717304747?via%3Dihub

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.

Meijide A, Röll A, Fan Y, Herbst M, Niu F, Tiedemann F, June T, Rauf A, Hölscher D, Knohl A (2017) Controls of water and energy fluxes in oil palm plantations: Environmental variables and oil palm age. Agricultural and Forest Meteorology 239: 71-85 http://www.sciencedirect.com/science/article/pii/S0168192317300771

Röll A, Niu FR, Meijide A, Hardanto A, Hendrayanto, Knohl A, Hölscher D (2015) Transpiration in an oil palm landscape: effects of palm age. Biogeosciences 12: 9209-9242. http://www.biogeosciences-discuss.net/12/9209/2015/bgd-12-9209-2015-print.pdf

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.

Van Griensven, A., Maharjan, S., & Alemayehu, T. (2014). Improved simulation of evapotranspiration for land use and climate change impact analysis at catchment scale. International Environmental Modelling and Software Society (iEMSs) 7th International Congress on Environmental Modelling and Software.

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

2.1.1. Land use and soil characteristics

2.1.2 Watershed characteristics

1. Macro watersheds 2. Small watersheds

2.2 Flow simulation

2.2.1 SWAT model

1. Crop and soil parameters 2. Input data 3. Model validation and calibration

2.2.2 Simulated C and BFI values

2.2.3 Observed C and BFI values

1. Observed C values 2. Observed BFI values

The general SWAT model and the SWAT model for the study area are described in Subsection 2.2.1. (See the description in the following paragraphs)

2.2.1 SWAT model We used the SWAT model version 2012 (Arnold et al., 2012). The SWAT model is a continuous model, i.e. a long-term yield model. The model was developed to simulate the impact of land cover/management practices on the streamflow in complex watersheds with varying soil, land use and management condition over long periods of time. Major model components include weather, hydrology, soil temperature and properties, plant growth, nutrients, and land management (Arnold et al., 2012; Neitsch et al., 2009). Delineation ofwatersheds and their sub-watersheds in our study area was carried out automatically by the SWAT model and was based on a digital elevation model (DEM) with a 30-m resolution. During the automatic delineation we pre-defined an area of 50.000 ha as a threshold for a minimum sub-watershed area. Based on this threshold, both study watersheds in our study area were further sub-divided into 25 and 23 sub-watersheds, respectively. The sub-watershed is further sub-divided into hydrological response units (HRUs) with homogeneous hydrological unit defined by topography, soil, and land use characteristics. Hydrological outputs are then calculated in the HRUs based on the water balance equation. Output of the SWAT model include total stream flow, surface flow and base flow. These output were used to calculate the C and BFI values for each sub-watershed. For this simulation, the SWAT model required other inputs such as climate data, as well as soil and land-use maps for each sub-watershed (Table 1).

We also carried out field data collection including hydraulic conductivity (SOL_K), bulk density (SOL_BD), available water content (SOL_AWC) and texture for SWAT model input. Digital Elevation Model with 30 m pixel resolution is available from the National Aeronautics and Space Agency. Rainfall and climate date are available from the Meteorology and Geophysics Agency. The streamflow data of the six macro watersheds were provided by the Ministry for Public work. The land use data are available from the Regional Planning office. All these data are freely available for research purposes by official request to the corresponding institutions. The time series streamflow and the rainfall records for the small catchments, the resampled soil hydraulic conductivity, bulk density, available water content and texture are deposited by the first author office at Bogor Agricultural University and EFForTS Database (https://efforts-is.uni-goettingen.de). The land-use and soil map for the study area was obtained from Jambi Province Regional Planning (BAPEDA, 2013) and Agricultural Plantation offices (Ditjenbun, 2013). Soils in our study area are dominated by two soil types, namely

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Tropodult and Dystropept (Figure 1).

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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 Performance of the SWAT model

3.2 Observed C and BFI values

3.3 Simulated C and BFI values

3.4 Correlation of percentage of forest covers in a watershed with C and BFI

3.5 Application of the research result

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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 the SWAT parameters such as CANMX and CN2 in subsection 2.2.1 of the method section (see the description in the following paragraphs).

