THE RELATIONSHIP BETWEEN LAND USE AND LAND COVER TO RUN-OFF COEFFICIENT VALUE IN BRANTAS WATERSHED AREA, TULUNGAGUNG - EAST JAVA, INDONESIA

Bowo Eko Cahyono[1,*], Asih Sumarlin[1], Nurul Priyantari [1], and Katsunoshin Nishi [2,]

[1] Department of Physics, Faculty of Mathematics and Natural Sciences, University of Jember Jl. Kalimantan 37 Jember 68121, Indonesia
[2] Center of Environmental Remote Sensing (CEReS), Chiba University, 1-33, Yayoicho, Inage-ku, Chiba-shi, Chiba, Japan 263-8522

*e-mail: bowo_ec.fmipa@unej.ac.id

Received: 31-01-2023; Revised: 08-11-2023; Approved: 13-11-2023

Abstract. The Ngrowo-Ngasinan sub-watershed is a part of Brantas Watershed which has an important role for the aquatic ecosystems in the Brantas watershed. Land cover changes in this sub-watershed can affect the infiltration rate and runoff water when the rain comes. This study aims to identify the land cover changes in the Brantas watershed area especially in the Ngrowo-Ngasinan sub-watershed Tulungagung regency. The identification was conducted by remote sensing technology by utilizing Landsat 8 image data. The land cover was classified into 6 classes based on 3 years Landsat 8 data that are 2014, 2016, and 2018 using supervised classification method. The results showed that the acuuracy of land cover classification was averagely 94% (high accuracy). This results of classification areas especially vegetation areas supporting by rainfall data collected from BPS are then used to calculate the runoff coefficient and flow rate in the sub-watershed area. Regarding to this reserch data, the most influenced area to the flow rate level is forest area. Decreasing forest area year by year caused the increasing flow rate values. There is an indication that decreasing forest area because of converting into field and settlement areas. In addition to land cover, regional rainfall also affects the flow rate (runoff) in the area.

Keywords: *watershed, land cover, Brantas, rainfall, runoff*

1 INTRODUCTION

The most influential factor in the watershed system or reservoir water system is the change in land cover in the water catchment area. The extent of open land or deforestation will accelerate inflow into the reservoir which has an impact on high levels of erosion and accumulation of sedimentation which can affect or shorten the planned life of the reservoir (Nurdin et al., 2016). The impact of changes in land cover on a large scale can be seen from changes in the hydrological function of the watershed which begins with a decrease in regional rainfall and is followed by water yields in the watershed (Pwitan, 2000). Changes in land use in watershed areas that do not pay attention to conservation principles can result in reduced water absorption. This causes an increase in the amount of runoff water that enters the river. This is one of the causes of increasing the peak discharge/maximum discharge of a watershed. If the peak discharge value of a river is too large, the river water will overflow and can cause flooding in the watershed area (Saraswati et al., 2017).

Research that discusses the effect of land cover changes on watersheds with supervised classification is Fauzi et al. (Fauzi et al., 2018). In this study, the area studied was the Penggung Sub-watershed, Jember Regency. The result of the research is that there is a decrease in forest area of 6.42 km2 and a change of function into rice fields with an area of

4.14 km2. In addition, changes in land use area affect the peak discharge by 32.4%. Another research conducted by Sriartha (Sriartha, 2015) who used Landsat 8 imagery and Geographic Information Systems (GIS) had estimated the peak discharge in the Unda watershed of Bali Province. The result of this research is the peak discharge with the rational method produces a value of 16.07 m^3/s.

Land use which not consider conservation principles can cause several problems such as floods (Rahman et al., 2021; Cahyono et al., 2022; Sugianto et al., 2022) and landslides (Chen et al., 2019; Meneses et al., 2019; Knevels et al., 2021; Rabby et al., 2022). The information regarding land cover changes is important for the urban planning decision maker to take action in anticipating the occurring of floods and landslides (Laili et al., 2020).

In general, flood occurs during the rainy season. Decreasing land cover causes water infiltration low and runoff will increase and it leads the flood happening (Astuti, 2017) even Mewded et al. (2021) stated that reducing land cover will increase runoff to 20%.

