Wijaya_May_GEOMATE

by Artikel 11 Artikel 11

International Journal of GEOMATE, May 2019, Vol.16, Issue 57, pp.157 - 162
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2019.57.8189
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

HYDROLOGICAL CHARACTERISTICS AND WATER MANAGEMENT IN THE AIR SUGIHAN SUB-RIVER BASIN, SOUTH SUMATERA, INDONESIA

*Wijaya Mardiansyah[1,2], M. Yusup Nur Khakim[1], Dedi Setiabudidaya[1], Satria J. Priatna[3,] and Iskhaq Iskandar[1]

[1]Faculty of Mathematics and Natural Sciences, Sriwijaya University, Indonesia;
[2]Graduate School of Sciences, Faculty of Mathematics and Natural Sciences, Sriwijaya University, Indonesia; [3]Faculty of Agriculture, Sriwijaya University, Indonesia

*Corresponding Author, Received: 20 Nov. 2018, Revised: 03 Jan. 2019, Accepted: 16 Jan. 2019

ABSTRACT: Characteristics of suboptimal land, which is usually located in a river basin area, is strongly influenced by soil conditions, hydrology and climate, in which its management requires an integrated data assessment and utilization. In order to examine the climatic and hydrological conditions as well as the tidal effect in the Air Sugihan sub-river basin, a water balance analysis was conducted on the combined climatic data obtained from satellite remote sensing and in-situ monthly tidal data for a period of 2001-2013. The climatic data includes a monthly precipitation data, surface winds, surface temperature, surface, and subsurface runoff. The water balance analysis shows that the average total annual runoff occurring in the study area was about 87.7 mm/month or equal to 102.67 m^3/s. In addition, the water balance in the study area indicates an annual variation, in which the water deficit conditions are occurring in April to September with a peak during a dry season in August, while the surplus peak is occurring in November-December. However, the area is still experiencing a net annual surplus of about 302,468.81 m^3/month. Furthermore, the water balance conditions in the Air Sugihan sub-river basin are significantly correlated with the tidal fluctuations indicated by a coefficient correlation of $r = 0.88$.

Keywords: Air Sugihan Sub-River Basin, Hydrology, Precipitation, Tidal Effect, Water Balance

1. INTRODUCTION

The hydrological cycle describes the water cycle on the earth surface. Solar radiation and other climate factors cause evaporation on the Earth surface (land, ocean and other water bodies) and vegetation. The most air will be lifted and become cool, then it will be transported by the wind which depends on the atmosphere condition. Some of the water vapor condenses to form clouds and returns to the Earth surface as precipitation. As the water from precipitation reaches the Earth surface, some parts will penetrate the Earth surface and become groundwater, and others will be accommodated temporarily in the surface basins (surface detention) then flow to the ocean through the river before it evaporates back into the atmosphere [1]. The hydrological cycle forms a water balance on the Earth system. Therefore, the sustainable exploitation of natural resources is a key role in managing the hydrological cycle. Forest vegetation is an important factor for regulating evapotranspiration, soil humidity, infiltration, and increasing surface runoff. Note that the surface runoff significantly influences the discharge flow [2].

Management of the suboptimal land requires good management on the water balance, so that it may become a productive land for cultivation. In Indonesia, most of the suboptimal land are agroecosystem lands, which are sour-dry land, dry land in the tropical area, tidal swamp land and swampland. The sour-dry landless of nutrient, sour and dry, while the dry land in the tropical area usually does not have enough water for cultivation and it is usually rocky land with thin topsoil layer. The tidal-swamp land has several problems, such as it is difficult to set the water management, it has pyrite layer and thick peat layer, and it experiences seawater intrusion. On the other hand, in the swampland, it is difficult to predict and set the water level and soil sour [3]. In addition, the previous study has shown that the productivity of the tidal land or suboptimal land is very diverse. This productivity diversity is influenced by soil types, water supply, and climate [4].

In order to manage suboptimal land, agricultural conservation is required [5]. The planning of agricultural conservation system involves three following inventory steps:

1. Inventory of biophysical resource. This inventory is designed to evaluate the land capability/suitability class for a specific commodity, required agro-technology and conservation techniques, as well as the level of land damage.

2. Inventory of farmer socio-economic conditions, and
3. Inventory of external influences, such as trading of agricultural commodities products, condition and distance to the trading places, education/training tools, rural financial institution and farmer community organizations.

This study is designed to analyze possible impacts of climate condition and tidal on the hydrological cycle in the Air Sugihan sub-river basin. The analysis is based on the water balance calculation that utilizes several data, including precipitation, surface winds, temperature, surface and subsurface runoff and the tidal data in the study area.