According to Griensven et al. (2014), the SWAT is designed for temperate regions so that it is necessary to adapt the crop parameters for application in a tropical region. In this respect, we adjusted the crop parameters, directly related to the flow component such as CANMX and CN. To adapt these values we carried out field measurement on several important hydrological component including interception, infiltration, and overland flow (Figure 2).

Canopy Storage (CANMX)

Interception reduces the amount of water reaching the ground and consequently reduces streamflow. We measured interception in oil palm, rubber, agroforest, and forest trees at the plot between November 2012 and February 2013. In total there were 30 rainfall events during this time, representing light to heavy rain. In oil palm, rainfall is not only intercepted by leaves and branches but also by hollow spaces between fronds and trunk. This type of interception is called trunk storage and may have led to the slightly increased interception in oil palm. Interception in oil palm was rather similar to interception in the forest. The measured interception (Figure 3) values were used as an estimate of (CANMX), which serves as an input parameter for the SWAT model. The CANMX is the maximum amount of water that can be trapped in the canopy and trunks when they are fully developed. Higher CANMX values reduce potential runoff during heavy rains. Beside CANMX we also adapted other crop parameters such as OV_N, BLAI. CHTMX, T_BASE and T_OPT (Table 2).

Adapted CN values for oil palm and rubber land uses.

One important parameter of the SWAT model related to surface runoff modeling is SCS curve number (CN, Arnold et al., 2012). It determines proportion of rainfall becoming surface runoff. Its value range from 0-100. The bigger the value the higher the proportion of surface run of on a particular rainfall event. The SCS curve number (CN) is differentiated into Hydrologic Soil Groups (HSG) A,B,C, and D which are a function soil's infiltration. We measured soil infiltration and surface runoff in the typical land use types in our study area i.e. oil palm, rubber, and forest. Infiltration was measured using a double-ring infiltrometer. No infiltration measurement was carried out under agroforest as infiltration in agroforest is likely similar to infiltration in secondary forest. Infiltration measurements in different land-use types from the study area showed the following order: oil palm harvest path (3 cm h-1) < rubber (7-7.8 cm h-1) < forest (47 cm h-1). The infiltration in the oil palm, rubber plantations were markedly lower than those at the forest.

The surface runoff in oil palm and rubber plantation were significantly higher than those in agroforest and forest (Figure 4). Low infiltration capacity in oil palm and rubber plantations was one reason for higher surface the plantation land use (Tarigan et al. 2016).

Due to the high surface runoff and the infiltration rate, we adopted HSG-D category for all HRUs in oil palm and rubber land uses irrespective of soil types (Table 3). For forest and agroforest, we assumed that the CN value was similar to those of forest evergreen (FRSE) and forest mixed (FRST) values in the SWAT crop database respectively.

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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 (see the description in the specific comment nr. 19 below) We calibrated the model using the Latin hypercube sampling approach from the Sequential Uncertainty Fitting version 2 in the SWAT Calibration and Uncertainty Procedure (SWATâĂŘCUP) package. First parameter ranges were determined based on minimum and maximum values allowed in SWAT. The SWATâĂŘCUP is an interface for auto-calibration that was developed for SWAT. The interface links any calibration/uncertainty or sensitivity program to SWAT (Abbaspour, 2015). The discharge

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data of BH and MT watersheds used for calibration and validation were available for the period of 2005-2014. The calibration was carried out in year 2007-2009 and the validation in year 2012-2014. We evaluated the model using Nash-Sutcliff efficiency (NSE) and Percent Bias (PBIAS). The NSE is a normalized statistic that determines the relative magnitude of the residual variance ("noise") compared to the measured data variance ("information") (Nash and Sutcliffe, 1970). The PBIAS measures the average tendency of the simulated data to be larger or smaller than the observations Gupta et al., (1999). 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. The model input parameters that were used for the calibration process and their fitted values after calibration are shown in Table 4.

The ALPHA_BF (baseflow recession constant) was calculated from daily streamflow hydrograph plotted on semi-log paper.