Many areas in Indonesia experienced with flood and one of them is Tulungagung regency (PUPR, 2022). The Ngrowo-Ngasinan watershed is one of the Brantas watersheds covering areas in the Trenggalek and Tulungagung Regencies (Priswanto, 2021). The existence is important to flood control in those two regencies.

This study aims to provide information regarding the relationship of land use and land cover in the Ngrowo Ngasinan watershed to the runoff coefficient value as indicator of potentially flood occurring. This study uses remote sensing technology in identifying land use and land cover changes.

2 MATERIALS AND METHODOLOGY

2.1 Research Area

This research was focused to the Ngrowo - Ngasinan sub-watershed which is located in the Tulungagung Regency, East Java. Geographically, Tulungagung Regency is located along 111°43' – 112°07' East and 7°51' – 8°18' South

(Nawasis, 2012), Rainwater catchment areas that contribute to the water amount of river in Ngrowo-Ngasinan lay in the 3 regencies namely Tulungagung, Trenggalek and Ponorogo. Based on the river flow map, this sub-watershed covers 14 sub-districts out of 19 sub-districts in Tulungagung Regency as shown in Figure 1. It means that almost 75% of Tulungagung will be affected by the condition of this sub-watershed.

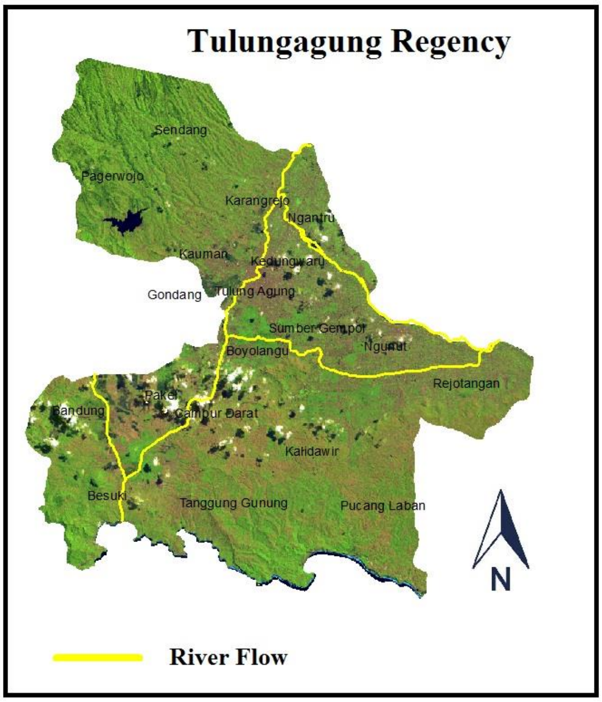

Figure 1-1. Map of the river flow in the Ngrowo-Ngasinan sub-watershed as a study area

2.2 Materials and tools

The materials of this research are Landsat 8 images acquired on 26 October 2014, 24 May 2016 and 1 June 2018. Those data are processed to get land use/ land cover classification as an analisis input in this study. The data processing is carried out using ER Mapper 7.1 and ArcGIS 10.3. The image data used was obtained from the Landsat LAPAN's Catalog. Calculation of flow rate requires regional average rainfall data from the Central Bureau of Statistics (BPS) of Tulungagung Regency to calculate the run-off coefficient (BPS, 2018b). In addition, to validate the data, data on the forest area of Tulungagung Regency from the East Java Provincial Forestry Service were also used.

2.3 Research methods

This research was conducted by collecting the necessary data such as image data and average rainfall data. The image data was obtained from Landsat 8 that has 11 bands. Only 5 bands of those data will be considered to be processed further that are band 2, 3, 4, 5, and 6. Those bands were chosen because each band has a role to distinguish the biophysical vegetation parameters in the image.

The data from the 5 bands firstly be combined and once the combining data have been succeed, the next processes are image corrections namely geometric, radiometric, and atmospheric correction. Geometric correction is conducted to correct the positional errors and to transform the original image into a new image that has geometric characteristics of a map. The radiometric corrections are used to improve the radiometric quality of the data. Meanwhile atmospheric correction is done to eliminate or minimize bias in each spectral band. In addition, this correction is useful for improving image quality due to surface reflection errors or the curvature of the earth and the direction of sunlight.

