Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2017-116, 2017
Manuscript under review for journal Hydrol. Earth Syst. Sci.
Discussion started: 29 May 2017

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Minimum forest cover for sustainable water flow regulation in a watershed under rapid expansion of oil palm and rubber plantations

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Abstract. In many tropical regions, rapid expansion of monoculture plantations has led to a sharp decline of forest cover, which potentially degraded the water flow regulation function of watersheds. The flow regulation function of a watershed is defined as the ability of the watershed to store the rain water, therefore reducing the direct runoff and sustaining the baseflow during dry season. In the tropical region where rainfall is highly seasonal, water flow regulation is an important ecosystem function of a watershed. It determines the proportion of direct runoff of the rainfall and the proportion of the baseflow in the streamflow. The higher the proportion of the direct runoff of the rainfall the higher the probability that water resources problems occur such as flooding in the wet season and drought in the dry season. Therefore proper water flow regulation function of a watershed is a key factor for water resources management. It is generally known that forest land use improves the water flow regulation function of a watershed. The contribution of forest land use on water flow regulation function of a watershed depends primarily on its proportion in the entire watershed. In a watershed where expansion of agricultural plantations occurs rapidly, the spatial planner needs 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 employed the SWAT hydrological model to calculate two indicators of water regulation function of a watershed: the proportion of the direct runoff to the rainfall (C) and the proportion of the baseflow in the total streamflow (BFI). Using regression analysis, we show a strong correlation between indicators of water flow regulation (C and BFI values) with the proportion of forest cover and agricultural plantation cover in a watershed. To achieve the required C value of less than 0.35, the proportion of forest cover in the entire watershed should be greater than 30% and the proportion of plantation cover should be less than 40%. The results of this study are very useful 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.

Keywords: baseflow index-BFI, direct runoff coefficient-C, agricultural plantation expansion; water flow regulation; tropical rainforest

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1. Introduction

The water flow regulation function of watersheds is the ability of watersheds to retain rain water. It is one of the most important soil-hydrological processes in the tropical region with highly seasonal rainfall (Lele, 200). Functional water flow regulation reduces flood peaks by moderating direct runoff. In addition, water is released more slowly so that flows are sustained into or through the dry season (Le Maitre et al., 2014; Hewlett, 1967). Soil water infiltration through the soil surface and percolation through the soil profile are important processes in water flow regulation in a watershed. They determine how much water flows as a direct runoff and how much percolates to the water table where it sustains the baseflow (Tarigan et al., 2016; Le Maitre et al., 2014). The infiltration properties of forest are critical in terms of how the available water is partitioned between runoff and base flow (Bruijnzeel, 1990)]. Forest vegetation provides organic matter and habitat for soil organisms facilitating higher infiltration compared to other land uses (Hewlett, 1967).

In Southeast Asia, the transformation of tropical lowland rainforest into plantations such as oil palm and rubber plantations is happening at an accelerating rate, with consequences for water dynamics. For example, in the Jambi Province of Indonesia, where the rainforest has largely been transformed into plantations (Drescher et al., 2016), inhabitants experience water shortage during dry season (Merten et al., 2016) and dramatic increase of flooding frequency in wet season (Tarigan, 2016). These water shortage problems are often associated with the decrease of infiltration due to the loss of forest cover and the increase of plantation cover in the watershed (Dislich et al., in press; Bruijnzeel, 1989; Bruijnzeel, 2004). Oil palm and rubber plantations show distinctly higher direct runoff compared to that of forest land use (Tarigan et al., 2016). According to Yusop et al. (2007) and Rahim et. al. (1992), the baseflow of an oil palm catchment in Malaysia was 54% of total water flow, which is lower than baseflow values of forested catchments. Annual runoff can increase after forest conversion due to the reduction of tree stand evapotranspiration, while baseflow decreases due to the lower infiltration rate in deforested areas (Dinor et al., 2007). Rainfall infiltration is often reduced to the extent that insufficient rainy season replenishment of groundwater reserves results in strong declines of dry season flows (Bruijnzeel et al., 2004). Similarly, the infiltration capacity in oil palm plantations in Bungo, Jambi, Indonesia was only half of that in natural forests (Sunarti et al., 2008). Plantation establishment and harvesting activities involve soil disturbance and compaction, which in turn reduce infiltration rates. In Papua New Guinea, the lowest infiltration rate was found in the harvest path (Banabas et al., 2008). Thus, land use transformation of tropical rainforests into plantation land uses has considerable effects on water infiltration rates.