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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. (See the description in the following paragraphs)

The CN value is the most sensitive parameter of the SWAT model . We realize that SWAT is designed for temperate regions so that it is necessary to adapt the crop parameters for SWAT model input in the tropical region (Van Griensven et al., 2014). To avoid wrong parameterization of the sensitive value we carried out the following steps: a) Adapting CN and CANMX values based on the field measurement on water cycle related directly to the flow components including interception, infiltration, and surface runoff (see general comment 4 above), b) Replicating SWAT model simulation in two study watersheds, and c) Collecting time series streamflow data to calculate observed C and FBI and to get impression whether the C and BFI values calculated form the SWAT model really reflects the field observation (despite good performance of the model in our study).

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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 changed to: “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”

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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.

Abstract In many tropical regions, rapid expansion of monoculture plantations has led to a sharp decline of forest cover potentially degraded the water flow regulation function of watersheds. In a watershed where expansion of agricultural plantations occurs rapidly, the regional planner need to know the minimum proportion of forest cover required to maintain proper water flow regulation function of a watershed. Research dealing with this issue is still rare, especially in the tropical area where oil palm expansion occurs at alarming rate. We investigated the impact 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 model gave satisfactory performance with the NSE values of 0.80-0.88 (baseline calibration) and 0.80 - 0.85 (validation); and the PBIAS values of -2.9 - 1.2 (calibration) and 7.0-11.9 (validation). 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 new contribution of our study is the establishment of quantitative relation between forest cover and flow indicators in a watershed, which can be used as a guide for regional planners to determine the minimum proportion of forest conservation area to maintain a sustainable ecosystem service of water flow regulation in a watershed.

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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 while shortening the abstract.

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4) Line 40 “ Lele, 200” please add 0

We thank the referee for the correction.

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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

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6) Line: 46:”base flow” remove space

Revision made; we inserted the space.

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7) Line 46: “)]” remove the square bracket

Revision made; we removed the square bracket

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

We thank the referee for pointing this out; we have improved the language Line 69-71. As a consequence of reduced infiltration rate in the plantation areas, the surface runoff become higher promoting higher peak discharge. One alternative to reduce this impact is by maintaining sufficient proportion of the forested areas in the watershed promoting higher infiltration rate.

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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 72-73 Distributed hydrologic models such as the Soil and Water Assessment Tool (SWAT) ecohydrological model (Arnold et al., 1998; 2012) are useful to understand the effects of land use changes on watershed flow regulation

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10) Lines 80-81: ": : :: : : 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.

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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 and the location coordinates.

Line 88-89 The study site covers an area of approximately 31 868 km2, is located at 1o54'31.4"S - 103o16'7.9" E in the Jambi Province of Sumatra (Fig. 1a).

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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. (see the description in the following paragraphs)

The oil palm expansion in our study area (Jambi Province) increased almost 400% from 150,000 ha in 1996 to 600,000 ha in 2011 (Setiadi et al., 2011). The area under rubber increased from 500,000 to 650,000 ha in the same time period (Ditjenbun, 2013). In 2013, only 30% of Jambi Province was covered with rainforest (mainly located in mountainous areas), while 55% was already converted into agricultural land, and 10% of the land was degraded/fallow potentially converted to monoculture plantation (Drescher et al. 2016).

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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 moved this part to method section.

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14) Line 99: Replace "&" with and

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

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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"

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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.

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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 2.2.1 under which we have described the general SWAT model and the model setup in the general comment nr. 5.

2.2.1 SWAT model setup 1. Crop and Soil parameters 2. Input data 3. Model validation and calibration

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

Revision made; we have replaced "ha" with "km2"

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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 added subsection 2.2.1 in the method section describing the SWAT model setup including input data, plantation-crop parameter and model validation and calibration. The subsections have been described in detail in the general comment 2, 4 and 5

2.2.1 SWAT model 1. Crop and Soil parameters 2. Input data 3. Model validation and calibration

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20) Line 122: Add SWAT-CUP reference

Revision made; we have added the SWAT-CUP reference. Line 122 The SWATâĂŘCUP is an interface for auto-calibration that was developed for SWAT model (Abbaspour et al., 2007, 2011, 2015).

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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 a new subsection (2.2.1) in the method section (see also general comment nr. 5). The program SUFI-2 and PBIAS in the SWAT-CUP software package were used for calibration and validation (.Abbaspour et al., 2011). The calibration and validation periods of the SWAT model were carried out in 2007-2009 and 2013-2014 respectively (Figure 5).

