Civil and Environmental Science Journal
Vol. 7 No. 2 (2024)

Civil and Environmental Science Journal (CIVENSE)

Journal homepage: https://civense.ub.ac.id/index.php/civense/index

Original research article

Land Use Response in Volume of Infiltrated Analysis to Control Fire Risk in the Liang Anggang Tropical Peatland Forest in South Kalimantan

Novitasari[a*], Nurfansyah[b], Holdani Kurdi[a], Muhammad Aulia Ramadhani[a], Muhammad Maulana[a], Nur Nailia[a]

[a]Department of Civil Engineering, Faculty of Engineering, Universitas Lambung Mangkurat, Banjarmasin 70123, **Indonesia**
[b]Department of Architecture, Faculty of Engineering, Universitas Lambung Mangkurat, Banjarmasin 70123, **Indonesia**

ARTICLE INFO

Keywords:
Land use;
Volume of infiltrated water;
Liang Anggang Protected Forest;
South Kalimantan

ABSTRACT

Liang Anggang Protected Forest is an area formed from peatland. Peatlands have a role in conserving water resources, reducing floods, preventing seepage of seawater, and so on. Damage to the water system in peatlands is often caused by individual activities that are not well controlled. This is thought to have resulted in the depletion of water in the peat soil, making the soil dry and flammable in the dry season. This research aims to analyze the rate of infiltrated water in the Liang Anggang Block 1 Protected Forest area. It was also found that the volume of infiltrated water in the natural conditions of the protected forest, assuming that there is no current use of the protected forest area, is 9,097,126.998 m^3/year, and the total after there is current utilization of 8,498,889.127 m^3/year. Due to the current utilization carried out in the area under review, the infiltration volume value decreased by 6.576%. Based on this research, it is very necessary to maintain land use in the Liang Anggang protected forest to maintain the volume of infiltrated water in the area.

1. Introduction

Forest and peatland fires occurred in Indonesia, including Kalimantan [1], [2]. The forest and land fires in Kalimantan were extensive due to the existing conditions in the area, most of which were flammable peatlands [3]. Forest and land fires that occur in Kalimantan Province can not only disrupt public health and cause inflammatory diseases of the respiratory tract, but they can also disrupt smooth transportation due to poor visibility, especially aviation transportation [4]. In South Kalimantan, peat land burned in 2015 was more than 18 thousand hectares. From 2016 to 2018, the area of fires decreased sharply due to wet and dry factors. In 2019 and 2023, forest and land fire disasters increased again due to the long dry season [5]. People often set land fires during the dry season in locations close to main roads. This fire eventually spread to peatlands due to dry conditions, such as during El Nino [6].

The long dry season causes dry soil and little soil infiltration [7], [8]. Water entering through the soil surface into the soil is usually called infiltration [9]. Infiltration is one source of soil moisture to provide water needs for plant needs [10]. Various things influence the rate of infiltration, including the type of soil surface [11], how the land is processed, soil density, and the nature and type of plants [12]. The volume of infiltrated water is influenced by rain, evapotranspiration, and land use [13]. Many studies have been carried out regarding the relationship between land use and infiltration, but none have been carried out on peatland conditions [14]. Land use changes in South Kalimantan are very massive. This change in land use causes various problems, such as flooding [15]. This change also has an impact on agricultural extensification [16]. One of the areas in South Kalimantan that is experiencing changes in land use is the Liang Anggang protected forest. More than half of the Liang Anggang Block I protected forest areas have changed function, and other parts are damaged and prone to fire. The Liang Anggang Protected Forest, most of which is peatland, needs special attention due to the increasing number of conversions for various purposes such as agriculture, plantations, and settlements. Based on several studies above, it was found that changes in land use prevent water from entering the ground, during the rainy season, it causes flooding and during the dry season, it causes the land to dry out and potentially flammable.

The novelty in this research is to develop a land use response in analyzing the infiltrated volume to control fire risk in tropical peatland forests in South Kalimantan,

*Corresponding author: Department of Civil Engineering, Universitas Lambung Mangkurat, Banjarmasin 70123, **Indonesia**
E-mail address: novitasari@ulm.ac.id (Novitasari)
doi: 10.21776/ub.civense.2024.007.02.1
Received: 17 Oct 2023; Revised: 19 May 2024 Accepted: 29 Oct 2024

especially in Liang Anggang Protected Forest. The initial hypothesis of this research is that changes in land use are one of the triggers for land drought because rainwater, which should be stored during the rainy season, cannot be stored perfectly. In this research, we digitized the use of non-forest land and calculated the volume of infiltrated water resulting from the reduction in forest area at that location.