Reduced infiltration rate of plantation land uses should be compensated by maintaining a sufficient proportion of forest cover elsewhere in the watershed. The question arises, what proportion of forest cover must be present in a watershed to obtain sufficient water flow regulation function of the watershed. Useful tools to answer this question are SWAT (Soil & Water Assessment Tool) models. SWAT model was recommended for evaluation of hydrological ecosystem services of a watershed (Vigerstol et al., 2011). It quantifies the water balance of a watershed on a daily basis (Arnold et al., 2012; Neitsch et al., 2009). The SWAT modeling approach is one of the most widely used and scientifically accepted tools to assess the water management in a watershed (Gassman et al., 2007; Zhang et al., 2013).

The objective of this study is to quantify minimum proportion of forest cover in a watershed for sustainable water flow regulation. We chose a study area with rapid expansion of oil palm and rubber plantations on Sumatra, Indonesia. As indicators of water flow regulation function of the watersheds, we used the direct runoff coefficient and the baseflow index. The direct runoff coefficient (C) is the direct runoff ratio of to rainfall. The baseflow index (BFI) is the proportion of the baseflow in the streamflow. We employed the SWAT hydrological model to simulate watershed flow components required for calculation of the C and BFI values. Then, we used regression analysis to determine quantitative relations of C and BFI with the proportion of forest cover and oil palm and rubber plantation cover in the watersheds.

2. Methods

2.1 Study area

The study area was situated in the Jambi Province of Sumatra, Indonesia (Fig. 1a). The area is experiencing rapid development of plantations, mainly oil palm and rubber plantations (Drescher et al., 2016). The climate is tropical humid with average temperature of 27 °C and average rainfall of 2700 mm yr^{-1}. Rainy season occurs during October until March. Flooding events occur normally in the

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months of January and February. A dry season with monthly precipitation less than 100 mm occurs from June until September. The soil types in the study area are dominated by clay Acrisols (Allen et al., 2015).

The steps of data analysis in this study consisted of: a) calculation of sub-watershed flow components in two selected macro watersheds using SWAT model, b) streamflow data analysis for calculation of observed C and BFI values, c) land-use map analysis of the watersheds and d) the calculation of the minimum proportion of forest cover and maximum proportion of plantation cover in a watershed for proper water flow regulation (Fig. 2).

2.2 Simulated C&BFI values

To analyze correlation between the proportion of particular land-use types in a watershed and the C&BFI values requires time series streamflow data of some watersheds that are representative of the distribution of land use in the study area. In absence of such data in the study area, we performed SWAT hydrologic modeling to simulate flow components of the sub-watersheds and calculated C&BFI values from the simulated data. 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 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). We used SWAT model version 2012 to simulate the streamflow components of sub-watersheds. The simulated streamflow components were required to calculate the C&BFI values taken as the indicators of water flow regulation. Model input data for the watershed modeling are topography, soil, land use, weather, and streamflow data (Table 1).

The model simulation was performed in the two biggest out of six macro watersheds in the study area (Fig. 1a), namely Batanghari Hulu (BH) and Merangin Tembesi (MT). The area of BH and MT watersheds were 1,841,518 ha and 1,345,268 ha, respectively. Both watersheds were chosen to represent the land use transformation from forest to plantation land uses. The BH watershed was dominated by forest and rubber plantations (49 % and 14 % cover, respectively). On the other hand, the MT watershed was dominated by forest and oil palm plantations (30 % and 32 % cover, respectively).

In the SWAT modeling steps, the BH and MT watersheds were sub-divided into smaller sub-watersheds. Delineation of the watershed and their sub-watersheds was based on automatic delineation of a digital elevation model (DEM) with a 30-m resolution (Table 1). BH and MT watersheds were sub-divided into 25 and 23 sub-watersheds, respectively. The calibration of the SWAT model was carried out using the SWAT-CUP software. The SWAT-CUP is an interface for auto-calibration that was developed for SWAT. The interface links any calibration/uncertainty or sensitivity program to SWAT (Abbaspour, 2015). In SWAT-CUP, users can manually adjust parameters and ranges iteratively between auto calibration runs. Parameter sensitivity analysis helps to focus the calibration and uncertainty analysis and provides statistics needed for goodness-of-fit tests. The discharge data of BH and MT watersheds were available for the period of 2005-2013. These data were used for the model calibration and validation. The calibration and validation results were expressed as Nash-Sutcliff efficiency-NSE (Nash and Sutcliffe, 1970)

2.3 Observed C&BFI values

To ensure that the simulated C&BFI values obtained from SWAT model was in order of magnitude with observed values, we conducted field data analysis to determine observed C& BFI values. The field data analysis for the observed C values were carried out in two small watersheds (Fig. 1c). Meanwhile, the field data analysis for observed BFI values were carried out in the six macro watersheds (Fig. 1b). The simulated C&BFI values obtained from SWAT model were compared to the observed values.

