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The utilization of satellite imagery data to predict hydrology characteristics in Dodokan Watershed

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Abstract

Satellite imagery has been widely used in many fields, including watershed management, environmental management, and disaster mitigation. In watershed management field, this dataset provides the land use map that is an input for watershed management planning and prediction of hydrology characteristics of a watershed. It can be done using hydrology model that requires detailed parameters such as: land use type, soil characteristics, topography, and climatic data. This research was conducted in Dodokan Watershed at Nusa Tenggara Barat Province with area of 54,279.25 ha. The hydrology characteristics of Dodokan watershed was predicted using the Soil and Water Assessment Tool (SWAT) model. Based on the analysis of three years rainfall datasets (2010-2012), land use map (2012) and soil characteristics data (2014) as well as average of curve number of 75.03, the highest surface runoff volume was 35.18 mm with the highest rainfall of 52.39 mm and runoff coefficient is 0.33.

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Keywords: hydrology characteristic; satellite imagery data; SWAT; watershed

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1. Introduction

Watershed is an area of land that is bounded by hydrologic system, where all of the water that is under it or drains off of it goes into the same outlet [1, 2]. As a system, watershed condition is affected by land-water-climate-people interaction. When it is not balance, the problems will arise due to declining of the quality and quantity of watershed hydrology [3-5]. Watershed degradation is often preceded by the destruction of forests as a result of changes in forest land to other utilization such as settlement and agriculture [6, 7]. Population and economic growth are also reason of the declining in the carrying capacity of the watershed [8, 9].

Dodokan watershed, which is located in West Nusa Tenggara Province, Indonesia, is an example of a watershed that its condition has affected the sustainability of watershed. This is associated with both rapid population and economic growth in Mataram City. Land cover in Dodokan Watershed is dominated by dry land agriculture and mixed dry land agriculture with area of 13,827.65 ha (25.48%) and 17,908.24 ha (32.99%) respectively, while forest cover only about 5.29% from watershed area. Under these circumstances, it is important to know the hydrological condition of Dodokan watershed so that the stakeholders can make a right decision according to watershed management.

Satellite imagery data especially land cover/land use map is also used as an input for watershed management planning and prediction of hydrology characteristics [10-12]. The prediction of hydrology characteristics can be done manually with an equation or automatically with a hydrology model [13, 14]. The SWAT (Soil and Water Assessment Tool) model is a river basin-scale hydrological model and developed to predict the impact of land management practices, climate and other influences on the water, sediment and agricultural chemical on complex watershed with variations in soil, land use and management over a long time period [15-17].

The aim of this study is to analyze the hydrological condition of Dodokan watershed based on land use map and its characteristics using the SWAT model.

2. Methodology

2.1. Watershed description

The research was conducted in Dodokan watershed in Lombok Island, Indonesia (Fig. 1) with total area of 54,279.25 ha. Dodokan watershed is geographically situated between 8°36’-8°52’ S and 116°50’-116°21’ E. The watershed is administratively located between West Lombok and Central Lombok Regency, West Nusa Tenggara Province. Landform in the research area is dominated by flat terrain about 43.38% and undulating volcanic plains of 24.16%. The elevation in Dodokan watershed ranges between 5-725 m above sea level.

Soil types in Dodokan watershed are Regosol, Litosol, and Mediteran (Fig. 2). Most of Dodokan watershed area is utilized as agricultural lands (58%), that is divided into dry land agriculture and mixed dry land agriculture with an area of 13,828 ha and 17,908 ha respectively (Table 1).

2.2. Description of SWAT model

The hydrological condition of Dodokan Watershed was predicted by executing SWAT version 2012. The inputs of model consist of soil type, land use type, contour data from Shuttle Radar Topography Mission (SRTM) with resolution 90 x 90 m, and climate datasets (rainfall, temperature maximum and minimum, solar radiation, relative humidity, and wind speed).

2.3. Prediction procedure

The research procedure is depicted in Fig. 3. The characteristics of soil were collected from both field observation and laboratory analysis. Land use map was derived from land cover map 2012 and classified by Forest Planology Agency Department of Ministry of Environmental and Forestry and its characteristic came from field survey and literature. The daily climate data collected from 2010 to 2012. The location of rainfall and climate gage is represented in Fig. 4.

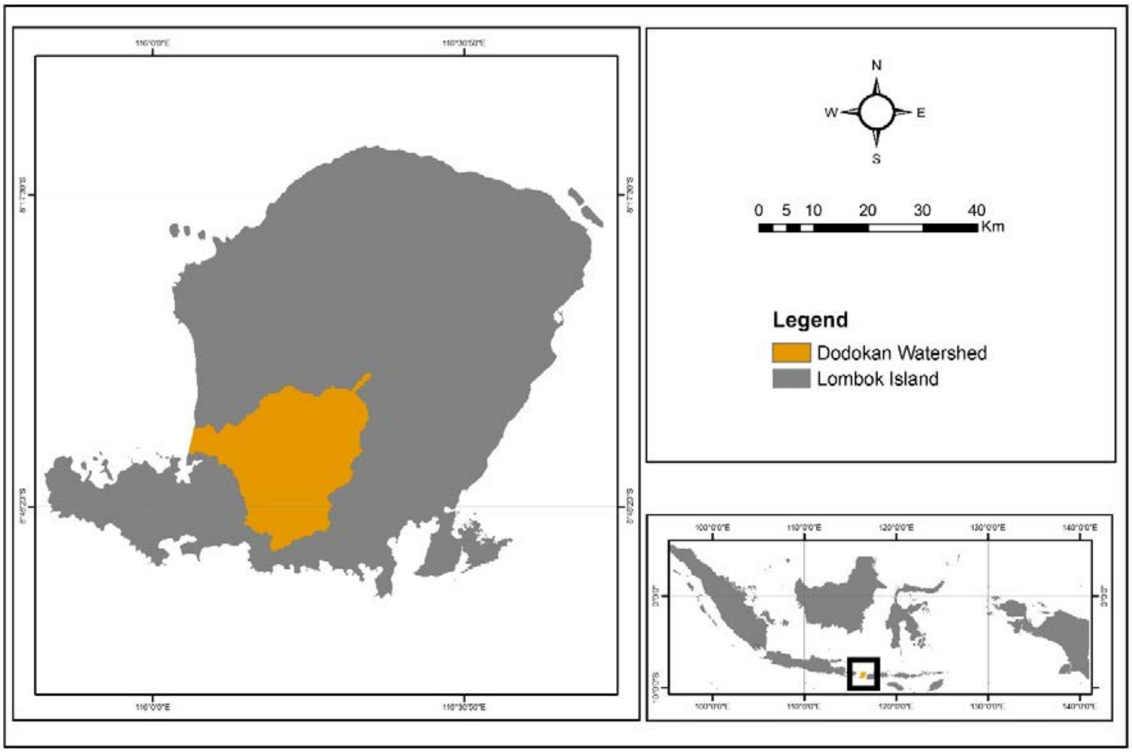


Fig. 1. The research area: Dodokan Watershed.

Table 1. Land use types in Dodokan Watershed.

No.	Land Use Type	Area (ha)
1	Water Body	1,055.42
2	Transportation	262.84
3	Bermuda grass	3,003.19
4	Forest Evergreen	141.09
5	Forest Mixed	2,728.00
6	Residential-Medium Density	1,056.45
7	Dry Land Agriculture	13,827.65
8	Mixed Dry Land Agriculture	17,908.24
9	Rice	14,134.07
10	Wetlands-Non-Forested	162.31
Total		54,279.25

The model simulation for Dodokan watershed was performed for 3-year data period of 2010-2012. The year of 2010-2011 was run for the model warm-up period. This period is needed by the model because there is uncertainty factors in watershed management that affect the process in hydrological modelling [18, 19]. The last year (2012) was applied for the calibration process in daily period.