2. Method

2.1. *Land Use*

Land use is a process of preparing, regulating, providing, and intentionally using land for human use according to established rules and systems. According to Government Regulation of Republic Indonesia, Number 16 of 2004 concerning Land Use Management, it can be concluded that land use means the control, use, and utilization of land in the form of a series of land uses based on the rules of the relevant institutions that use the benefits of land for community needs reasonably [17]. The land that will be reviewed in this research is divided into three land conditions based on previous research [18], namely: 1. Land with no vegetation density (bare). Bare land is an area that is not cultivated because it is infertile or becomes infertile after being cultivated and does not grow plants. 2. Land with moderate vegetation density. Land with moderate density is an area planted with various types of perennials and/or annual plants and/or a combination of perennials and annuals or fruit plants, and it is not clear which one stands out. 3. Land with very dense vegetation density (forest). Very dense vegetation density is an area covered with trees whose tree canopies can cover/rub against each other [19].

According to Suharto [20], land use patterns that use tree-type vegetation cover will have high groundwater retention capacity. Land use patterns that use grass and shrub cover vegetation will have a low value for soil water retention capacity. The variable determination of groundwater storage capacity in land use patterns is influenced by the size of the land cover vegetation. Then, the measure of organic content in the soil determines groundwater drainage. So, land use patterns with forest vegetation or gardens with tree-lined plants ultimately become an effective form of conserving water and land resources.

A number that refers to the ratio between the size of the water on the surface and the existing rainfall called the runoff coefficient [21]. The surface flow coefficient is an indicator in determining whether or not there is physical damage in a watershed. If the C coefficient is significant, this means that more rainwater becomes puddled on the surface rather than absorbed by the soil. This condition causes the amount of groundwater to decrease, making it less profitable in terms of water resource distribution [22]. The runoff coefficient (C) will be influenced by the characteristics and condition of the soil. Seeing the initial water saturation condition, a decrease in the infiltration rate will occur with continuous rain. Apart from that, groundwater, soil density, porosity, and depression reserves also influence the C coefficient value. The C value is for uniform land use, where this condition is rarely found for relatively large land areas. If a watershed consists of various land uses with different runoff coefficients, then the C coefficient used is the watershed coefficient [21].

2.2. *The Volume of Infiltrated Water*

According to Sunjoto [13], the volume of water infiltrated is the total amount of water that enters the soil through the surface. The volume of infiltrated water can be calculated using the equation as follows: $V=A \times (1-C) \times (R_t-ET_0)$, with V as the volume of infiltrated water (m^3/year), A as area (m^2), C as the runoff coefficient, R_t as rainfall intensity (m/year), and ET_0 as evapotranspiration (m/year).

The volume of infiltrated water is not always the same due to many influencing factors, for example, land use and rainfall. As time goes by, the need for land used will continue to grow so that there will be differences in infiltration values on the same land at different times and using different land use. The infiltration change ratio can be calculated using the equation infiltrated volume ratio as $V_a/V_b \times 100\%$, where V_a is the total volume after land use change (m^3/year), and V_b is the total volume before land use change (m^3/year) [13].

2.3. *Data*

The data that will be taken in this research consists of primary data and secondary data. Primary data is a source of research data obtained directly in the field. The data obtained was in the form of infiltration tests, land elevation obtained from measurements using a digital level (waterpass), and verification surveys of land use data obtained from manual area plotting. Secondary data is a source of research data obtained from intermediary media or indirectly in the field. In this research, the secondary data required is a literature study, a map of the research area [23], climatology data, and annual rainfall from 2000 to 2021 obtained from the Class II Syamsudin Noor Banjarmasin Meteorological Station [24]. The secondary data required is annual rainfall and annual evapotranspiration, while the primary data consists of data on the current condition of existing land cover.

Based on the analysis of secondary data and primary data from field observations, the volume of infiltrated water is calculated based on annual rainfall minus evapotranspiration multiplied by the area affected by land cover. Analysis of the volume of infiltrated water was carried out on land conditions before land use changes occurred (Case 1) and after land changes occurred (Case 2). Based on these two conditions, the ratio of reduction in infiltrated water volume resulting from the change of forest areas to residential areas can be seen.

2.4. *Research Sites*

The research was conducted at the Liang Anggang Protected Forest Area Block 1, Gambut District, Banjar Regency and Liang Anggang District, Banjarbaru City, South Kalimantan. The condition of the peat soil at the research location consists of peat that has not been decomposed (fibric). Based on Banjarbaru City Regional Regulation Number 13 of 2014, the Liang Anggang Block 1 Protected Forest area covers an area of 960 ha, which is geographically located at 114.703027°E to 114.735139°E and 3.374692°S to 3.419231°S (Banjarbaru City DPRD, 2014). Based on the Decree of the Minister of Environment and Forestry of the Republic of Indonesia Number: SK.6629/MENLHK-PKTL/KUH/PLA.2/10/2021, the Liang Anggang Block 1 Protected Forest area covers an area of 960.3 ha [25] as shown in **Figure 1**. Based on the Banjarbaru City Public Works and

Spatial Planning Department, the Liang Anggang Block 1 Protected Forest area covers an area of 948.6 ha, as seen in Figure 2. The area used in this research is based on the Banjarbaru City Public Works and Spatial Planning Department, which is 948.6 ha [23]. The difference is in the area of Sambang Lihum Mental Hospital.

3. Results and Discussion

3.1. *Land Elevation*

Land elevation data was taken at the research location manually using a digital level and GPS (Table 1). Peatlands have elevation differences that are not very significant, so only simple equipment is needed. It was used to determine the initial coordinates.

This data was used to survey the slope of the land in the Liang Anggang Protected Forest area, Block 1. Measurements were carried out at three different locations close to the infiltration testing point in the Liang Anggang Protected Forest area Block 1, South Kalimantan.

Measurements are carried out in the direction of water flow in channels where water flows from high to low places in the center of the area. The flow of water in the channels can only be seen directly to determine the direction of flow. It is estimated that the direction of the flow indicates a lower elevation on the land. The data from land elevation measurements is presented in Table 1. It shows that the lowest elevation point is at the GHL 2 WP point with a slope in the direction of the flow, as shown in the red arrow in Figure 3. It can also be concluded that from measurements taken at 3 different locations, the GHL 2 WP point has a lower elevation compared to the GHL 1 WP and GHL 3 WP points. When it rains, water will accumulate in the area at the GHL 2 WP point, which is in the middle of the protected forest.

3.2. *Land Use*

The land use area was determined from Google Earth satellite imagery; however, the plotting of this area was less accurate because the area was taken manually, or the determination of points was only seen with your own eyes, without using tools. After plotting manually, the shaded area can be obtained for different land use areas. Currently, Liang Anggang protected forests are widely used for non-forest purposes, such as plantations, not only community plantations but also palm plantations. The area per land use can be seen according to color, as in Figure 4 to Figure 9.

As can be seen in Figure 7 and Figure 8, a route area is a route area without asphalt pavement, and the surface is not overgrown with plants because it is often passed by people. Meanwhile, the foot route area is a route without asphalt pavement, and the surface is overgrown with plants because people rarely pass it. From Figure 4 to Figure 9, it can also be concluded that the area of the Liang Anggang Block 1 Protected Forest before land use was 948.6 ha, and after land use was 515.9 ha as forest area. The 45.6% of the land was turned into non-forest land.

Protected forests are forest areas that have the primary function of protecting life support systems to regulate water management, prevent flooding, control erosion, prevent seawater intrusion, and maintain soil fertility. The Liang Anggang Block 1 Protected Forest area should be an area that functions as a protected forest, but currently, part of the area is used by the surrounding community for various land uses where the use of the forest area should be regulated in the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number 8 of 2021 [25].

Figure 1. Area of protected forest [26]

Figure 2. Area of protected forest [23]

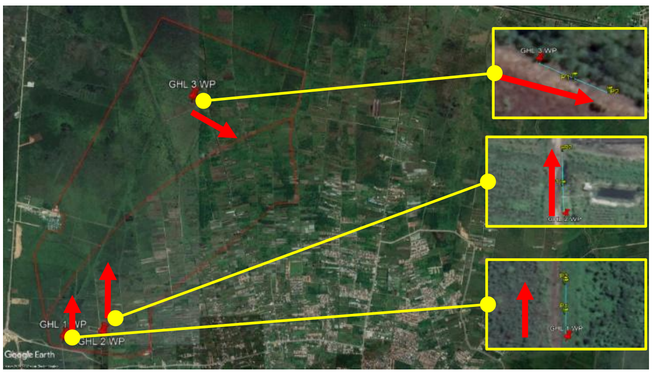

Figure 3. Coordinate point

Table 1. Land elevation data

Location	GHL 1			GHL 2			GHL 3		
Name	GHL 1 WP	P1	P2	GHL 2 WP	P1	P2	GHL 3 WP	P1	P2
Distance (m)	15.1			19.2			10.8		
		17.1			21.3			10	
Elevation (m)	10	9.9	9.9	7	6.9	6.9	8	7.8	7.7

Figure 4. Protected forest area (948.6 ha)

Figure 5. Palm plantation (5.0 ha)

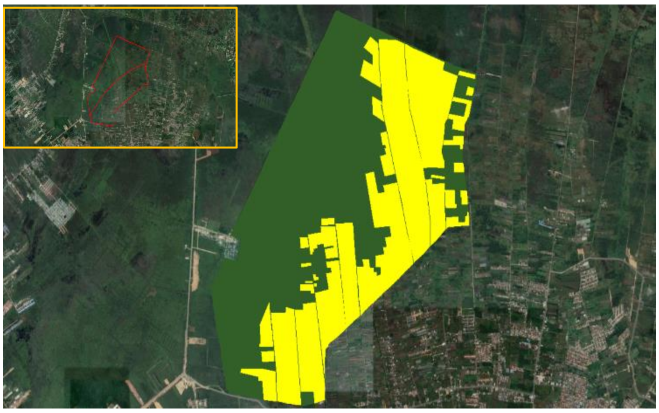

Figure 6. Community plantation (409.3 ha)

Figure 7. Route area (13.7 ha)

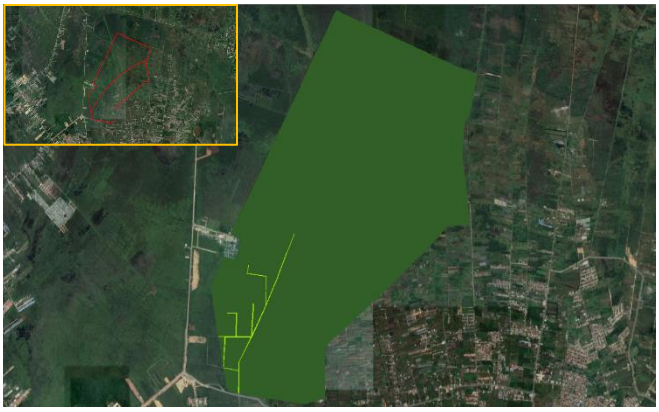

Figure 8. Foot route area (4.3 ha)

Figure 9. Building area (0.4 ha)

3.3. *Runoff Coefficient*

The runoff coefficient is one of the results of primary data observations by paying attention to each existing land cover. The changes in land use cause changes in water infiltration into the soil which are assessed by changes in the runoff coefficient value. A runoff coefficient is needed to calculate the volume of infiltrated water in an area. The coefficient values are obtained as in Table 2.

The runoff coefficient in Case 1 is 0.25 for a natural forest, while the runoff coefficient in Case 2 is 0.299 for the change of forest into a non-forest area. Land changes that occurred in the Liang Anggang Protected Forest area were analyzed using the runoff coefficient value. Determination of the runoff coefficient based on land use density from direct observation in the research area. The C value is taken based on the density of the land cover.

Table 2. Land use and runoff coefficient

No	Land use	Area (ha)	%	Range	coeff (C)
1	Palm oil plantation	5.0	0.5	0.2-0.35	0.35
2	Community plantation	409.3	43.2	0.2-0.35	0.35
3	Route area	13.7	1.44	0.5-0.7	0.6
4	Foot route area	4.3	0.5	0.1-0.35	0.35
5	Building	0.4	0.04	0.4-0.6	0.6
6	Protected Forest	515.9	54.4	0.1-0.4	0.25
	Σ	948.6	100	0.299	

3.4. *The Volume of Infiltrated Water Analysis*

The daily rainfall and climatology data used in this research is located at the Syamsudin Noor Banjarmasin Class II Meteorological Station. The data obtained consists of daily rainfall data every year from 2000 to 2021, as shown in Figure 10 and Table 3. This data was obtained from the online BMKG Class II Meteorological Station Syamsudin Noor Banjarmasin [24].

In 2010, the rainfall data recorded in BMKG online for one year was 0, whereas in 2013, no data was presented. The two years of data were not included in the calculation because, in some literature, it is stated that missing data cannot be determined accurately [27]. From the monthly rainfall data presented in Figure 10, the average annual rainfall for 20 years from 2000 to 2021 is 2592.5 mm/year. The maximum annual rainfall occurred in 2007 at 3249.3 mm/year, and the minimum occurred in 2009 at 1954.7 mm/year. Evapotranspiration Analysis: Calculating Evapotranspiration (ET_0) using the Penman-Monteith. The data obtained consists of temperature, humidity, wind speed, and daily sunlight duration. The data was obtained from the BMKG online [24].

Figure 10 also presents the data from the evapotranspiration analysis (ET_0). The annual average evapotranspiration (ET_0) for 20 years from 2000 to 2021 is 1313.8 mm/year. The maximum annual Evapotranspiration (ET_0) occurred in 2019 at 1416.1 mm/year, and the minimum occurred in 2000 at 1216.4 mm/year. Climatological data records in 2013 were not recorded on BMKG online, so data from that year cannot be used to calculate evapotranspiration (ET0). Data from 2010 was also not used in calculating evapotranspiration (ET_0) because it was to adjust the data used in calculating annual rainfall for 20 years.

The volume of infiltrated water is calculated using the formula with land area data, rainfall data, and evapotranspiration data (ET_0) [13]. The volume of infiltrated water was calculated under conditions before land use changes (Case 1) and after land use changes (Case 2) in the Liang Anggang Block 1 Protected Forest area. The average annual rainfall data is 2592.5 mm/year. Potential Evapotranspiration (ET_0) as 1313.8 mm/year. Before the land use change (Protected Forest Area) to 948.6 ha, the runoff coefficient for flat forest conditions (0-5%) was 0.25. The volume of infiltrated water is obtained as in Table 4.

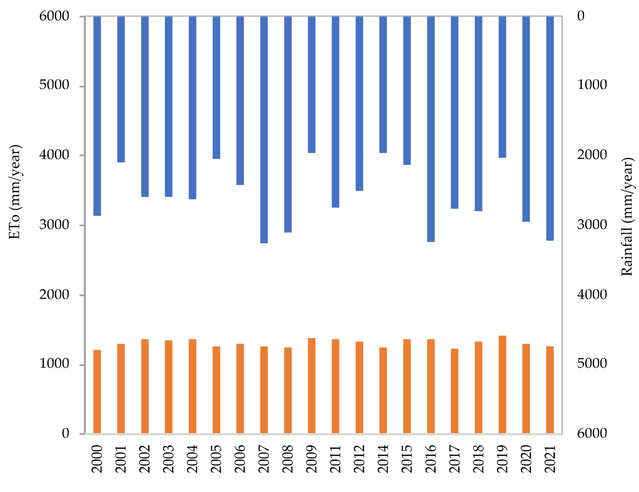

Figure 10. Rainfall and Evapotranspiration (2000 to 2021)

Table 3. Rainfall and ET_0

Year	Rainfall (mm/year)	ET_0 (mm/year)
2000	2860.6	1216.4
2001	2093.4	1291.8
2002	2597.7	1359.5
2003	2597.7	1355.3
2004	2618.6	1372.6
2005	2051.0	1265.8
2006	2412.7	1302.1
2007	3249.3	1260.7
2008	3096.4	1243.1
2009	1954.7	1376.6
2011	2740.6	1362.6
2012	2501.7	1335.7
2014	1955.6	1251.8
2015	2137.4	1374.3
2016	3243.3	1363.1
2017	2757.3	1226.8
2018	2790.9	1340.4
2019	2024.4	1416.1
2020	2945.1	1299.1
2021	3221.0	1262.1
Mean	**2592.5**	**1313.8**

Table 4. The infiltrated water volume value

No	Land use	The volume of infiltrated water (m^3/year)
1	Palm oil plantation	41,922.831
2	Community plantation	3,402,115.826
3	Road	69,800.631
4	Footpart area	35,764.064
5	Building	2,066.348
	Non-Forest Land use	3,877,004.722
	Protected Forest (after)	4,621,884.405

The volume of water infiltrated in naturally protected forest conditions *is* 9,097,126.998 m^3/year (Case 1). The volume of water infiltrated after the current utilization of protected forest after land use planning is 4,621,884.405 m^3/year, and non-forest land use is 3,877,004.722 m^3/year. The total after current use is 8,498,889.127 m^3/year (Case 2).

3.5. *Discussion*

3.5.1. *Land Use Response to Runoff Coefficient*

Changes in land use in the Liang Anggang protected forest caused a change in the runoff coefficient value from 0.25 to 0.299. This change is not very significant. The change from forest area to non-forest or plantation area of 45.6% does not have a large impact on changes in the runoff coefficient. The relatively small decrease was caused by the change from forest to non-forest, which was mostly used as community plantations. If the change in land use is for other purposes such as residential or industrial or other uses that causes water to not be able to seep into the ground.

3.5.2. *The Volume of Infiltrated Water*

The volume of infiltrated water volume ratio contains the value of the ratio of the reduction in the volume of infiltrated water after current use in protected forests (Case 2), the ratio of the volume of infiltrated water between the natural conditions of protected forests (Case 1) and current use in protected forests (Case 2).

Figure 11. The volume of infiltrated water ratio

Figure 11 shows the ratio of changes in land use from Liang Anggang Protected Forest to 45.4% non-forest use. The results of the infiltrated water volume ratio analysis above show that due to the current use of protected forests as non-forest land, the volume of infiltrated water in the study area has decreased by around 6.576%.

It can be seen that the change in land use in the Liang Anggang Protected Forest from natural forest to non-forest land causes a decrease in the runoff coefficient and the volume of infiltrated water entering the soil. A recommendation that can be given from this research is to maintain the infiltration rate to maintain forest vegetation to increase groundwater stores in the forest.

4. Conclusion

The conclusion that can be drawn from this research is that changes in land use that occur in the Liang Anggang Protected Forest cause changes in water infiltration into the soil. The greater change from natural forest to non-forest land use causes a reduction in the volume of infiltrated water and causes forest areas to become dry. This will lead to fires, both intentional and unintentional fires.

This research can continue to be developed by trying to simulate changes in other non-forest land uses, such as increasing palm plantations or community settlements. With this research, the government needs to be more aware of land changes occurring in the Liang Anggang Protected Forest area, which will lead to future disasters such as wildfires.

Author Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

Funding

No funding information from the authors.

Availability of data and materials

All data are available from the authors.

Competing interests

The authors declare no competing interest.

Additional information

No additional information from the authors.

References

[1] M. J. Wooster, G. L. W. Perry, and A. Zoumas, "Fire, drought and El Niño relationships on Borneo (Southeast Asia) in the pre-MODIS era (1980–2000)," *Biogeosciences*, vol. 9, no. 1, pp. 317–340, Jan. 2012, doi: 10.5194/bg-9-317-2012.

[2] V. Liesenberg, H.-D. V. Boehm, H. Joosten, and S. Limin, "Spatial and temporal variation of above ground biomass in tropical dome-shaped peatlands measured by Airborne LiDAR," in *Proceedings of International Symposium on Wild Fire and Carbon Management in Peat-Forest in Indonesia*, 2013.

[3] A. Hoscilo, S. E. Page, and K. Tansey, "Development of post-fire vegetation in the tropical ecosystem of Central Kalimantan, Indonesia," in *Proceedings of the 13th International Peat Congress: Tropical Peatlands*, 2008.

[4] R. Kumalawati, Nasruddin, and Elisabeth, "Strategi Penanganan Hotspot Untuk Mencegah Kebakaran Di Kabupaten Barito Kuala Kalimantan Selatan," in *Prosiding Seminar Nasional Lingkungan Lahan Basah*, 2019, pp. 351–356.

[5] D. Susanto, "Implementasi Kebijakan Restorasi Gambut di Kalimantan Selatan dari Persfektif Komunikasi Kebijakan (Studi Kasus di Kecamatan Candi Laras Utara Kabupaten Tapin)," Universitas Islam Kalimantan MAB, 2020.

[6] BNPB, "Info Bencana," BNPB. Accessed: Mar. 01, 2024. [Online]. Available: https://www.bnpb.go.id/informasi-bencana/buletin-info-bencana-januari-2023

[7] Fathurrahman, I. F. Radam, N. Novitasari, and Rusdiansyah, "Testing the Infiltration Rate of Datar Ajab Village, