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Research article

Assessment of land use impact on hydrological response using Soil and Water Analysis Tool (SWAT) in Babak watershed, Lombok Island, Indonesia

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Abstract

Changes in land utilization may affect the hydrological function of a watershed. The land use impact on the hydrological response was assessed in the Babak watershed, one of the strategic watersheds on Lombok Island, West Nusa Tenggara, Indonesia. The hydrological response obtained from the analysis using the Soil and Water Analysis Tool considered discharge, runoff, water yield, erosion and sediment transported. Land use change impact was estimated in 2010 and 2013. The results showed that the hydrological response in the Babak watershed was not only influenced by land use change but also by other factors such as climate, soil, geology and topography.

Introduction

Land use change may affect the quality of the environment, through erosion (Cebecauer and Hofierka, 2008; Zokaib and Naser, 2012; Paroissienet al., 2015), soil damage(Talakua, 2009), discharge and surface runoff (Nunes et al., 2011; Shukla et al., 2016), sedimentation (Yan et al., 2013) and also decreased air quality and biodiversity (Li et al., 2013). In a watershed, land use change may affect the hydrological response (Nunes et al., 2011; Shukla et al., 2016). The Babak watershed is one of strategic watersheds on Lombok Island with high utilization of water resources (The Southeast Nusa Tenggara River Region I Institute, 2012). The watershed supplies water to most of Lombok Island in the form of smallholder water consumption, bottled drinking water industry, irrigation, ponds and also for recreation. A decrease in the hydrological function may be associated with increased changes in critical land uses in the Babak watershed. Based on Murtilaksono (2014) during 2008–2014, land with critical status in the Babak watershed increased by more than 11%, with only 39% remaining categorized as not critical, where the critical land issue in the Babak watershed has been attributed to land use change and physical conditions such as soil, geology, topography and climate. The Babak watershed has been classified as a restored watershed (Murtilaksono, 2014), indicating that many aspects were not working properly, including: land use, water (quality, quantity, continuity), social economics, investment in waterworks and spatial planning of the Babak watershed. Thus, critical land issues in the Babak watershed must be overcome immediately.

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One determinant of critical land is a land use pattern that is not appropriate, requiring land use changes and improvement in land cover in the watershed (Nunes et al., 2011; Li et al., 2013). Young (1990) stated that land use was highly dependent on government policy. In Indonesia, land use is regulated under Law No.26/2007 which covers spatial planning (Government Law, 2007). As a strategic watershed with high water resources utilization, the management of the Babak watershed is under the Ministry of Public Works and Public Housing of the Republic of Indonesia, which manages several facilities such as dam and irrigation channels (The Southeast Nusa Tenggara River Region I Institute, 2014). Monitoring of land use change in the Babak watershed is urgently needed to assess the change in water response which is related to the ability of the watershed to supply water resources. In this case, the monitoring can be done through the analysis of a spatial data series.

Watershed management is the best way to restore a critical watershed. Data of land use and the hydrology of the watershed are required to prepare watershed management activities that are suitable. The hydrological characteristics can be obtained from an observation data series, while land characteristics can be used to develop the hydrological response on the watershed. The Soil and Water Analysis Tool (SWAT) is one option to assist in obtaining potential hydrological data on the watershed where there are limited data available (Stehr et al., 2008) such as in the Babak watershed. The SWAT model can make predictions regarding the water yield, evaporation, erosion, sediment yield and soil fertility (Neitsch et al., 2011), as well as showing the environment quality in a watershed. A hydrological model is satisfactory if it produces resultsin line with the field observation data. The validity of the model can be determined using the coefficient of determination (R^2) and the Nash-Sutcliffe index (NSI) for some values (Stehr et al., 2008). A satisfactory model following validation can then be used to predict watershed condition (Ayana et al., 2012).