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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 163-167 Overall, the model performance was satisfactory with the NSE values of 0.80-0.88 (calibration) and 0.80 - 0.85 (validation); and the PBIAS values of -2.9 - 1.2, (calibration) and 7.0-11.9 (validation).

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

Correction made

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

Correction made

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25) Lines 162-163 repetition see line 121

We thank the referee for pointing this out. We have removed the line 162-163

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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.

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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. Actually, we made comparison in Line 198-202 for C value, and Line 201-214 for BFI value. The lines 165-167 was misplaced which have been moved to Subsection 2.2.3 (Line 135)

Line 198-202 To find out whether the simulated C values (Table 3) are comparable to the observed C values obtained from small watershed experiments (Table 4), we selected simulated C values from all sub-watersheds (Table 5) with a land cover proportions similar to those of the two observed small watersheds. The comparison showed that the average of the simulated C values of 0.6 (Table 5) is very similar to the average of the observed C values of 0.59 (Table 4).

Line 201-214 The correlation of the simulated and the observed BFI values respectively with forest cover showed different slope (Fig. 5a and 6). As an example, to achieve a BFI value of 0.5, the required proportion of forest cover based on the simulated BFI was

45 % (Fig. 5a). Meanwhile, to achieve a similar BFI values, the required proportion of forest cover based on the observed values was 33% (Fig. 6). Thus, the SWAT model underestimated the simulated BFI value. This can be explained by the fact that the SWAT model (version 2012) considered only shallow groundwater in the streamflow simulation (Neitsch et al., 2009). The observed BFI on the other hand included deep groundwater flow as well.

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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 (Subsection 2.2.1)

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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 180-184 Infiltration data in different land-use types from the study area (Tarigan et al. 2016) showed the following order: oil palm harvest path (3 cm h-1) < rubber (7 cm h-1-7.8 cm h-1) < forest (47 cm h-1). Low infiltration capacity in oil palm and rubber plantations was the reason for higher C values in the sub-watersheds with high proportions of the plantation land use.

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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

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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. The SWAT model is considered as long-term yield model and not an event-based model. In addition, both watershed in our study were partitioned into 48 sub-watershed, which reduce the degree of rainfall spatial variability in the watersheds.

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

The mentioned sub-watershed in Figure 4a is the sub-watershed with number 19 in the BH watershed. The reason why the C value is low despite the low forest cover was due to the fact that the proportion of oil palm and rubber plantation in this sub-watershed is 0 %. In addition, the proportion of agroforest in this sub-watershed is 30% which help reducing the C value.

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33) Line 207: please improve the language

Revision made. We have improved the language. The correlation of the simulated and the observed BFI values respectively with forest cover showed different slope (Fig. 5a and 6).

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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, especially the watershed with significant proportion of groundwater in the total flow. We have enriched the discussion with the suggested literature. (see the description in the following paragraphs)

Line 211: The SWAT model underestimated the simulated BFI value in our study area. The reason is that the SWAT model considered only shallow groundwater in the stream flow simulation (Neitsch et al., 2009). Meanwhile, the observed BFI included deep groundwater flow. To improve the performance of the SWAT model for deep groundwater flow (low flow) simulation, Pfannerstill et a.l, (2014) modified groundwater module by splitting the active groundwater storage into a fast and a slow contributing aquifer. The result of this modification leads to better prediction of low flow. Bailey et al. (2017) coupled SWAT with physically-based, spatially-distributed groundwater model (MODFLOW) to improve groundwater flow process in SWAT.

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

Revision made. We thank you the referee for the correction

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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.

The sub-watershed nr. 23 is the only sub-watershed in MT watershed with high proportion of steeper slope (76% of the sub-watershed). The steep slope increased the C value and decrease the BFI. Among 48 considered sub-watersheds, only 2 of them have such a kind of slope characteristics. This type of sub-watersheds is normally situated at the upper-mountainous catchment area. These area are not suitable for the oil palm development.

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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.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2017-116, 2017.