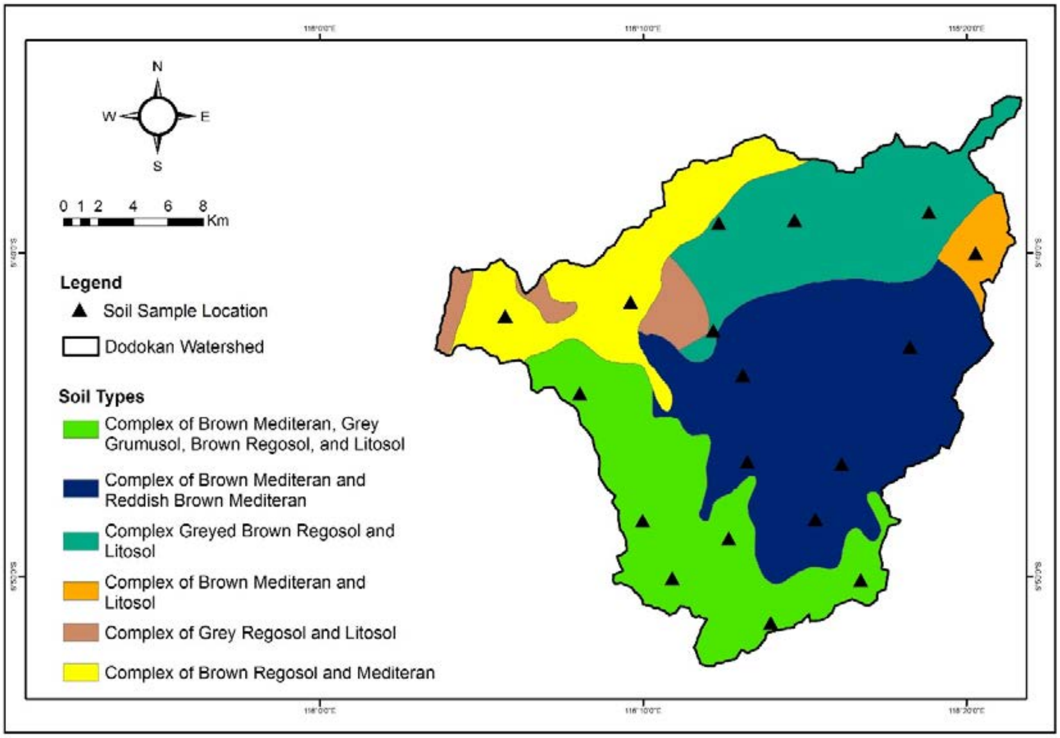


Fig. 2. Soil types and soil sample location in Dodokan Watershed

3. Results and Discussion

The determination coefficient (R2) and Nash-Sutcliffe efficiency value (NS) before calibration were 0.42 and 0.37, respectively. Therefore, the model cannot be applied for predicting hydrological condition of Dodokan watershed yet. Figure 4 shows the simulation and measurement hydrograph before calibration and the correlation between simulation and measurement results. Figure 5 (a) shows that the predicted model of the discharge was lower than the observation value in some point but were higher discharge at other points. Therefore, calibration process was done to optimized some parameters of the model which affecting the discharge pattern. Calibration resulting R2 value increased to 0.48 and NS of 0.40 (Figure 6). The NS prior to calibration and after calibration was not significantly change. This is suggested because the value of some selected parameters in calibration process were not optimum yet for the watershed. In spite of the fact that, the NS value is categorized as satisfy value [20]. So that the model can be applied to predicts the hydrological condition of Dodokan watershed. Some SWAT researches in Indonesia also show that the model is able to predict the hydrological condition of a watershed [21-23].

Table 2 shows the hydrological characteristics of Dodokan watershed. The highest surface runoff was in April of 83.48 mm which is derived from 216.25 mm rainfall. Based on data analysis, the portion of rainfall contributing surface runoff was 38.60%. This value is related to discharge pattern depicted in Figure 5. The predicted discharge is lower than observation value although the calibration process was done. The coefficient runoff of Dodokan watershed is 0.33. it indicates that Dodokan watershed condition still remains good. However, the watershed should be managed in better way to obtain the sustainability of Dodokan watershed.