2.3.1 Observed C values

The observed C values were calculated from hydrographs of two small watersheds in the study area (Fig. 1c). Based on our previous plot experiments (Tarigan et al., 2016), surface runoff from the oil palm and rubber plantations were significantly high compared to that of forest land-use. We therefore focused our field measurement on the small watersheds with a high proportion of plantation cover in the entire watershed. The two watersheds were purposively selected so that the proportion of plantation cover (oil palm and rubber) in both small watersheds matched some of the sub-watersheds used in the SWAT simulation model.

The dominant land-use type in the first watershed was oil palm (90%), meanwhile 80% of the second watershed was covered by rubber plantations. Both watersheds were instrumented with rectangular weirs and automatic water level recorders. The direct runoff components of the hydrographs were separated by using the straight line method described in (Blume et al., 2007). After hydrograph separation, we calculated the direct runoff coefficient (C). The direct runoff coefficient C is the percentage of rainfall that appears as surface runoff during a rainfall event, or directly following a rainfall event. We did not calculate BFI values along with C values in the small watershed experiments, because BFI calculation requires longer hydrograph records. The hydrograph records of the small watersheds were available in the time period 2013-2015.

2.3.2 Observed BFI values

Observed BFI values were derived from longer historical daily streamflow data of the six macro watersheds from 2005-2013 (Fig. 1b, Table 2). The BFI values were calculated on an annual basis using the Institute of Hydrological procedures (Institute of Hydrology; Wahl and Wahl, 1995). The BFI is the total volume of baseflow divided by the total volume of the steamflow for a particular period. The base flow is calculated using daily time series of streamflows. We didn't calculate C values along with BFI values in the macro watersheds, because C calculation requires at least hourly instead of daily hydrograph records.

3. Results and Discussion

The BH and MT watersheds were delineated into 25 and 23 sub-watersheds respectively for the SWAT simulation model (Fig. 3). The model gave satisfactory performance with the NSE values of 0.88 and 0.86 for calibration and 0.85 and 0.84 for validation in BH and MT watersheds respectively. In addition to the result of the model calibration and validation procedures, we also compared simulated C&BFI values with the observed C&BFI values obtained from the field experiments in the small watershed (Section 3.2) and in the macro watersheds (Section 3.3) respectively.

3.1 The correlation of C&BFI values and the proportion of land-use types in watersheds

The SWAT model simulated flow components of all 48 sub-watersheds in both watersheds. From these simulated data, we derived 48 data vectors, each vector consisting of C&BFI, the proportion of forest area, and the proportion of other land-use types of each sub-watershed (Fig. 3a, 3b and Table 3). Four land uses dominated both watersheds, namely forest, agroforest, plantations (oil palm and rubber), and shrubland (Fig. 3c and 3d).

The C values significantly decreased with increasing forest cover proportion ($R^2 = 0.73$, $p < 0.05$, Fig. 4a) and significantly increased with increasing plantation cover proportion (oil palm and rubber) in the sub-watersheds ($R^2 = 0.74$, $p < 0.05$, Fig. 4b). Other land uses such as shrubland (Fig. 4c), agroforest (Figure 4d), and dryland farming (result not shown) did not show meaningful correlation with the C values.

Low infiltration capacity in oil palm and rubber plantations was the reason for higher C values in sub-watersheds with high proportions of the plantation covers. This reasoning is in line with infiltration data from the study area (Tarigan et al. 2016) showing the infiltration rate in different land-use types increases in the following order: oil palm harvest path (3 cm h^{-1}) < oil palm circle (3 cm h^{-1}) < rubber harvest path (7 cm h^{-1}) < between rubber trees (7.8 cm h^{-1}) < under frond piles (30 cm h^{-1}) < forest (47 cm h^{-1}).

The Ministry of Forestry of Indonesia considers C values of less than 0.35 as acceptable for a good watershed service in Indonesian watersheds (Ministry of Forestry Decree, 2013). Based on our study, to achieve a C value of less than 0.35, the proportion of forest cover in the sub-watershed should be greater than 30% (Fig. 4a) and the proportion of plantation cover should be less than 40% in a sub-watershed (Fig. 4b).

The BFI values showed significant positive correlation with the proportion of forest cover ($R^2 = 0.78$, $p < 0.05$) and significant negative correlation with the proportion of plantation cover ($R^2 = 0.83$, $p < 0.05$, Fig. 5a and 5b). Other land-use types such as shrubland (Fig. 5c), agroforest (Fig. 5d), dryland farming (result not shown) did not show significant correlation with the BFI values.

3.2 Observed C values

To verify the C values obtained from the SWAT simulation (Table 3), we determined the C values from the field experiment in two small watersheds in the study area. Both watersheds were covered 80 to 90% by plantations (rubber or oil palm). We selected nine individual rainfall events and then averaged the C values. The averaged C value obtained from the field experiment were 0.59 (Table 4).

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

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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).

3.3 Observed BFI value

Observed BFI values were derived from longer historical daily streamflow data of the six macro watersheds from 2005-2013 (Fig. 1b). The observed BFI value had a significant correlation with the proportion of forest cover in the macro watersheds (Fig. 6).

When comparing the correlation graph of the proportion of forest cover with the simulated BFI (Fig. 5a) and the observed BFI values (Fig. 6) respectively, there was a difference. 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.

3.4 Application of the research results

How can we manage the declined ecosystem service of water flow regulation under rapid transformation of rainforest into agricultural plantation? Land sparing and land sharing approaches have been proposed as mitigation strategies to balance ecology and socio-economic functions in a landscape with significant agricultural areas (Lambin et al., 2011). Under the land sparing concept, one part of land is allocated for conservation (forests) while the other part is used intensively for a production purpose (i.e. agriculture areas). Related to the land sparing approach, the results of this study are needful as a guide for regional planners to determine the required proportion of forest conservation area to reach a sustainable ecosystem service of water flow regulation in a watershed. Based on our study, to achieve a C value of less than 0.35, the proportion of forest cover in the entire watershed should be greater than 30% (Fig. 4a) and the proportion of agricultural plantation cover should be less than 40% in the watershed (Fig. 4b).

4. Conclusions

The study presented here shows how a watershed hydrological model like the SWAT can be used to help spatial planners to determine the minimum proportion of forest cover and the maximum proportion of agricultural plantation cover in a watershed to maintain a sustainable water flow regulation. The simulated C values were in order of magnitude with observed values. Meanwhile the simulated BFI values were underestimated by the SWAT model.

Overall, our study showed a strong correlation between indicators of water flow regulation (C&BFI values) with the proportion of forest cover and agricultural plantation cover in a watershed. The results of this study are very useful 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.

5. Data availability

The 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).

Acknowledgements. This study was performed in the framework of the joint Indonesian-German research project EFForTS-CRC 990 (http://www.uni-goettingen.de/crc990) and was funded by the Directorate General of Higher Education (DIKTI), Indonesia

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Figures:

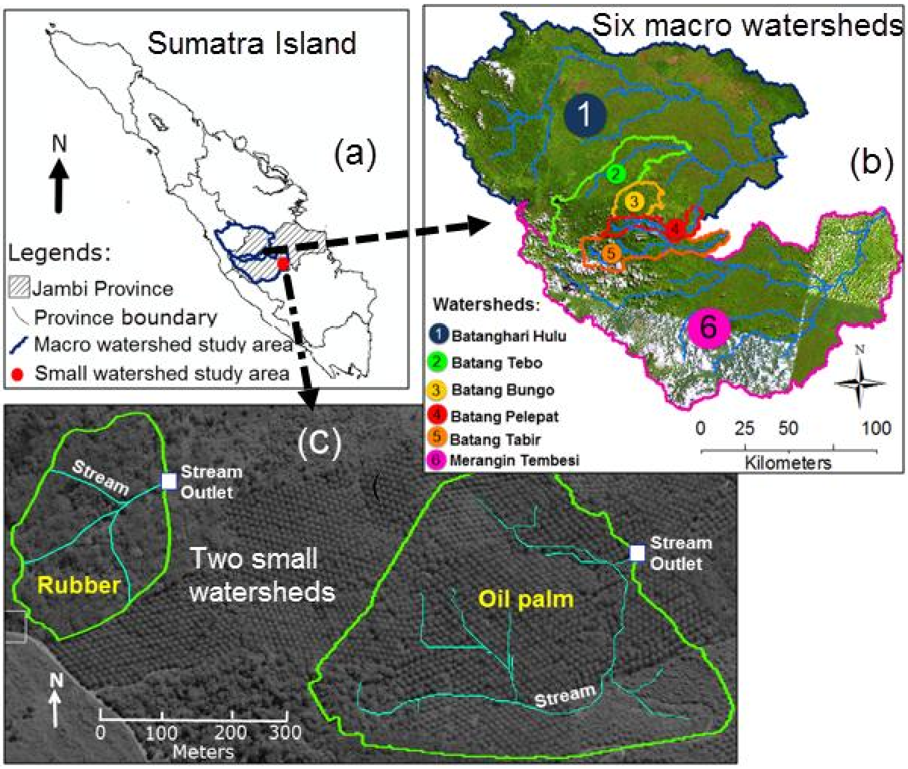

Figure 1. Study area in the Jambi Province, Sumatra Island, Indonesia (a), the location of macro watershed experiments (b) and the location of small watershed experiments (c).

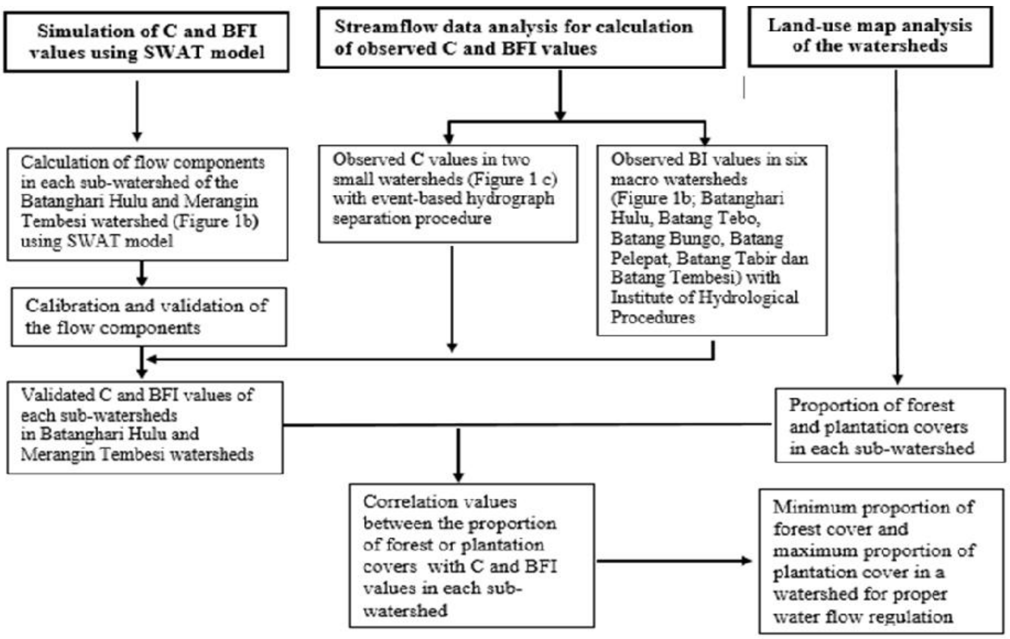

Figure 2. Main steps of data analysis in this study

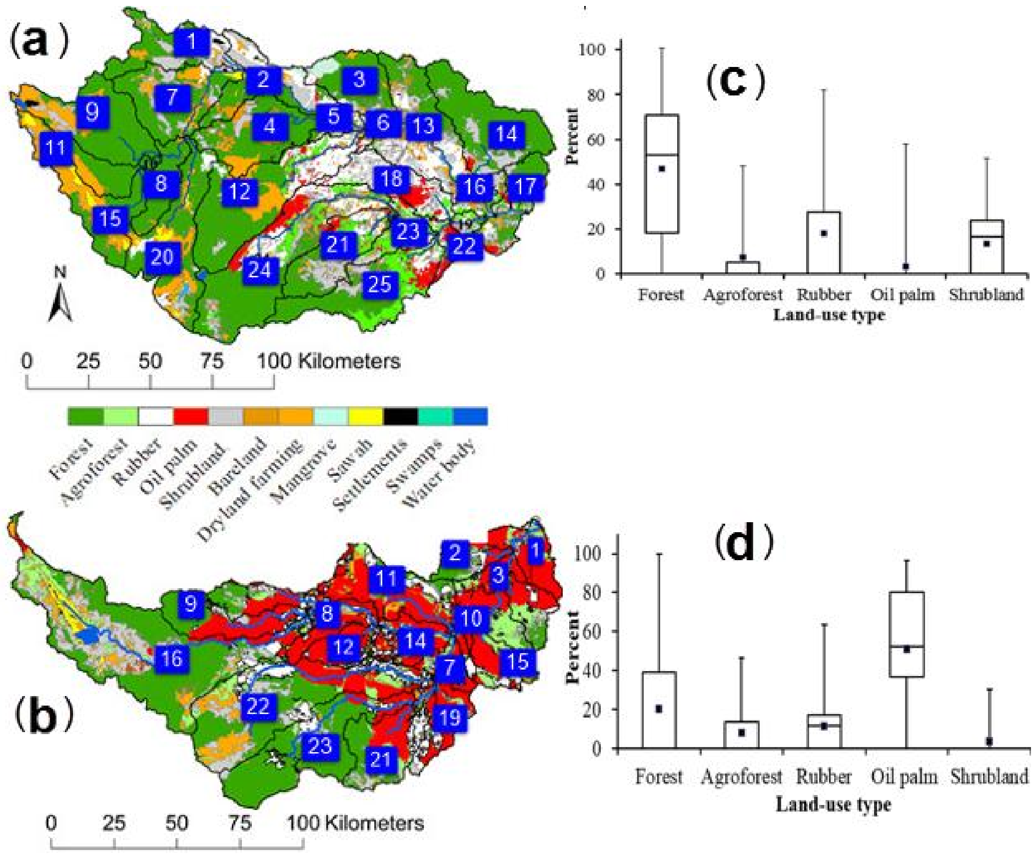

Figure 3. Land-use types and the sub-watershed numbering of the BH (a) and MT (b, Tarigan et al., 2016) watersheds. The box whisker plots (c and d) represent the distribution of the proportion of the land-use types in all sub-watersheds in both watersheds.

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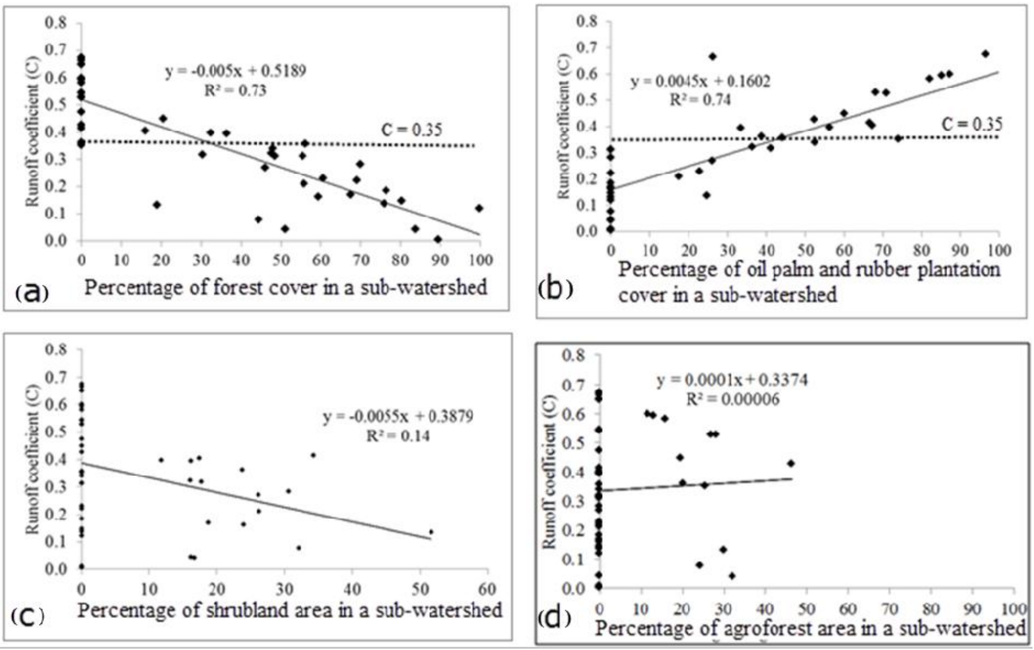

Figure 4. Relation between simulated C values and the proportion of various land-use types in the BH and MT sub-watersheds. Dotted lines indicate the maximum acceptable C value, according to the Ministry of Forestry Decree (2013).

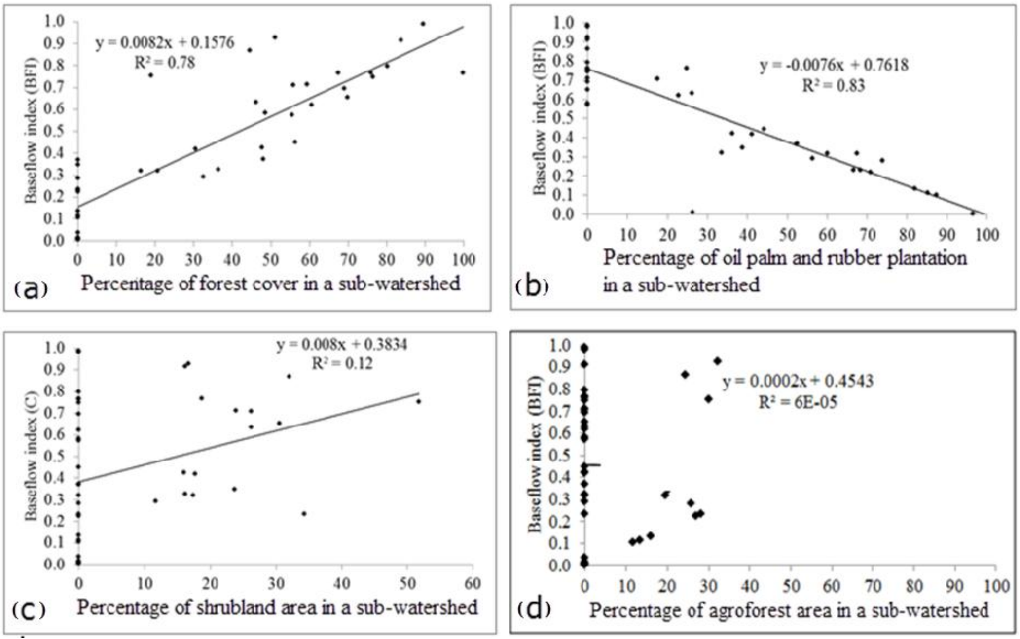

Figure 5. Relation between simulated BFI and the proportion of particular land-use type in a sub-watershed.

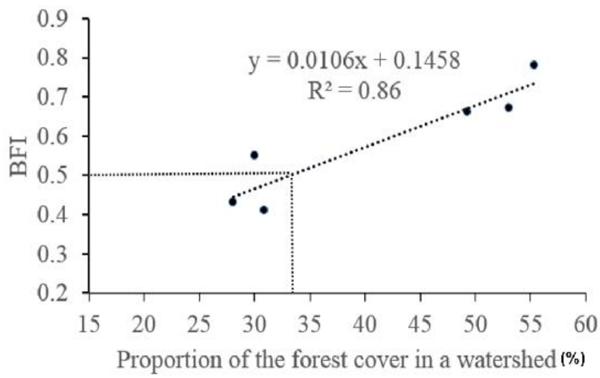

Figure 6. Correlation between the observed BFI values and the proportion of the forest cover (%) in six macro watersheds (see Fig. 1 a)

Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2017-116, 2017
Manuscript under review for journal Hydrol. Earth Syst. Sci.
Discussion started: 29 May 2017

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Tables:

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 of year 2013 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*)

Table 2. Characteristics of macro watersheds selected for calculation of BFI values

Watershed	Watershed area (ha)	Proportion in the watershed (%)	
		Forest	Plantation
Batang Tabir	107,442	53.1	27.6
Batang Pelepat	41,250	55.4	39.8
Batanghari Hulu	1,841,518	49.3	17.1
Batang Bungo	40,220	35.1	55.8
Batang Tebo	180,950	25.1	30.2
Merangin Tembesi	1,345,268	30.9	42.3

Table 3. Proportion of the land-use types, C&BFI values in each sub-watershed of both watersheds