Some studies have used the SWAT model analyze the impact of land use change on the watershed function in Indonesian watersheds. Firdaus et al. (2014) used SWAT to analyze the river regime coefficient as the hydrological response to different soil conservation options in the Lengkong watershed; Iqbal et al. (2015) applied SWAT to show the downward trend of water availability due to the impact of land use change in the Tapung watershed. The evaluation of the land and hydrological characteristics of the watershed can be to determine watershed health both qualitatively and quantitatively (Murtiono and Paimin, 2016) and such data can be used to develop the watershed management planning to overcome watershed problems that arise due to critical land activities such as erosion and flooding. In this regard, the aim of the current study was to assess the land use impact on hydrological response in the Babak watershed.

Materials and Methods

Description of study site

The Babak watershed, a small watershed in Lombok Island, West Nusa Tenggara, is located 8°42’–8°67’S and 116°07’–116°39’E with an area of 299.48 km^2. This watershed is the North and Middle Lombok districts in the upper- and middle-stream of the watershed, and also in the Mataram municipality and West Lombok district in downstream (Fig. 1). Most of the Babak watershed is located on Rinjani Mountain so that the dominant parent material is volcanic (Bemmelen, 1949). The dominant rock type is andesitic in the upper stream, basaltic in the middle stream and alluvium in the downstream.

Based on the topographic mapping (scale 1:25,000), the width of the Babak watershed is 46.38 km and its perimeter is 120.62 km, while the total length of streams is 853.65 km. The Babak watershed can be categorized as elongated with a circularity ratio of 0.26, the drainage pattern is parallel with a drainage density of 3.01 km/km^2 and the average stream gradient is 0.047.

Based on data from 1985 to2014 (BMKG, the average annual rainfall in the study site is 1854.4 mm. The highest rainfall occurs in January with average 276.3 mm, while the lowest rainfall occurs in August with average 19.4 mm. The type of climate based on Schmidt and Fergusson (1951) is classified as ‘C’ (almost wet) with a Q value 0.571 and four dry months , seven wet months and one moist month in a year. Based on the climatic data mentioned above, from 2005 to2014, the highest monthly average temperature occurs in October (27.3°C) and the lowest occurs in September (23.4°C), the highest monthly maximum temperature occurs in October (32.1°C) and the lowest occurs in August (20.1°C) and the highest wind velocity occurs in August and September (9.1 knots), while the lowest occurs June (7.4 knots). Based on the Beaufort scale criteria (Wisnubroto et al., 1986), a wind velocity of 7–10.4 knots categorized as a ‘gentle breeze’ which can make the leaves and twigs of trees sway and will move a light flag. The highest solar radiation occurs in August (61.2 MJ/m^2/day).