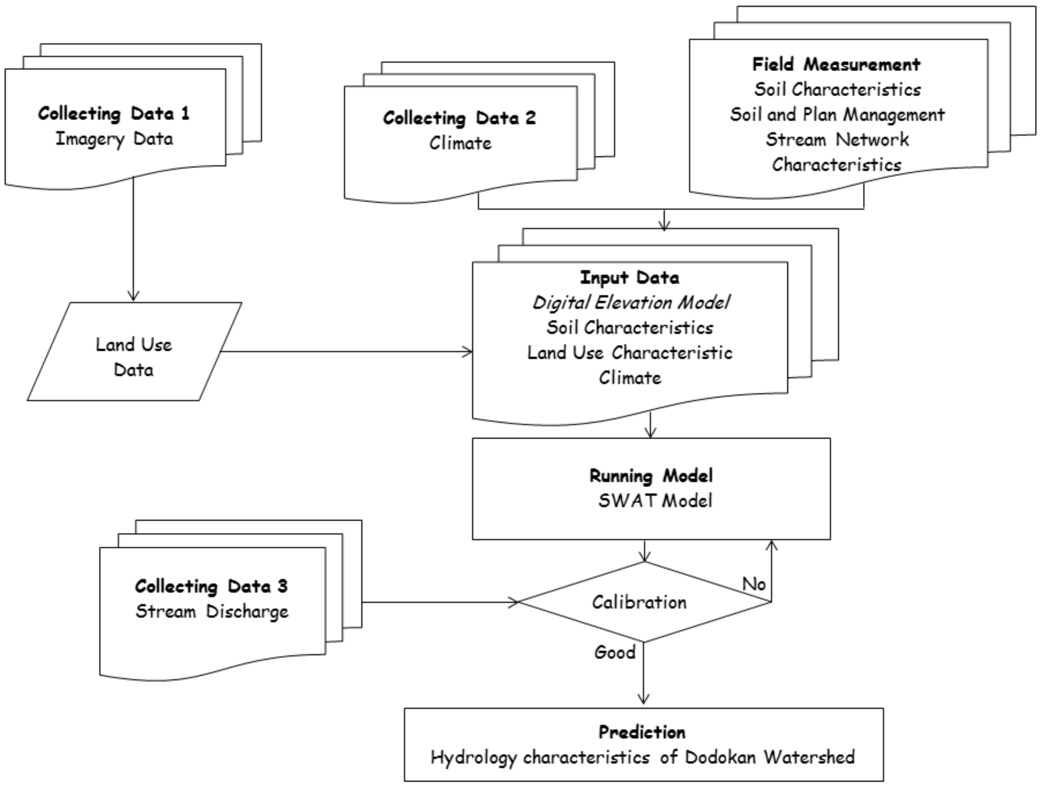


Fig. 3. Flow chart of research.

Table 2. Hydrological characteristics of Dodokan Watershed.

Month	Rainfall	Surface runoff	Lateral flow	Base flow
	------------------------------------- mm ---------------------------------			
Jan	114.5	33.05	14.06	36.45
Feb	95.38	26.57	8.97	34.81
Mar	125.57	32.39	15.44	36.92
Apr	216.25	83.48	21.78	43.93
Mei	135.24	49.57	11.68	48.02
Jun	6.63	0.04	0.37	27.85
Jul	12.42	0.37	0.77	7.65
Aug	0.55	0	0.01	2.4
Sep	15.38	1.05	0.82	0.87
Oct	19.89	0.27	1.13	0.34
Nov	150.27	48.52	12.43	1.09
Dec	192.65	78.46	15.53	3.94
Total	1,084.73	353.77	102.99	244.27