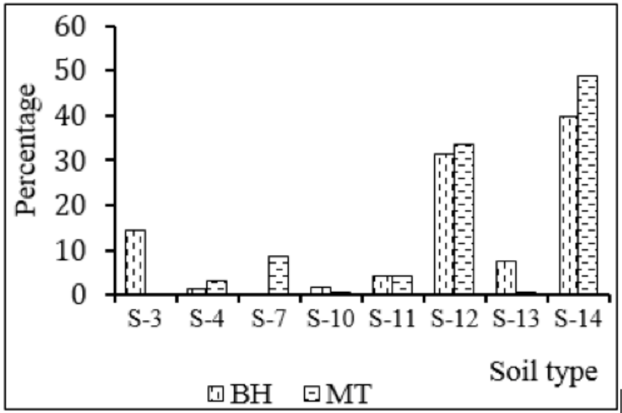

Figure 1. Soil type in BH and MT watersheds. Soil types respresent Fluvaquents (S-3), Humitropepts (S-4), Paleudults (S-7), Tropofluvents (S-10), Troposaprist (S-11), Tropodults (S-12), Dystrandepts (S-13), Dystropepts (S-14).

Fig. 1.

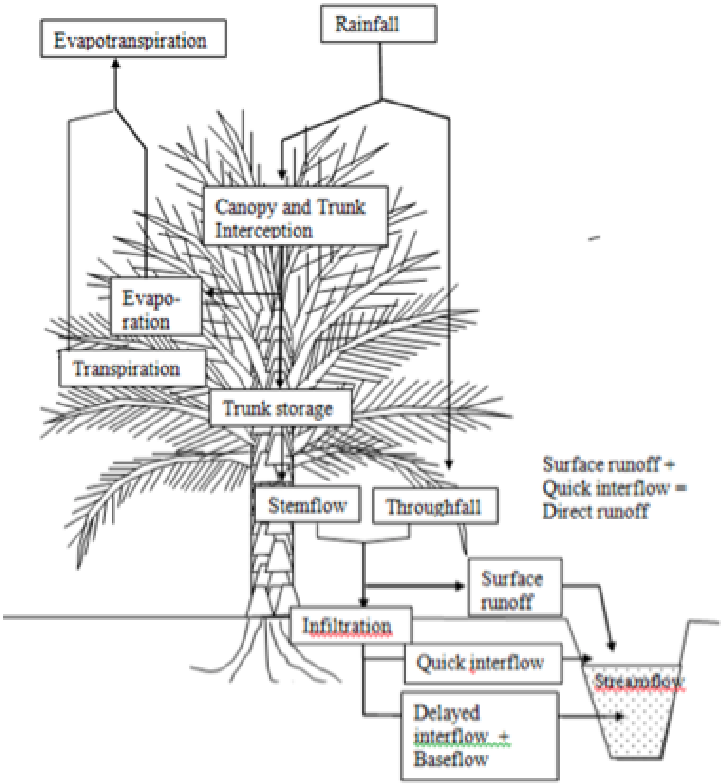

Figure 2. Oil palm hydrological components

Fig. 2.