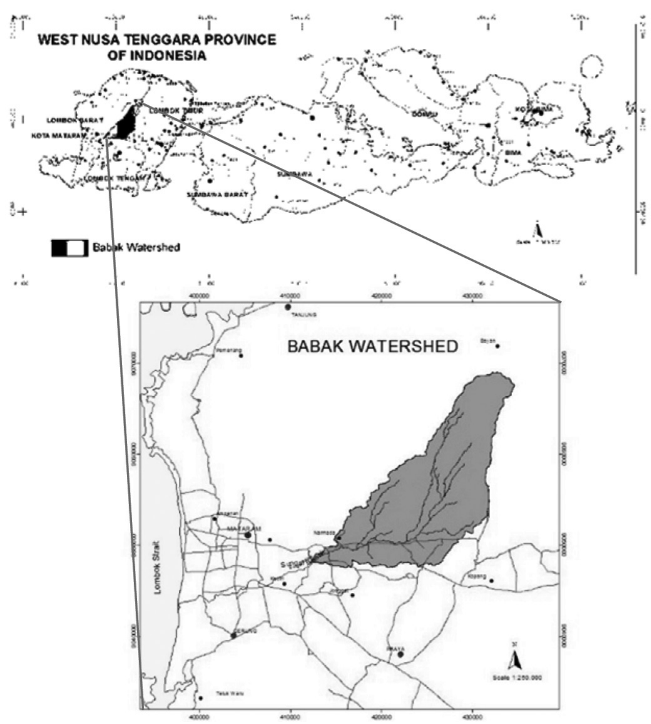

Fig. 1 Map of Babak watershed

Study materials

The primary data used in the study were soil properties: solum, texture, percentage of particle soil distribution, bulk density, albedo, water available capacity, C-organic, and also vegetation density. Soil samples based on stratified random sampling were taken at nine points and their properties were classified according to the criteria of FAO (2006) and Indonesian Soil Research Institute (2009). To posequence was used as the stratification, and point sampling in each toposequence was determined randomly. Three soil profiles for every toposequence were recorded, resulting in a total sampleof 9soil profiles and 23 layers. These data were used as soil attribute inputs in SWAT. Soil sampling locations were determined using topographical and geological mapping. The morphological characteristics were observed directly from the soil profiles in the field. The solum and soil layers were determined using a measuring tape, and the soil color was identified using a Munsell Soil Color Chart (Purwowidagdo), while the structure and roots were described using guidelines from FAO (2006). Undisturbed soil samples (approximately 0.5 kg/sample) were taken in each soil layer and taken to the soil laboratory for analysis.

The physical characteristics analyzed in the laboratory were soil texture, bulk density (BD), particle density (PD), porosity and soil erodibility. The texture was analyzed using the pipette method (Purwowidodo, 1992), PD was analyzed using the pycnometer method (Purwowidodo, 1992), the BD was analyzed using the ratio of absolute dry weight to soil volume weight, the porosity was analyzed using the ratio of BD and PD and the erodibility was analyzed using the formula from Wischmeier and Smith (1978). The chemical characteristics analyzed in the laboratory were: organic carbon (OC), pH, total N (TN), P and the cation exchange capacity (CEC). The methods used for these analyses were: the Walkley and Black method for OC (Purwowidodo, 1992), the Kjedahl method for TN (Purwowidodo, 1992), the Bray method for P (Purwowidodo, 1992) and the extracted ammonium acetate 1N (pH 7) for CEC. The soil morphological and physic-chemical properties were further analyzed using the matching method to identify soil quality.

The secondary data were daily rainfall and climate from the Water Resources Information Board of West Nusa Tenggara Province, the Department Agriculture of West Nusa Tenggara Province, the Meteorology, Climatology, and Geophysics Regional Agency of West Nusa Tenggara Province, while Climate Forecast System Reanalysis system (www.globalweather.tamu.edu) provided missing data. There were three water flow recording stations (SPAS) at Gebong, Lantan Daye and Perampuan, while the rainfall recording stations were Jurang Sate, Gerung, Pringgarata, Batukliang, Kopang and Kediri. Daily rainfall and climate data from 2007 to 2014were used in the study. The data from SPAS Perampuan were used for validation.

Spatial data in the form of a land use map for 2007 and 2013 was obtained from Landsat 7 ETM+imagery interpretation in path 116 and row 66 which was provided by the Indonesian Ministry of Forestry. The slope gradient map and digital elevation model (DEM) were analyzed based on the topographic map at 1:25,000 scale, while soil mapping units were analyzed based on the soil map at 1:250,000 scale.

Data analysis

The analysis software used was Arc SWAT 2012. The first step in SWAT is creating the watershed boundary and the arrangement of the hydrological respond units (HRUs) based on the land use map, slope gradient map, DEM map and soil map overlay. The next step considered the daily rainfall and climate (2007–2014) data input, followed by land use and soil attributes. Then, the SWAT model was run to get desirable outputs such as discharge (*flow_out)*, runoff (*SurfQ*), water yield (WYLD), erosion (SYLDt_ha) and sediment transported (SED_OUT tons). The output of the SWAT model was validated by comparison with the observed data from SPAS based on the coefficient of determination (r^2) and the Nash-Sutcliffe index (NSI). According to Steel and Torrie (1993), a good r^2 value should have a value approaching 1 (Equation 1):