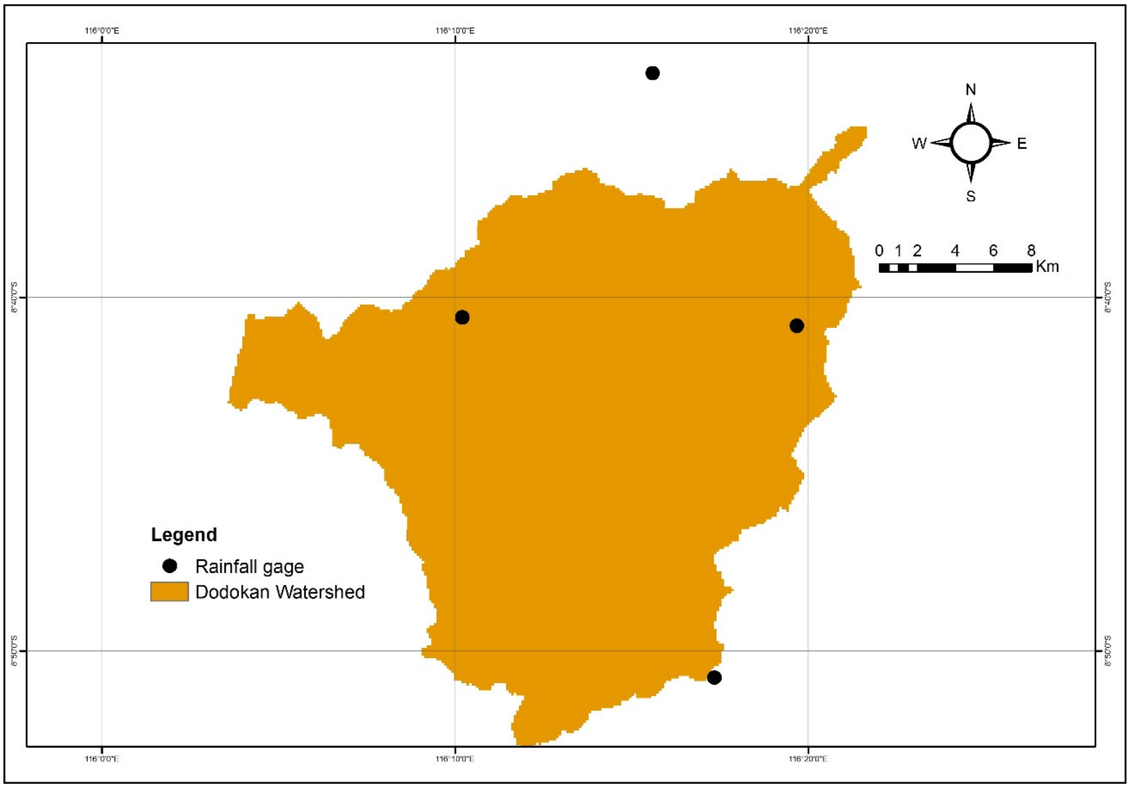
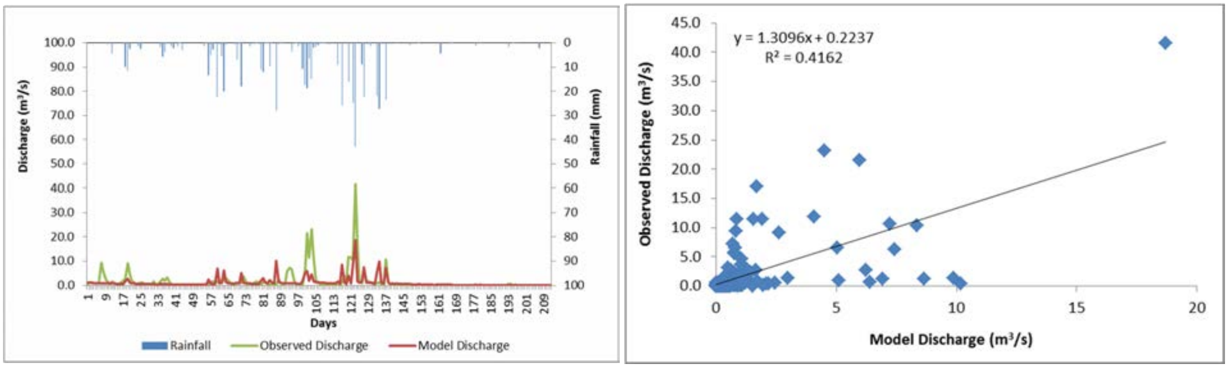
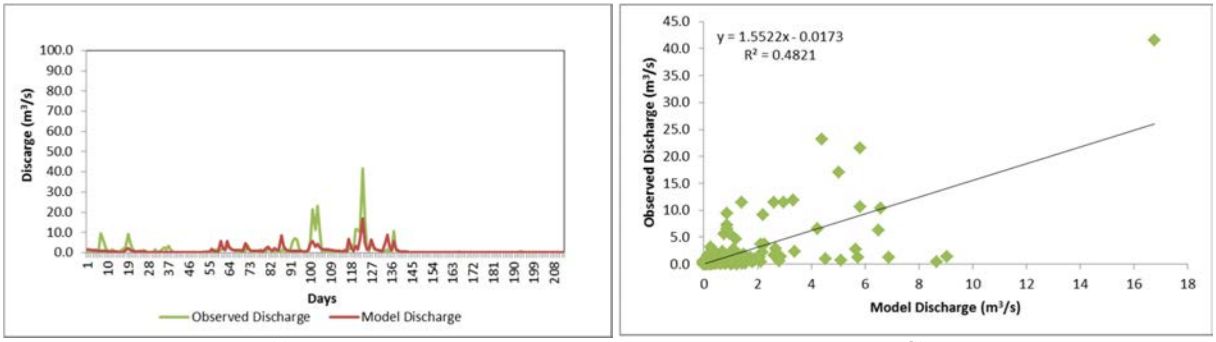


Fig. 4. Rainfall and climate gage in Dodokan Watershed



(a) (b)

Fig. 5. Simulated and measured discharge prior to calibration (a) and correlation between simulated and (b) measured stream flow prior to calibration.



(a) (b)

Fig. 6. Simulated and measured discharge for calibration period (a) and correlation between simulated and (b) measured stream flow for calibration period.

4. Conclusion

This study has successfully attempted to predict the hydrological characteristics of Dodokan watershed that utilized the satellite imagery data using SWAT model. The NS value of 0.40, runoff coefficient is 0.33 and the highest surface runoff is 83.48 mm.

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