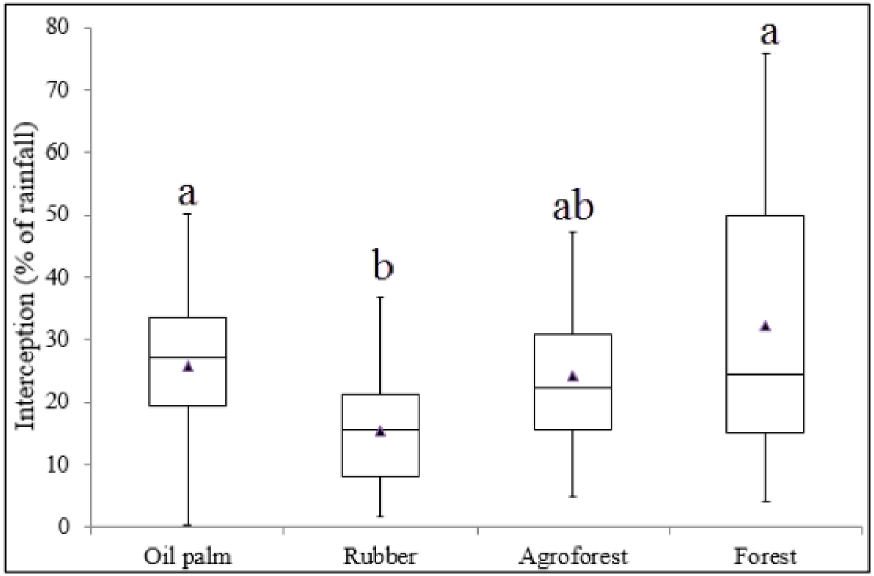

Figure 3. Interception of different plantation crops and forest. Different letters indicate significant differences of averages according to a Bonferroni-corrected posthoc t-test based on an ANOVA (p< 0.05)

Fig. 3.

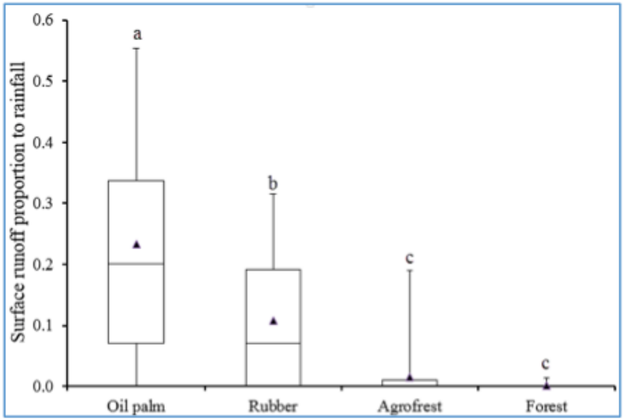

Fig. 4. Surface runoff of different land use types in the study area. The different letters indicate significant differences among averages according to a Bonferroni-corrected posthoc t-test based on an ANOVA ($p < 0.05$).

Fig. 4.

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Discussion paper

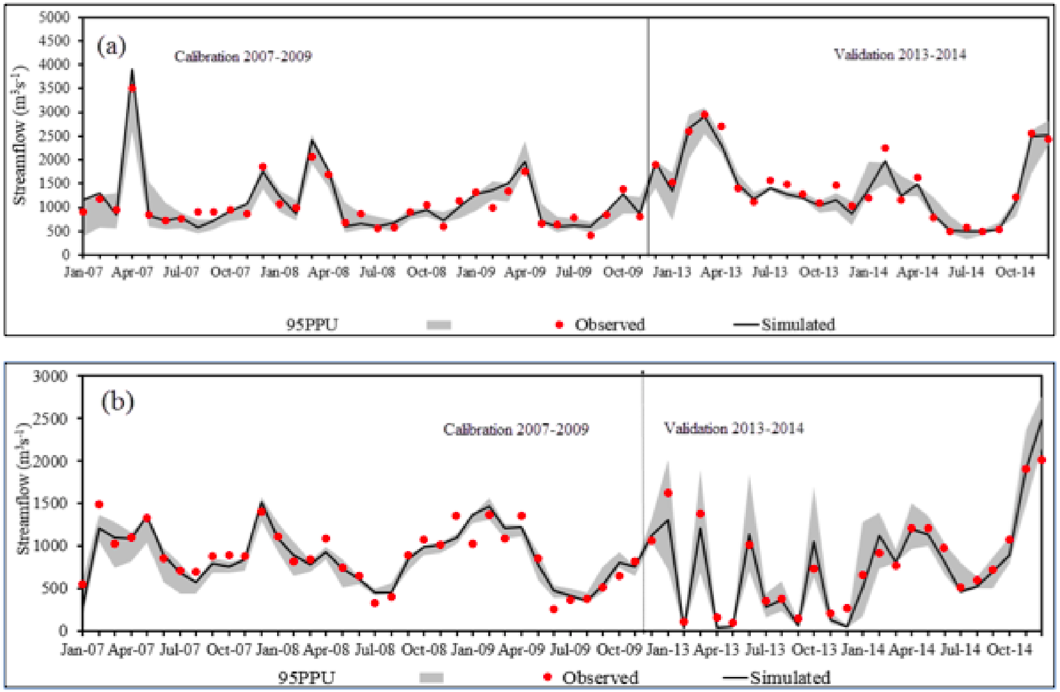

Figure 5. Observed vs. simulated streamflow and 95% uncertainty interval (95PPU) of behavioral simulations over time (defined as simulations with Nash-Sutcliff efficiency NSE > 0.5) for the BH (a) and MT (b) watersheds respectively.