$$r^2 = \left(\frac{\sum_{i=1}^{n}(Q_{0,i} - \overline{Q}_0)(Q_{s,i} - \overline{Q}_s)}{\sum_{i=1}^{n}(Q_{0,i} - \overline{Q}_0)^2} \right) \left(\frac{\sum_{i=1}^{n}(Q_{0,i} - \overline{Q}_0)(Q_{s,i} - \overline{Q}_s)}{\sum_{i=1}^{n}(Q_{s,i} - \overline{Q}_s)^2} \right) \quad (1)$$

where $Q_{0,i}$ is the observed discharge (m^3/s), $Q_{s,i}$ is the SWAT model of discharge (m^3/s), $\overline{Q}_0$ is the average observed discharge (m^3/s) and $\overline{Q}_s$ is the average SWAT model of discharge (m^3/s).

The simulation of the model category based on the NSI value was considered good if NSI > 0.75, satisfactory if 0.75 ≥ NSI ≥ 0.36 and less than satisfactory if NSI < 0.36 (Stehr et al. 2008), using Equation 2:

$$NSI = 1 - \left(\frac{\sum_{i=1}^{n}(Q_{0,i} - Q_{s,i})^2}{\sum_{i=1}^{n}(Q_{0,i} - \overline{Q}_0)^2} \right) \quad (2)$$

The SWAT analysis provided some basic information used to determine the condition of the Babak watershed. In Indonesia, the criteria and indicator of a watershed are set by state regulation in Ministry of Forestry Decree (2014) No.P.61/Menhut-II/2014 (Table S1), so the evaluation of the Babak watershed hydrological response was carried out according to this regulation.

Results and Discussion

Dynamics of land use change in Babak watershed

The soil morphology in the upper and middle toposequences had shallow soil depths (<45 cm) compared with the lower toposequence (197 cm), and almost all had 1–3 layers in each soil profile with a clear boundary. The soil physical properties showed that most of the soil texture was in the coarse category, the specific gravity was low (in the range 1.44–2.12g/cm^3), the bulk density ranged from 0.65g/cm^3 to 1.78g/cm^3, the porosity was low to high (0.06–0.65) and the erodibility was low to medium (0.01–0.3). The soil chemical properties showed that the pH was slightly acid to neutral (5.21–7.07), TN was low to medium (0.08–0.49%), the OC was from very low to high (0.47–5.6%), P was very low (1.85–4.73 mg/kg) and the CEC was from very low to high (1.2–36.4 cmol/kg).

Table S1 Criteria and indicators of watershed performance (Ministry of Forestry Degree, 2014)

No	Parameter	Criterion	Formula	Indicator	Classification
1	Discharge	River regime coefficient (KRS)	$KRS = \frac{Qmax}{Qmin}$	KRS ≤ 20	Very low
				20 < KRS ≤ 50	Low
			Qmax = maximum discharge (m^3/s)	50 < KRS ≤ 80	Moderate
			Qmin = minimum discharge (m^3/s)	80 < KRS ≤ 110	High
				KRS > 110	Very high
2	Runoff	Runoff coefficient (C)	$C = \frac{Q}{P}$	C ≤ 0.2	Very low
				0.2 < C ≤ 0.3	Low
			Q = annual discharge (mm)	0.3 < C ≤ 0.4	Moderate
			P = annual precipitation (mm)	0.4 < C ≤ 0.5	High
				C > 0.5	Very high
3	Water yield	Water use index (IPA)	$IPA = \frac{Q}{P}$	IPA > 6800	Very good
				5100 < IPA ≤ 6800	Good
			Q = water yield (cm/yr)	3400 < IPA ≤ 5100	Moderate
			P = total population	1700 < IPA ≤ 3400	Poor
				IPA < 1700	Very poor
4	Soil erosion	Erosion index (EI)	$EI = \frac{A}{TE}$	EI ≤ 0.5	Very low
				0.5 < EI ≤ 1.0	Low
			A = actual erosion (t/ha)	1.0 < EI ≤ 1.5	Moderate
			TE = tolerable erosion (t/ha)	1.5 < EI ≤ 2.0	High
				EI > 2.0	Very high
5	Sediment	Sediment transported (Sed)		Sed < 5	Very low
				5 < Sed ≤ 10	Low
				10 < Sed ≤ 15	Moderate
				15 < Sed ≤ 20	High
				Sed > 20	Very high

The results of land use map analysis in 2007 and 2013 showed that there were changes in the areas for specific land uses (Table 1). There was a decrease in the balance of natural vegetative land use (primary, secondary, plantation forest and shrub) with increasing artificial vegetative land use (mixed dry farming, dry farming and rice field). Each changed 0.26% from 2010 to 2013. Table 1 shows the dynamic patterns of land use change in the Babak watershed for 2010–2013 during which the primary forest, secondary forest, plantation forest, shrub and settlement all decreased. The decline in primary, secondary and plantation forest was probably caused by illegal land clearing as was evident from field observation where there was an absence of trees with some being replaced by shrubs. Some communities had opened up the forest for use as crop cultivation. The practice of cultivating seasonal crops in forest areas is only allowed in secondary forest areas (known as community forest activity) under the Regulation of the Ministry of Forestry No. P.37/Menhut-II/2007. A forest utilization license for community forest is granted to farmer groups who have submitted permits to the government that adhere to strict conditions. It would appear that land clearing in the study area has been carried out by a community group without the necessary utilization license. Mixed dry farming, dry farming and rice field were land uses that increased from 2010 to 2013. Based on field observation, mixed dry farming was usually located in settlement areas and some were in private forest. Some of the increase in these land uses resulted from forest plantations and shrubs.

Hydrological characteristics in Babak watershed

The results of the SWAT analysis showed in 2010 and 2013 there were 27 sub basins and 158 HRUs for basic discharge, runoff and water yield calculations in the Babak watershed. They were compared using r^2 and the NSI. After validation and calibration, in 2010, the r^2 value was 0.87 and the NSI value was 0.59, while in 2013, the r^2 value was 0.90 and the NSI value was 0.52. Based on Stehr et al. (2008), validation results indicated that the model was satisfactory and so it could be used for hydrological response analysis in the Babak watershed. The comparison of the observed discharge with the prediction model in 2010 and 2013 is shown in Fig. 2.

Watershed health can be seen from hydrological responses such as discharge, erosion and sedimentation. In Indonesia, regulation for the monitoring and evaluation of watersheds is controlled under the

Table 1 Land use change in Babak watershed in 2010 and 2013

Land use	2010		2013		% change
	Area (ha)	%	Area (ha)	%	2007–2013
Primary forest	4,195.2	14.01	4,175.9	13.94	-0.06
Secondary forest	2,723.1	9.09	2,715.3	9.07	-0.03
Plantation forest	824.2	2.75	816.5	2.73	-0.03
Shrub	7,506.3	25.06	7,464.1	24.92	-0.14
Settlement	604.5	2.02	602.5	2.01	-0.01
Water bodies	7.5	0.03	7.5	0.03	0.00
Dry farming	640.6	2.14	662.2	2.21	+0.07
Mixed dry farming	3,477.9	11.61	3,521.5	11.76	+0.15
Rice field	9,969.0	33.29	9,982.9	33.33	+0.05
Total	29,948.4	100.00	29,948.4	100.00	

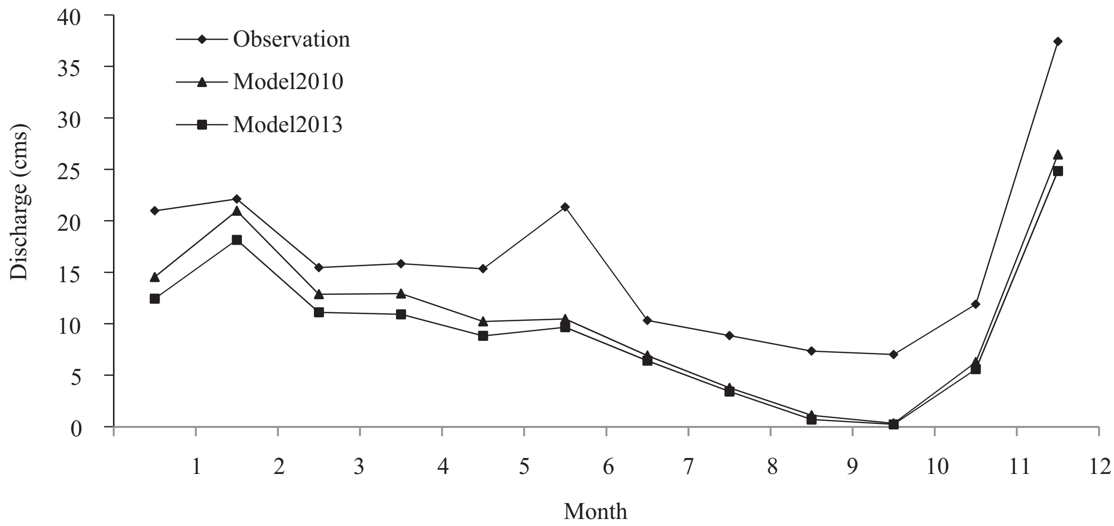

Fig. 2 Comparison of monthly observation of discharge and model prediction in 2010 and 2013

state Ministry of Forestry Degree No.P.61/Menhut-II/2014, that has two parameters related to discharge which can be used to show the hydrological function of the watershed: the river regime coefficient (RRC) and the water use index (WUI). The results showed that in general there was no fluctuation in the values of total discharge, maximum discharge, minimum discharge; and the river regime coefficient (Table 2).

During 2010–2013, the total discharge and maximum discharge tended to decrease; while the RRC increased by 13.20%. The RRC indicates the balance of discharge calculated from a comparison between the maximum (Qmax) and minimum (Qmin) discharge. It shows the continuity of discharge availability in the period, with a higher RRC indicating discontinuity of available discharge in that period (Asdak, 2010). The increase in the RRC during 2010 to 2013 indicated that there was a great imbalance between Q max and Q min, which would be expected if the Babak watershed had reduced rainfall storage in the rainy season, so that there was less water availability in the dry season. Some factors that may have influenced this condition include the climate and the physical characteristics of the watershed. Discharge has a positive relationship with rainfall, where the greater rainfall, the greater the discharge (Singh, 1997), while the physical characteristics of the watershed will affect the stream flow (Horton, 1945). Rainfall factors that affected the discharge were time variability and rainfall distribution; while the physical characteristics of the watershed were slope gradient, drainage density and the geology of the watershed. The results showed that the rainfall in 2013 had decreased 10.12% from 2010 and the total discharge had decreased 5.86%, indicating that rainfall contributed almost 50% of the discharge.

The hydrological response in the Babak watershed can also be shown using runoff, as reflected by the runoff coefficient (C) that depends on the rainfall in the watershed, where a closer to 0 is considered better (Asdak, 2010). A greater C value may affect flooding and erosion in a watershed (Asdak, 2010). The current results showed that the value of runoff in the Babak watershed was 457.44 mm in 2010 and 420.41 mm in 2010, while the C value in the ‘very low’ category in both years (Table 3).