2. DATA AND METHODS

2.1 Study Area

The study area covers the Air Sugihan sub-river basin having a total area of ±303,402,358 ha (Fig 1). It is located between 2 (two) regencies, namely the Banyuasin and the Ogan Komering Ilir regencies. The majority of Air Sugihan sub-river basin is a lowland with a slope of about 0 to 2%. Note that the estuary of the Sugihan River is located in the open sea, therefore it gets an influence of tidal variability from the Bangka Strait.

Fig. 1. The study area in the Air Sugihan Sub-River Basin bounded by yellow line with the total area of ±303,402,358 ha.

2.2 Data

This study used precipitation data recorded by rain gauge at Kenten station managed by the National Agency of Meteorology, Climatology and Geophysics (BMKG). In addition, the Tropical Precipitation Measurement Mission (TRMM) data were also used in this study [6]. We also used precipitation data observed by rain gauge located at the Sultan Mahmud Badaruddin II Airport Palembang. In order to evaluate the tidal effect, we also utilized the hourly tidal data recorded by a tide gauge located at the Tanjung Buyut station, Musi River for a period of 1 October – 1 November 2016, and at the Sugihan River a period of 2 - 22 October 2016.

In addition, the assimilation data with a resolution of 0.25° × 0.25° was used in this study, covering the area of the Air Sugihan sub-river basin for a period from January 2001 to December 2013. The data was derived from the Global Land Data Assimilation System (GLDAS) provided by the National Aeronautics and Space Administration (NASA). The data were based on an assimilation of the satellite- and ground-based observational data products, using advanced land surface modeling and data assimilation techniques [7]. This study used monthly products, which were generated by temporal averaging of the 3-hourly products. List of the GLDAS data used in this study is presented in Table 1.

Table 1 List of the parameter from GLDAS products used in the present study

No	Parameter	Unit
1	Surface net radiation	W m^{-2}
2	Shortwave radiation	W m^{-2}
3	Longwave radiation	W m^{-2}
4	Heat flux	W m^{-2}
5	Soil heat flux	W m^{-2}
6	Atmospheric pressure	Pa
7	Wind speed	m s^{-1}
8	Surface temperature	K
9	Air temperature	K
10	Surface albedo	%

2.3. Methods

The satellite TRMM precipitation data were first evaluated by calculating the correlation between the TRMM precipitation data and the rain gauge data.

Following [8], we calculate the correlation coefficient as follow,

$$r = \frac{1}{N-1}\sum_{i=1}^{N}\frac{(x-\bar{x})(y-\bar{y})}{S_x S_y}, \quad (1)$$

where S_x and S_y are the standard deviations of each variable.

The evapotranspiration in the study area is calculated by [9]:

$$ETP = \frac{R_n - G - H}{\lambda}, \quad (2)$$

where ETP is the evapotranspiration (mm/day), R_n is surface net radiation (W/m^2), G indicates the soil heat flux (W/m^2), H represents the heat flux (W/m^2), and λ is the evaporation of latent heat at the 20°C (2.45 MJ kg^{-1}).

The surface net radiation is calculated as follow [9]:

$$R_n = (1-\alpha)RS_{in} + RL_{in} - RL_{out}. \quad (3)$$

Note that the RS_{in} indicates the incoming shortwave radiation (W/m^2), RL_{in} and RL_{out} are the incoming and the outgoing longwave radiation (W/m^2), respectively.

Meanwhile, the heat flux is calculated as follow:

$$H = \gamma \frac{900}{T_a + 273}\Phi U_2 (T_s - T_a), \quad (4)$$

where γ is psychometric constants (kPa/°C), U_2 is the wind speed at 2 m above ground (m/s), T_s is the surface temperature (°C) and T_a is the air temperature (°C). Note that the constant Φ is defined as $0.665 \times 10^{-3} * P$, where P is the atmospheric pressure (kPa).

3. RESULTS AND DISCUSSION

3.1. Hydrological Characteristics

In order to evaluate the precipitation over the Air Sugihan sub-river basin, we first compared monthly precipitation data recorded by rain gauge at Kenten station managed by the BMKG Indonesia with those obtained from the TRMM data for the period of January 2001 – December 2013.

Figure 2 shows a scatter plot for comparison of precipitation data obtained from the rain gauge and those from the TRMM. It is shown that the TRMM data are significantly correlated with the rain gauge data with a correlation coefficient of $r = 0.82$ (above 95% confidence level). This indicates that the TRMM data is suitable for analysis of the precipitation over the Air Sugihan sub-river basin.

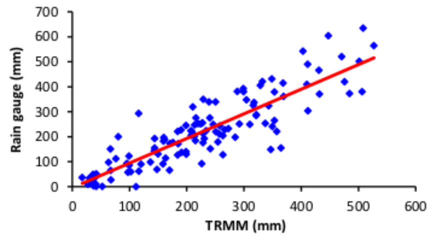

Fig. 2. Scatter plot of correlation between the rain gauge data and the TRMM data for a period of January 2001 – December 2013.

Monthly climatology of the precipitation over the Air Sugihan sub-river basin is presented in Fig 3. It is clearly shown that the monthly climatology of the precipitation has two peaks in March - April, and November – December, and one trough in July – August. This result differs from that suggested in the previous study in which the precipitation type in this area only has one peak and one trough [10]. This discrepancy could be related to the data period used in their study, which was from January 1961 – December 1993.

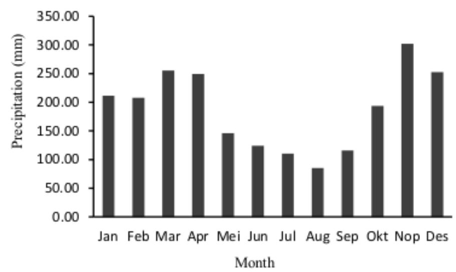

Fig. 3. Monthly climatology of the precipitation over the Air Sugihan sub-rive basin obtained from the TRMM data for a period of January 2001 – December 2013.

Analysis on the tidal data recorded at the Tanjung Buyut station, Musi River and the Sugihan River reveals that the tidal type observed at both stations is the mixed-predominantly diurnal tide with Forzal number of 2.99 and 2.03, respectively (Fig 4). The tides are dominated by three tidal constituents, namely K_1, O_1 and P_1 with periods of 23.93, 25.82, and 24.07 hours, respectively. Note that the tidal constituent of K_1 defines the soli-lunar constituent, O_1 is the main lunar constituent, and K_1 represents the main solar constituent.

The magnitudes of tidal constituents at the Tanjung Buyut station are K_1 = 1.46 m, O_1 = 0.52 m, and P_1 = 0.64 m. Meanwhile, the magnitudes of tidal constituents at the Sugihan River are K_1 = 0.18 m, O_1 = 0.21 m and P_1 = 0.07 m.

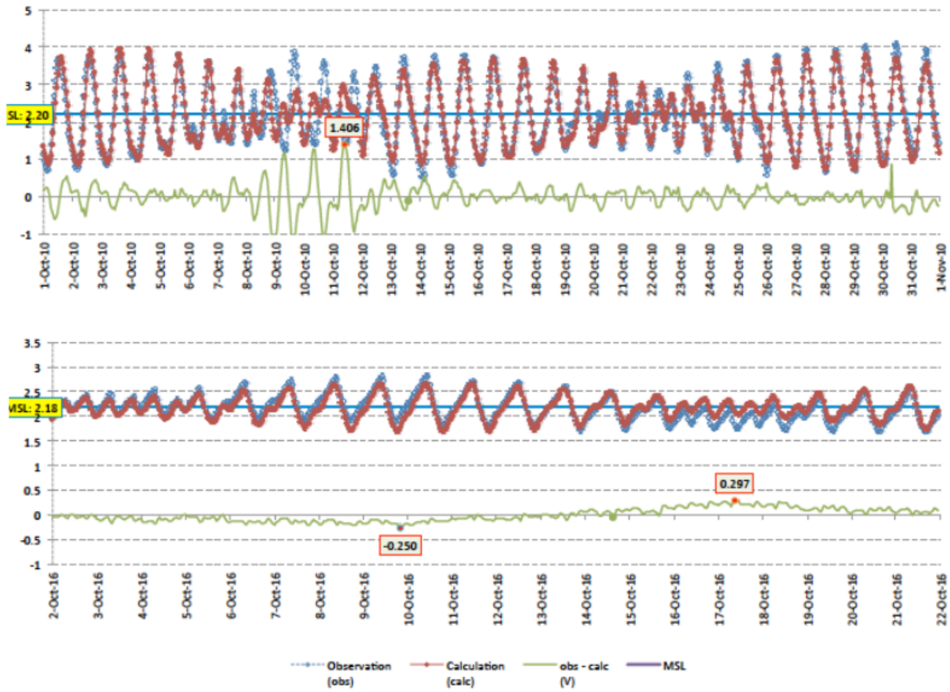

Fig. 4. Time series of water level at (a) Tanjung Buyut (b) Sugihan River stations

3.2. Water Balance

Table 2 shows the data for water balance calculation in the Air Sugihan sub-river basin. The calculation indicates that the study area experiences an annual net surplus of about 0.1 mm/month or equal to 302,468.81 m^3/month. The average total runoff is 87.7 mm/month or equal to 102.67 m^3/s.

Table 2. Data for the water balance analysis in the Air Sugihan sub-river basin

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
Precipitation (mm)	211.6	208.0	255.6	249.4	145.9	124.2	110.5	85.3	116.1	193.8	301.9	252.8	187.9
Surface Temperature (^{0}C)	26.0	26.3	26.6	26.9	27.2	26.8	26.3	26.6	26.9	27.3	26.9	26.2	26.7
Evapotranspiration (mm)	93.1	101.3	108.3	109.5	104.5	100.7	97.9	102.9	97.9	95.9	97.1	92.3	100.1
Wind magnitude (m/s)	1.7	1.7	1.3	1.1	1.4	1.5	1.7	1.9	1.9	1.5	1.1	1.4	1.5
Surface Runoff (mm)	7.4	6.2	6.8	6.2	2.2	2.8	1.6	1.2	2.2	4.6	17.2	7.9	5.5
Sub Surface Runoff (mm)	113.6	100.1	131.6	137.8	83.7	46.7	27.9	23.3	25.5	46.5	101.9	147.9	82.2
Total Runoff (mm)	120.8	106.3	138.4	143.9	85.9	49.5	29.5	24.5	27.7	51.1	119.0	155.9	87.7

Based on the field survey, it is found that that the water discharge in the estuary of the Sugihan River is about 200 – 300 m^3/s. Meanwhile, based on the water balance analysis, it is obtained that the water discharge in the upper stream of the Sugihan River is about 102.67 m^3/s.

Therefore, we may suggest that the Sugihan River receives additional water flush from the Musi River. In other words, it may conclude that the water level in the Musi River is higher than that in the Sugihan River.

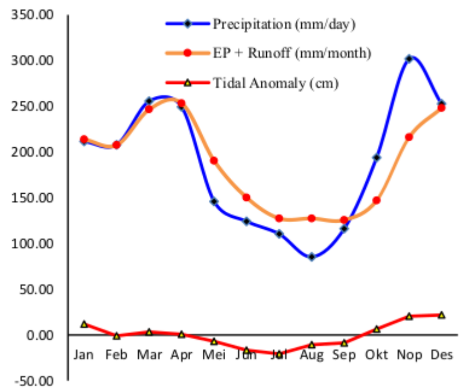

Fig. 5. Monthly water balance at the Air Sugihan sub-river basin together with tidal anomaly at Tanjung Buyut station, Musi River.

Figure 5 shows the monthly water balance in the Air Sugihan sub-river basin, together with the monthly tidal anomaly observed in the Tanjung Buyut station, Musi River. It is shown that the dry season (*low precipitation*) occurs in August, while wet season occurs twice a year; Mach – April and November – December. By combining the precipitation data and the evapotranspiration as well as the total runoff data, we found that the deficit period is started in April until September.

Based on the water balance analysis, it is found that monthly water storage in the Air Sugigan sub-river basin is about 0.1 mm/month. It means that most of the precipitation becomes surface runoff and only about 0.05% of the daily precipitation is storing in the area. The main factor affecting this runoff is land use. Fig 1 shows that most the area in the Air Sugihan sub-river basin is rice fields, shrubs, and swamp, which are covered by less vegetation.

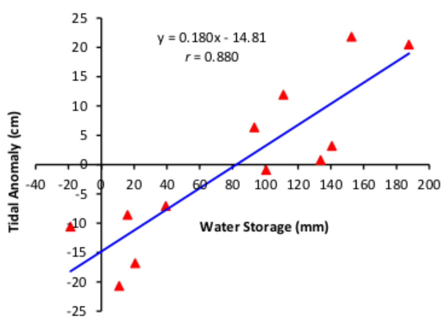

Fig. 6. Scatter plot of correlation between the water storage in the Air Sugihan sub-river basin and tidal data recorded at the Tanjung Buyut station.

In addition, the Air Sugihan sub-river basin is located in the tidal peat swap and near the coast. Therefore, tidal effects may also modulate the water balance in the area. Fig 6 reveals that the water storage in the Air Sugihan sub-river basin is highly correlated with the tidal with a correlation coefficient of r = 0.88 (without subsurface runoff calculation) and r=0.70 if subsurface runoff calculated.

4. CONCLUSIONS

Hydrological characteristic and water balance in the Air Sugihan sub-river basin is analyzed by using combined direct observation data, satellite remote sensing data and reanalysis data.

The analysis shows that the Air Sugihan sub-river-basin experiences rainy season twice a year in March - April and November – December, and one dry season in July – August. Meanwhile, the tidal analysis reveals that the Air Sugihan sub-river basin is dominated by the mixed-predominantly diurnal tide with Forzal number of 2.03. The magnitudes of tidal constituents at the Sugihan River are K_1 = 0.18 m, O_1 = 0.21 m and P_1 = 0.07 m.

The water balance analysis in the Air Sugihan sub-river basin shows that the area experiences an annual net surplus of about 0.1 mm/month or equal to 302,468.81 m^3/month. The average total runoff is 87.7 mm/month or equal to 102.67 m^3/s. In addition, the area has monthly water storage is about 0.1 mm/month. Most of the precipitation becomes surface runoff and only about 0.05% of the daily precipitation is storing in the area.

5. ACKNOWLEDGMENTS

This study is supported by the University of Sriwijaya through the *Hibah Unggulan Profesi* 2018 for the last author (Number: 0006/UN9/SK.LP2M.PT/2018). Part of this study is supported by the PT. OKI Pulp and Paper Mills.

6. REFERENCES

[1] Asdak, C., Hidrologi dan Pengelolaan Daerah Aliran Sungai. 2007, Gadjah Mada University Press, Yogyakarta

[2] Muchtar A. and Abdullah N., Analisis Faktor-Faktor yang Mempengaruhi Debit Sungai Mamasa, Jurnal Hutan dan Masyarakat, Vol. 2(1), 2008, pp. 174-187.

[3] Benyamin Lakitan and Nuni Gofar, Kebijakan Inovasi Teknologi untuk Pengelolaan Lahan Suboptimal Berkelanjutan, Prosiding Seminar Nasional Lahan Suboptimal "Intensifikasi Pengelolaan Lahan Suboptimal dalam Rangka Mendukung Kemandirian Pangan Nasional, 2013, ISBN 979-587-501-9

[4] Armanto, M.E., S.M. Bernas and R.H. Susanto. 2010, Land Evaluation as a Basic for Directing of Landuse to Support an Increase of Cropping Index in Reclaimed Tidal Land Area. The First Year of 2010, Final Research Report of Competitive National Strategy Research Grant. DIKTI, National Education Ministry of Indonesia, Jakarta, 2010.

[5] Naik Sinukaban, Potensi dan Strategi Pemanfaatan Lahan Kering dan Kering Masam untuk Pembangunan Pertanian Berkelanjutan, Kebijakan Inovasi Teknologi untuk Pengelolaan Lahan Suboptimal Berkelanjutan, Prosiding Seminar Nasional Lahan Suboptimal "Intensifikasi Pengelolaan Lahan Suboptimal dalam Rangka Mendukung Kemandirian Pangan Nasional. ISBN 979-587-501-9, 2013.

[6] Xianwu Xue, Yang Hong, Ashutosh S. Limaye, Jonathan J. Gourley, George J. Huffman, Sadiq Ibrahim Khan, Chhimi Dorji, Sheng Chen, Statistical and hydrological evaluation of TRMM-based Multi-satellite Precipitation Analysis over the Wangchu Basin of Bhutan: Are the latest satellite precipitation products 3B42V7 ready for use in ungauged basins?. Journal of Hydrology. 2013, 499 (2013) 91–99.

[7] Rodell, M., et al., The Global Land Data Assimilation System, Bull. Am. Meteorol, 2004, Soc., 85, 381–394.

[8] Emery, W. J., and Thomson, R. E.: Data Analysis Methods in Physical Oceanography. Second Edi. New York: Elsevier B.V, 2004.

[9] Narasimhan, B., R. Srinivasan, J.G. Arnold, and M. Di Luzio, Estimation of Long-Term Soil Moisture Using a Distributed Parameter Hydrologic Model and Verification Using Remotely Sensed Data. Transactions of Agricultural Engineers, 2005, 48(3):1101-1113.

[10] Aldrian, E. and R. D. Susanto, Identification of Three Dominant Rainfall Regions within Indonesia and Their Relationship to Sea Surface Temperature, J. Int. Climatology, 2013, 23, 1435 – 1452.

Wijaya_May_GEOMATE

ORIGINALITY REPORT

10%	%	10%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

1%

★ Meizhao Lv, Hui Lu, Kun Yang, Zhongfeng Xu, Meixia Lv, Xiaomeng Huang. "Assessment of Runoff Components Simulated by GLDAS against UNH–GRDC Dataset at Global and Hemispheric Scales", Water, 2018

Publication

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		