Fig. 5.

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Table 1. Model input data sources for the watershed modeling

Data type	Resolution	Description	Source Data
Topography	30 m	Digital Elevation Model with 30 m pixel resolution	LAPAN
Soils	1:250,000	Soil hydraulic conductivity, bulk density, available water content and texture were resampled in the field	Soil Research Institute, Ministry of Agriculture
Land use	1:100,000	Land use map with intensive ground check	Regional Planning office (BAPPEDA)
Rainfall and climate	Daily	Rainfall stations (Rantau Pandan, Siulak Deras, Muara Imat); climate station (Jambi, Pematang Kabau and Bungku)	BMG office (Meteorology and Geophysics Agency) and CRC990
Streamflow	Daily discharge data	Stations: Muara Tembesi, Rantau Pandan, Air Gemuruh, Batang Tabir, Batang Pelepat, Muara Kilis	Ministry for Public work (BBWS)

LAPAN: National Aeronautics and Space Agency (*Lembaga Antarikasa dan Penerbangan Nasional*), BAPPEDA: Regional Planning Agency (*Badan Perencanaan Daerah*), BMG: Meteorology and Geophysics Agency (*Badan Meteorologi dan Geofisika*), CRC990: Collaborative Research Centre 990, BBWS: Catchment Regional Agency (*Balai Besar Wilayah Sungai*)

Fig. 6.

Table 2. Adapted input of crop-parameters different land-use types

SWAT input parameters		Oil palm	Rubber	Agro-forest	Forest
CANMX	Original	0	0	0	0
	Adapted	4.0	2.7	4.3	5.8
OV_N*	Original	0.14	0.14	0.1	0.1
	Adapted	0.07	0.14	0.4	0.5
BLAI	Original	5	2.6	5	5
	Adapted	3.6**	-	-	-
CHTMX	Original	3.5	3.5	6	10
	Adapted	12			
T_BASE	Original	7	7	0	10
	Adapted	20	20	20	20
T_OPT	Original	20	20	30	30
	Adapted	28	28	30	30

* OV_N values are low in oil palm and rubber due to the clean weeded management practice
** Meijide et al. (2017)

Fig. 7.

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Table 3. Adapted CN values for typical land use types in the study area

		Hydrologic Soil Group			
Landuse		A	B	C	D
Oil palm	Original CN value	45	66	77	83
	Adapted CN value	-	-	-	**83**
Rubber	Original CN value	45	66	77	83
	Adapted CN value	-	-	-	**83**
Agroforest (FRST)	Original CN value	36	60	65	79
Forest	Original CN value	25	45	70	77

Fig. 8.

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Table 4. The calibration parameters used in the study, including the initial value range and the final calibrated values for the BH and the MT watersheds respectively.

Parameters	Descriptions	Initial value range	Best fit values	
		BH and MT	BH	MT
ALPHA_BF	Baseflow recession constant	0.0 – 1.0	0.94	0.91
GW_DELAY	Groundwater delay time (days)	30 - 450	62.5	57.2
GWQMN	Water depth in a shallow aquifer for a return flow (mm H2O)	0.0 – 2.0	0.99	0.45
GW_REVAP	Evaporation from the ground water (mm)	0.0 - 0.02	0.13	0.07
CH_N2	Manning's "n" value for the main channel	0.0 – 0.3	0.05	0.15
CH_K2	Eff. hydraulic conductivity in the main channel alluvium (mm/hr)	5.0 - 130	35.6	24.4
SOL_AWC	Available water capacity of the soil (mm H2O/mm soil)	- 0.2 – 0.4 (V)[a]	0.09	0.04
SOL_K	Saturated hydraulic conductivity (mm h^{-1})	- 0.8 – 0.8 (V)[a]	0.71	0.12
OV_N	Manning's "n" value for overland flow	- 0.2 – 1.0 (V)[a]	0.51	0.29

[a] (V) = Variable depending on land-use and soil, changes in calibration were therefore expressed as fraction

Fig. 9.