The image corrections are followed by ToA coversion that is converting digital number to reflectance value (Pareeth et al., 2019; Keerthi Naidu dan Chundeli, 2023). The mathematical expression to calculate the reflectance value is written in equation 1.

$$\rho_p = (M_p Q_{cal} + A_p) + \cos(Z) \qquad (1)$$

note:

ρ_p = Reflectance
Mp = Multiplication factor of band Reflectance
Ap = offset value of band Reflectance
Z = Zenith Angle of the Sun

The magnitude of the zenith angle of the sun is obtained from elevation angle by following the expression in equation 2.

$$Z = 90^o - \text{elevation angle} \qquad (2)$$

The values of multi band reflectance and elevation angle are taken from the metadata of each image data. Each satellite data has metadata which provides information on various types of data from a satellite imagery.

In term of the image has been successfully converted nto ToA reflectance, the next process is cropping the image according to the desired study area. The thing that needs to be done before cutting the image for this research is to make sure the projection system and the datum of both the satellite image data and the vector data of administration border that will be used as the pattern are the same. The vector data that is sub-district administrative boundary data in Indonesia is loaded in ArcGIS 10.3 software. This boundary is used as a basis of cropping area which will be studied. The image is cropped based on the administrative boundaries of the sub-districts that are included in the sub-watershed. The result of cutting the sub-district administrative boundary data is stored in Shape File (.shp) format. The Landsat image is then overlaid with the sub-district administrative boundary data that has been cut. The Landsat image is cropped according to the sub-district administrative boundary data in ArcGIS 10.3 software. The cropped image is saved in .tiff format so that the classification process can be carried out in the ER Mapper 7.1 software. This is because vector data that can be used in ER Mapper 7.1 software is only vector data with .tiff and .erv file formats.

The image that has been cropped according to the research area is then classified into 6 classes called forest, moor, field, settlement, water, and rice field. The classification was performed using the supervised classification method by applying maximum likelihood algorithm. The area of each land cover class can be calculated for the analysis purposes. The next process after classification is the calculation of the accuracy of the classification process. Overall Accuracy (OA) is the classification accuracy which is calculated by dividing the number of sample pixels that are correctly classified (the sum of all the diagonal cells in the error matrix) by the total number of sample pixels as mathematically expessed into eq 3.

$$OA=\frac{\sum_{i=1}^{r} x_{ij}}{N} \times 100\% \quad (3)$$

note:
OA = overall accuracy
N = Total number of pixels
x_{ij} = Cell values in row i and column j
r = Number of rows or columns in the error matrix.

This test is carried out to see the level of accuracy of the classification process that has been carried out. So if the classification process produces a small accuracy value, it is necessary to reclassify. It aims to produce land cover area with high accuracy.

The analysis of changes in land cover area was carried out by comparing the results of the mapping of land cover classes with the previous year. The results of the classification will produce the area for each land cover class and are presented in the form of a bar chart. The value of the change in land cover area that will be generated is the change in land cover area in 2014 - 2016 and changes in land cover area in 2016 - 2018. The results of the land cover area in this study are calculated based on Landsat 8 image data acquired on October 26, 2014, May 24, 2016 and June 1, 2018.

The amount of flow rate is obtained through the calculation process of rainfall and run off coefficient. The calculation of rainfall is carried out using the formula of the Algebraic Method as follows:

$$p=\frac{1}{n}\sum_{1}^{n} P_i \quad (4)$$

note:
p = average rainfall (mm/year)
P_i = Rainfall at each station (mm/year)
n = Number of rainfall stations

The calculation of the flow rate also takes into account the magnitude of the run off coefficient which is calculated based on the results of the land cover area map. The run off coefficient equation can be presented with an equation like the following:

$$C=\frac{\sum_{i=1}^{r}(d_i \cdot Q \cdot 86400)}{(p \cdot A)} \quad (5)$$

note:
C = Run-off coefficient
di = number of days in month i
Q = Average monthly discharge (m^3/s), 86400 is the number of seconds
P = annual average rainfall (mm/ year)
A = Watershed area (m^2)

The amount of flow discharge is generated using the Rational Method formula which is presented in the following equation:

$$Q_p=0,002CiA \quad (6)$$

note:
Q_p = flow rate/peak discharge (m^3/s)
C = run-off coefficient
I = Rain intensity (mm/hour)
A = Watershed area (ha)

The flow rate obtained are the result of land cover classification calculations from Landsat 8 satellite imagery data which were acquired on 26 October 2014, 24 May 2016 nd 1 June 2018.