Sub-wat. nr.	Proportion of land-use types F	AF	RP	OP	S	C	BFI
BH watershed							
1	56	0	17	0	26	0.21	0.71
2	46	0	26	0	26	0.27	0.63
3	90	0	0	0	0	0.00	0.99
4	76	0	0	0	0	0.18	0.75
5	16	0	67	0	17	0.40	0.32
6	0	0	67	0	34	0.41	0.23
7	68	0	0	0	19	0.17	0.76
8	100	0	0	0	0	0.01	0.98
9	80	0	0	0	0	0.15	0.79
11	55	0	0	0	0	0.31	0.57
12	61	0	23	0	0	0.23	0.62
13	30	0	41	0	18	0.32	0.42
14	84	0	0	0	16	0.04	0.91
15	49	0	0	0	0	0.31	0.58
16	0	20	39	0	24	0.36	0.35
17	59	0	0	0	24	0.16	0.71
18	0	0	82	19	0	0.48	0.03
19	19	30	0	0	52	0.13	0.75
20	69	0	0	0	0	0.22	0.69
21	45	24	0	0	32	0.08	0.87
22	0	26	16	58	0	0.35	0.28
23	0	48	33	0	20	0.23	0.61
24	66	5	25	5	0	0.14	0.76
25	44	32	0	7	17	0.04	0.93
MT watershed							
1	0	13	0	85	0	0.59	0.11
2	56	0	0	44	0	0.36	0.45
3	0	16	0	82	0	0.58	0.13
4	21	20	12	48	0	0.45	0.32
5	32	0	19	38	12	0.40	0.29
6	0	46	0	52	0	0.43	0.37
8	0	0	15	86	0	0.54	0.01
9	48	0	0	53	0	0.59	0.11
10	0	0	0	96	0	0.34	0.37
11	0	0	19	69	0	0.67	0.00
12	0	0	13	88	0	0.66	0.01
14	0	0	20	80	0	0.54	0.01
15	0	27	14	57	0	0.65	0.01
16	70	0	0	0	31	0.53	0.22
17	0	28	11	57	0	0.28	0.65
19	0	12	31	57	0	0.53	0.23
20	0	0	63	37	0	0.60	0.10
21	48	0	0	36	16	0.65	0.01
22	36	0	17	17	16	0.32	0.42
23	100	0	0	0	0	0.40	0.32

Remarks: Sub-wat. nr.=Sub-watershed number (based on Fig. 3 a and b); F = Forest; AF = Agroforest; OP = Oil palm plantation; RP = Rubber plantation; S=Shrubland; C= Runoff coefficient, BFI = Baseflow index

Table 4. The observed C values derived from the field experiments in the two small watersheds

Event Nr.	Rainfall Intensity (cm h^{-1})	Rainfall Volume (m^3)		Runoff (m^3)		Runoff coefficient (C)	
		1st small-watershed	2nd small-watershed	1st small-watershed	2nd small-watershed	1st small-watershed	2nd small-watershed
1	6.0	8,960	3,136	4,500	1,320	0.53	0.42
2	3.0	5,180	1,813	2,625	840	0.54	0.46
3	1.4	4,095	1,433	3,000	810	0.73	0.57
4	0.6	1,456	509.6	1,080	255	0.74	0.47
5	10.7	14.923	5,223	11.250	3,900	0.75	0.72
6	3.1	6,006	2,102	4,050	1,020	0.67	0.49
7	2.3	8,188	2,885	6,150	1,584	0.75	0.54
8	2.2	4.416	1,465	2,400	780	0.57	0.53
9	9.6	8,916	3,121	5,400	1,650	0.61	0.53
Average						0.65	0.53
Total						0.59	

Remark: The 1st and 2nd small watershed were dominated by rubber and oil palm plantations, respectively.

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Table 5. The simulated C values of all sub-watersheds from SWAT simulation (Table 3) with proportion of plantation cover similar to the two small watersheds

Code of selected sub-watershed from Table 2*	Percentage of		Runoff coefficient (C)
	Oil palm	Rubber	
BH-18**	82	19	0.49
MT-1	85	0	0.59
MT-8	86	15	0.54
MT-10	96	0	0.67
MT-11	69	19	0.67
MT-12	88	13	0.54
MT-14	80	20	0.65
MT-20	37	63	0.65
Average			0.60

Remarks:
* Selection was based on the total proportion of plantation (oil palm and rubber) cover of more than 80% in the entire sub-watershed
** BH-18= Sub-watershed nr. 18 in Batanghari Hulu watershed, MT-1= Sub-watershed nr.1 in Merangin Tembesi watershed.