The C values indicated that the Babak watershed was in good condition because only a limit amount of rainfall became runoff. The highest runoff occurred in shrub and the lowest in settlement. Runoff has a negative relationship with the land cover, where the greater the land cover, the lower runoff (Zokaib and Naser, 2012; Cadaret et al., 2016) because the vegetation can reduce run off and intensify infiltration (Wischmeier and Smith, 1978; Cadaret et al., 2016; Gomyo, 2016). In the current study, only the artificial vegetation land use (dry farming, mixed dry farming and rice field) had a negative relationship with runoff. This condition was probably caused by other factors such as soil parameters and the ground litter or under

Table 2 Rainfall, total discharge (Q), maximum discharge (Q max), minimum discharge (Q min) and river regime coefficient (RRC) in Babak watershed in 2007 and 2013

Parameter	Year		% change in 2007–2013
	2010	2013	
Rainfall (mm)	2,975.15	2,428.37	-10.12
Total Q (cms)	845.81	752.20	-5.86
Qmax (cms)	181.46	170.12	-3.23
Qmin (cms)	2.11	1.52	–
RRC	85.81	111.91	13.20
RRC classification	High	Very high	–

Table 3 Runoff and runoff coefficient in Babak watershed by land use in 2010 and 2013

Land use	Runoff (mm)		Runoff coefficient	
	2010	2013	2010	2013
Primary forest	79.75	72.88	0.027	0.024
Secondary forest	56.33	51.43	0.019	0.017
Plantation forest	24.18	22.18	0.008	0.007
Shrub	145.81	133.06	0.049	0.045
Settlement	1.72	1.78	0.001	0.001
Dry farming	10.40	9.84	0.003	0.003
Mixed dry farming	63.52	59.38	0.021	0.020
Rice field	75.73	69.86	0.025	0.023

storey. Most of the natural vegetation land uses (primary, secondary, plantation and shrub) had the same soil texture as the artificial vegetation land use (sandy loam), but the under storey for the natural vegetation land use was higher than for artificial vegetation land use (Table 4), so the runoff did not have a negative relationship with the area of the land use.

The water yield analysis results showed that there were fluctuations in the monthly water yield in the Babak watershed. In 2010, and 2013, the lowest water yield occurred in October and the highest was in December (Fig. 3). The water yield in 2010 was greater than in 2013, as was the discharge (Table 2). In comparison to the RRC

Table 4 Under storey in Babak watershed by land use

Land use	Under storey (Individuals/ha)
Primary forest	37,500
Secondary forest	107,250
Plantation forest	79,167
Shrub	49,531
Dry farming	31,667
Mixed dry farming	48,889
Rice field	–

classification (Table 2) indicated that condition was in line with the research resulted by Asdak (2010) that a watershed that cannot utilize water in the rainy season, results in a low water yield in the dry season, as shown in the September and October data (Fig. 3).

The water yield may support watershed performance, as shown by the water use index (Table 5). The water use index was calculated based on the water yield and total population in the Babak watershed. The population data were sourced from The West Nusa Tenggara Centre of Statictical Agency (2014) based on an assumption of 1% population increase annually. Table 5 shows that the water use index in the Babak watershed decreased from 2010 to 2013 but both years were classified as in good condition, indicating that the watershed could supply the water needed, although at minimum levels in September and October.

Other hydrological responses were erosion and sedimentation. Erosion was classified as good if it did not exceed tolerable erosion (Asdak, 2010). The current results showed that most of the erosion in the Babak watershed was classified as very low to low (Table 6). Greater erosion occurred in the shrub layer, while the lowest was in settlement. Primary forest had a higher erosion rate than secondary forest (Table 1). The greater the decrease in the forest area decrease, the greater the erosion, which was in line with Paroissien et al. (2015). Another factor that resulted in erosion in the secondary forest being lower than in the primary forest was the slope gradient in the primary forest was greater than in the secondary forest, so that with the same soil properties, the steep gradient slope probably triggered greater erosion (Shen et al., 2016). The pattern of the erosion in the Babak watershed was also in line with the runoff (Table 3) which increased with increase erosion. Runoff and erosion had a positive relationship as reported by Nunes et al. (2011).

Erosion is strongly linked with the sediment transported in a watershed. The current results showed that there was decreased sediment transportation in the Babak watershed from 2010 to 2013 (Fig. 4). Based on the Ministry of Forestry Degree No. P.61/Menhut-II/2014, the monthly sediment transported in the Babak watershed was classified as low. The total sediment transported decreased from 8.4 t/ha in 2010 to 6.82 t/ha in 2013. The pattern of sediment transported was in line with the pattern of runoff in the Babak watershed, as increased runoff will increase the sediment transported (Nunes et al., 2011). The amount of sediment transported also depends on the physical characteristic of the watershed such as the stream gradient and the geology. The dominant geology in the Babak watershed consists of andesitic igneous rock which is hard and solid, so that it is resistant to weathering and erosion. The stream gradient in the Babak watershed was not steep, so the sediment delivery was less intensive.

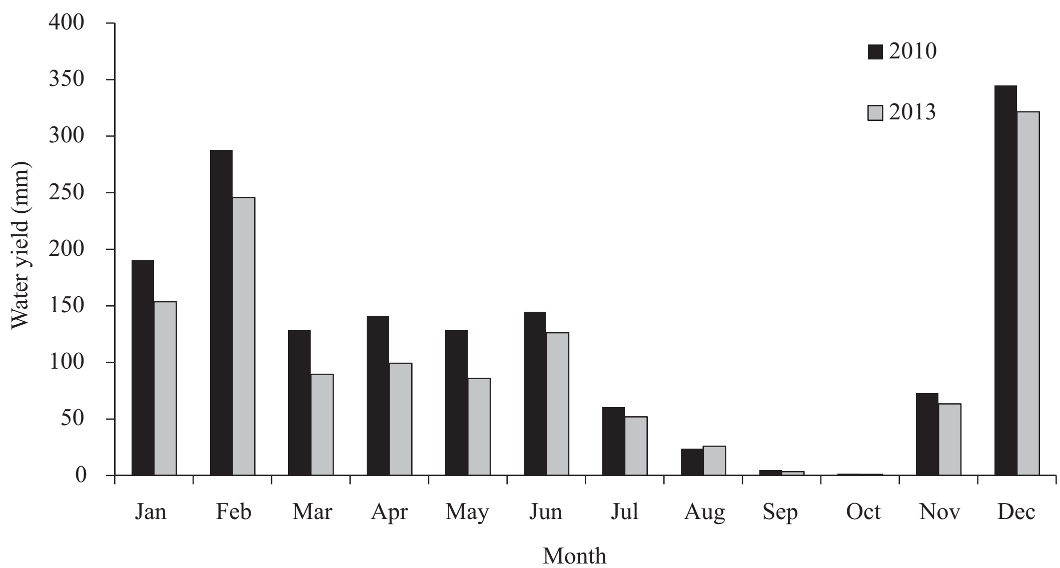

Fig. 3 Monthly water yield in Babak watershed year in 2010 and 2013

Table 5 Water use index in Babak watershed in 2010 and 2013

	2010	2013
Water yield (mm/year)	1,528.52	1,267.99
Water yield (m^3/yr)	457,766,831.30	379,743,189.30
Total population	55.35	57,058.00
Water use index	8,271.01	6,655.42
Classification	Good	Good

Table 6 Tolerable erosion (TE) and erosion rate in Babak watershed in 2010 and 2013

Land use	TE (t/ha)	Erosion (t/ha)	
		2010	2013
Primary forest	21.08	20.74	14.64
Secondary forest	17.81	14.65	10.33
Plantation forest	23.78	6.29	4.45
Shrub	23.89	37.92	26.73
Settlement	27.93	0.45	0.36
Dry farming	30.29	3.71	1.98
Mixed dry farming	25.34	16.52	11.93
Rice field	24.83	19.69	14.03

The results of the SWAT analysis showed that in general, the hydrological response of the Babak watershed was not influenced by land use change. However, it was influenced by other factors such as the physical characteristics of the watershed including the climate, soil, geology and topography. Land use change only affected a small part of the hydrological response such as the impact on primary and secondary forest due to erosion.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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