3 RESULTS AND DISCUSSION

Land cover is the natural features of the earth such as vegetation, biota, soil, topography, forests, water, man-made structures and so on. Land cover information has a significant role as thematic information for planning, controlling and spatial planning in order to create sustainable development. Through the help of satellite imagery and remote sensing techniques, land cover that appears in the image can be grouped and then analyzed for changes. Land cover change is a change in appearance on the earth's surface. Detection of land cover change over a period of time is important for understanding the relationship between humans and natural phenomena, as they relate to making decisions about the management and use of natural resources (Barrett, 1999).

Identification of land cover classes using the supervised classification method was performed by identifying pixels of the same color and grouping them into land cover classes. The results of the classification carried out on Landsat 8 for 26 October 2014, 24 May 2016 and 1 June 2018 are shown in Figure 3 to Figure 5.

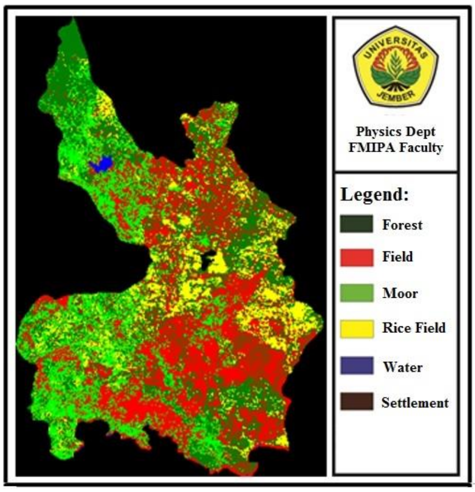

Figure 3-1. Land cover map on October 24, 2014

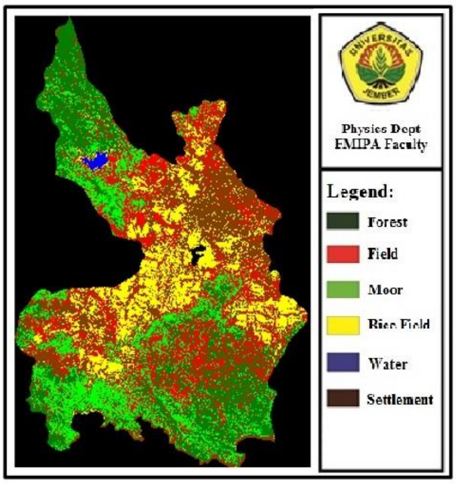

Figure 3-2. Land cover map on May 26, 2016

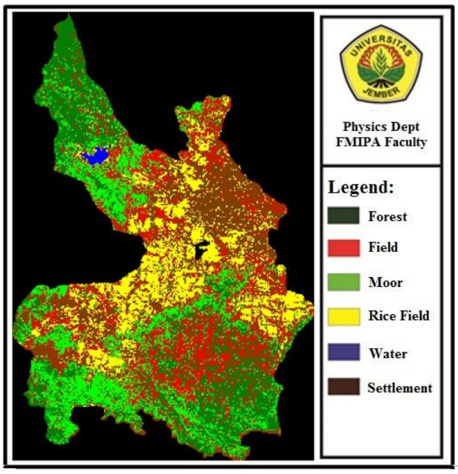

Figure 3-2. Land cover map on June 1, 2018

Accuracy testing is very important after carrying out the classification process. The results of the accuracy test are used to see how accurate the results of the classification that have been carried out before and to see the magnitude of the error in the classification process. Accuracy is calculated using an error matrix (confusion matrix) and calculated using Equation 3 so that the resulting level of accuracy for each classification process is obtained.

Table 3-1. The overall accuracy value of the Land cover supervised classification result

Year	Overall Accuracy (%)
2014	94.90
2016	92.34
2018	94.75

An accuracy value above 85% means that the classification results can be accepted with an error of less than or equal to 15% so that the accuracy results obtained are feasible to use. Based on the accuracy that has been obtained, the results of this classification can be said to be good and acceptable because the accuracy value is more than 85%. Classification must be repeated if the overall accuracy value is less than 85%. The higher the level of accuracy, the better the classification results will be.

According to Nawasis (2012), settlements are land used for all types of buildings, including the surrounding area which in daily use is related to residential needs such as mukim houses, industrial areas, trade areas, office areas, recreation areas, and so on. Settlements in Tulungagung Regency are clustered around the direction of river flow, roads and areas that have the potential to develop. The total area is approximately 18.922%. This land is classified as fertile land and flat surface with soil slopes ranging from 0-8^{o}.

Based on the results of images that have been classified, there are wide differences in each land cover class. The difference in the area of each land cover class is shown in the form of a bar chart as shown in Figure 6

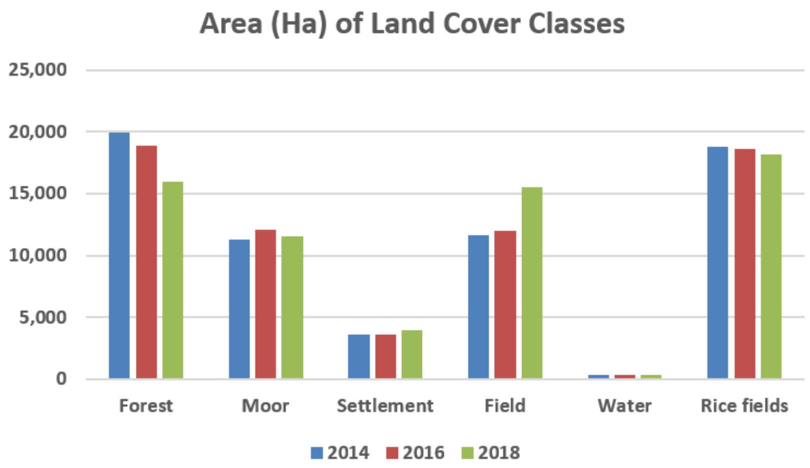

Figure 3-4. Land Cover classes area (Ha) in 2014, 2016, and 2018

The forest has decreased, it is suspected that it has changed its function to become fields, while the rice fields are thought to have changed its function to become settlements. Land cover that experienced an increase was fields and settlements. Based on the results of field observations, the fields have increased due to the opening of new land for the community agricultural sector. Settlements have increased due to the construction and expansion of buildings. Moorland and water are land cover which fluctuates due to regional rainfall. The respective results of land cover area in the Ngrowo-Ngasinan sub-watershed are shown in Table 2.

Table 3-2. Differences in the area of land cover in the Ngrowo-Ngasinan sub-watershed

No.	Land Cover Class	Area (ha) 2014	2016	2018
1.	Forest	19,975	18,912	15,981
2.	Moor	11.286	12,084	11,528
3.	Settlement	3,599	3,642	3.995
4.	Field	11,640	11,973	15,548
5.	Water	368	384	379
6.	Ricefield	18,761	18,634	18,198
	Total	65,629	65,629	65,629

Based on the results that have been obtained that there is a decrease in forest area. Reducing forest-class land cover can result in changes in the existing ecosystem in the region. In addition, the moor, which is one of the watershed ecosystems, is also experiencing changes. The change in the area of the moor was due to the fact that in 2014 and 2018 there was relatively low rainfall so that it experienced a drought which resulted in a lot of dry land. Whereas 2016 was a year that had very large rainy days, causing wild plants on dry land in the region to thrive.

Flow discharge is the amount of water flowing in unit volume per time. Debit is a unit of water quantity that comes out of the watershed. The discharge unit used is cubic meters per second (m^3/s). Flow discharge is the rate of water flow (in the form of water volume) that passes through a cross section of a river per unit time (Asdak, 2010). Debit is a coefficient that states the amount of water flowing from a source per unit time, usually measured in liters per second (Dumairy., 1992).

According to the Central Statistics Agency (BPS, 2018a), the average rainfall in 2014 was 126 mm/year, in 2016 it was 234.7 mm/year and in 2018 it was 135 mm/year. The biggest rainy day in Tulungagung Regency in 2014 was in December and the smallest was in September. While the largest rainfall is in December and January, while the lowest is in September and October. The biggest rainy day in 2016 was in November and the smallest was in July. While the largest rainfall is in November while the lowest is in September and July. The biggest rainy day in 2018 was in January and the smallest was in August. While the largest rainfall is in January while the lowest is in August. Days and rainfall are influenced by, climatic conditions, topography and rotation or confluence of air currents. Rainfall and rainy days are not evenly distributed between time and regions, resulting in a conflicting situation, for example, flooding occurs in one area while drought in another area occurs at the same time.

Changes in land cover can affect the flow rate of a watershed. The most influential land cover in the watershed ecosystem as a whole is forest. In this study, the land cover that influences the ecosystem of the Ngrowo-Ngasinan sub-watershed is forest and moor. The area of the moor varies according to the regional rainfall. The forest area as the main factor of the watershed ecosystem, in 2014 was still large enough to produce a fairly low flow rate. The large area of forest and moor will prevent rainwater from entering the river. In 2016 there was a decrease in forest area so that the flow rate produced was greater than the previous year. This is due to the reduction in the catchment area so that the amount of rainwater entering the river increases. In 2018 there was a very large decrease in forest area resulting in a larger flow rate. This is due to the reduction in the catchment area so that the amount of rainwater entering the river increases. Based on observations, the southern forest in this location has been converted into fields due to the opening of new land for the community's agricultural sector. The decrease in forest area causes an increase in the area of field cover.

According to the East Java Provincial Forestry Service (Putriatni, 2019), the forest area in Tulungagung Regency in 2014 was 31,545 ha, in 2016 it was 31,738 ha and in 2018 it was 28,731 ha. The results of the flow discharge from the research results are greater than the results from the data from the East Java Provincial Forestry Service. This is because the forest area from the study resulted in a smaller area value compared to data from the East Java Provincial Forestry Service. If the land cover area is small, the runoff coefficient value is large so that the flow rate is also large. Based on this data, a graph of the relationship between land cover and flow rate in the Ngrowo-Ngasinan sub-watershed is obtained which is shown in Figure 7. The graph shows the flow rate that always increases with changes in land cover in 2014, 2016 and 2018. The decrease in the area of land cover was identified as changing its function to other land cover. If the land cover area decreases, the run off coefficient value will increase so that the flow rate will also increase and vice versa. In this study, the land cover in question is forest and moor.

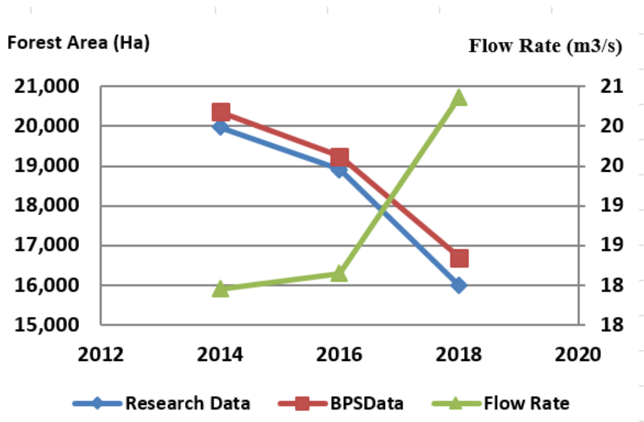

Figure 3-5. The relationship between land cover and flow rate (Graph the relationship between land cover and floatate)

The total forest area from the research results is a combination of the area of forest land cover and dry fields. The area of land cover resulting from the study is smaller than data from the East Java Provincial Forestry Service. This is because the Landsat 8 data used in this study were taken only at certain times, namely October 2014, May 2016 and June 2018. The seasons in these months were dry so that much of the vegetation was dry, especially dry fields. This has implications for a decrease in the area of forest and moor classification so that the value of the run off coefficient is greater. If the value of the run-off coefficient is large, the value of the flow rate is also large. In other words, the water discharge resulting from this research is slightly over estimated. Based on the research forest area and data from the East Java Provincial Forestry Service, this study has an error or difference in forest area, namely in 2014 it was 0.91%, in 2016 it was 2.34% and in 2018 it was 4.25% or an average of 2.5%. The average value of this error can be considered as a correction factor for the flow discharge value obtained from this study

3 CONCLUSION

The largest land cover changes occurred in the forest class and the field class. Changes in the area of the moor and water cover classes are influenced by regional rainfall. If the rainfall is high, the area of the moor and the water class will be greater, on the other hand, if the rainfall is low, the area of the fields will also decrease. Changes in land cover affect the flow rate of a watershed system, especially in the forest and dry fields. The larger the forest area, the smaller the flow rate in the Ngrowo-Ngasinan sub-watershed. On the other hand, if the forest area is reduced, the flow rate in the Ngrowo-Ngasinan sub-watershed will be large. In addition, the flow rate is also influenced by regional rainfall and rainy days. The increase in flow rate is caused by a decrease in forest area. This results in reduced water absorption so that runoff that falls on the surface enters the river and flows to a lower place. Future research should use data from the classification results on average per year so that the results of the flow rate values are more accurate.

ACKNOWLEDGEMENTS

Thanks to the LP2M of Jember University for supporting fund to this reseach though the scheme of Thesis reworking in the year of 2022.

REFERENCES

Asdak, C. 2010. *Hidrologi dan Pengelolaan Daeah Aliran Sungai* Yogyakarta: Gadjah Mada University Press.

Astuti, I. S. 2017. Impact of Land Use Land Cover Change on Runoff and Water Quality of An Increasingly Urbanized Tropical Watershed in Java, Indonesia. *Ph.D Thesis*. Athens Georgia: The Graduate School of the University of Georgia University of Georgia.

Barrett, E. C. 1999. *Introduction to Environmental Remote Sensing* London: Chapman and Hall.

BPS. 2018a. *Nama-nama Sungai Penting dan Panjang Sungai Menurut Kecamatan*, Badan Pusat Statistik. https://tulungagungkab.bps.go.id/statictable/2018/03/07/1249/-nama-namasungai-penting-dan-panjang-sungai-menurut-kecamatan-2015-pt.html. [8 April 2018].

BPS. 2018b. *Rata-rata Curah Hujan dan Jumlah Hari Hujan 2015-2017* Tulungagung, StatisticsBerau Agency of Tulungagung Regency. https://tulungagungkab.bps.go.id/indicator/151/35/2/rata-rata-curah-hujan-dan-jumlah-hari-hujan.html. [20 December 2018].

Cahyono, B. E., Putri, E. I. S. & Nugroho, A. T. 2022. Pemetaan Daerah Genangan Banjir dan Keterkaitan dengan Penggunaan Lahan, Jenis Tanah dan Curah Hujan di Kabupaten Konawe Utara. *Jurnal ILMU DASAR* 23 (2): 93-100.

Chen, L., Guo, Z., Yin, K., Shrestha, D. P. & Jin, S. 2019. The influence of land use and land cover change on landslide susceptibility: A case study in Zhushan Town, Xuanen County (Hubei, China). *Natural Hazards and Earth System Sciences* 19 (203): 2207-2228.

Dumairy. 1992. *Ekonomika Sumberdaya Air* Yogyakarta: BPFE.

Fauzi, R., Utomo, D. & Taryana, D. 2018. Pengaruh Perubahan Penggunaan Lahan Terhadap Debit Puncak di Sub DAS Penggung Kabupaten Jember. *Jurnal Pendidikan Geografi* 23 (1): 50-61.

Keerthi Naidu, B. N. & Chundeli, F. A. 2023. Assessing LULC changes and LST through NDVI and NDBI spatial indicators: a case of Bengaluru, India. *GeoJournal* 88 (4): 4335-4350.

Knevels, R., Brenning, A., Gingrich, S., Heiss, G., Lechner, T., Leopold, P., Plutzar, C., Proske, H. & Petschko, H. 2021. Towards the Use of Land Use Legacies in Landslide Modeling: Current Challenges and Future Perspectives in an Austrian Case Study. *Land* 10 (9): 954.

Laili, S., Cahyono, B. E. & Nugroho, A. T. 2020. Analisis Kualitas Air Di Danau Batur Menggunakan Citra Landsat-8 OLI/TIRS Multitemporal. *Elipsoida* 3 (1): 71-79.

Meneses, B. M., Pereira, S. & Reis, E. 2019. Effects of different land use and land cover data on the landslide susceptibility zonation of road networks. *Nat. Hazards Earth Syst. Sci.* 19 (3): 471-487.

Mewded, M., Abebe, A., Tilahun, S. & Agide, Z. 2021. Impact of land use and land cover change on the magnitude of surface runoff in the endorheic Hayk Lake basin, Ethiopia. *SN Applied Sciences* 3 (8): 742.

Nawasis. 2012. *Buku Putih Sanitasi: Program Percepatan Pembangunan Sanitasi Permukiman (PPSP).* Tulungagung:

Nurdin, Syaiful, B., Sukendi & Zulkarnai. 2016. Analisis Perubahan Tutupan Lahan Daerah Tangkapan Air (DTA) Waduk Pembangkit Listrik Tenaga Air (PLTA) Koto Panjang, *Proceedings of Seminar Nasional "Pelestarian Lingkungan dan Mitigasi Bencana"* 28 Mei 2016, at Pekanbaru. *Universitas Riau.*

Pareeth, S., Karimi, P., Shafiei, M. & Fraiture, C. D. 2019. Mapping Agricultural Landuse Patterns from Time Series of Landsat 8 Using Random Forest Based Hierarchial Approach. *Remote Sensing* 11 (5): 601.

Priswanto, H. 2021. Das Ngrowo-Ngasinan: Pengaruh dan Manfaatnya Terhadap Tinggalan Arkeologi di Trenggalek. *Purbawidya* 10 (2): 155-166.

PUPR. 2022. *Monev Sistem Pengendali Banjir Sistem Ngasinan, Ngrowo dan Parit Agung di Kab Trenggalek dan Tulungagung* Surabaya - Indonesia, Direktorat Jenderal Sumber Daya Air, Balai Besar Wilayah Sungai Brantas. https://sda.pu.go.id/balai/bbwsbrantas/post/detail/monev-sistem-pengendali-banjir-sistem-ngasinan-ngrowo-dan-parit-agung-di-kab-trenggalek-dan-tulungagung. [5 November 2022].

Putriatni, D. J. 2019. *Laporan Kinerja DInas Kehutanan Propinsi Jawa Timur Tahun 2018*. Surabaya:

Pwitan, H. 2000. Perubahan Penggunaan Lahan Dan Pengaruhnya Terhadap Hidrologi Daerah Aliran Sungai *Skripsi.* Bogor: Fakultas MIPA IPB.

Rabby, Y. W., Li, Y., Abedin, J. & Sabrina, S. 2022. Impact of Land Use/Land Cover Change on Landslide Susceptibility in Rangamati Municipality of Rangamati District, Bangladesh *International Journal of Geo-Information* 11 (89): 1-16.

Rahman, M., Ningsheng, C., Mahmud, G. I., Islam, M. M., Pourghasemi, H. R., Ahmad, H., Habumugisha, J. M., Washakh, R. M. A., Alam, M., Liu, E., Han, Z., Ni, H., Shufeng, T. & Dewan, A. 2021. Flooding and its relationship with land cover change, population growth, and road density. *Geoscience Frontiers* 12 (6): 101224.

Saraswati, G. F., Suprayogi, A. & Amarrohman, F. J. 2017. Analisis Perubahan Tutupan Lahan DAS Blorong Terhadap Debit Maksimum Sungai Blorong Kendal. *Jurnal Geodesi UNDIP* 6 (2): 90-98.

Sriartha, I. P. 2015. Penggunaan Citra Landsat 8 dan Sistem Informasi Geografis untuk Estimasi Debit Puncak di Daerah Aliran Sungai Unja Provinsi Bali. *Jurnal Sains dan Teknologi* 4 (2): 621-634.

Sugianto, Deli, A., Miswar, E., Rusdi, M. & Irham, M. 2022. The Effect of Land Use and Land Cover Changes on Flood Occurrence in Teunom Watershed, Aceh Jaya. *Land* 11 (1271): 1-18.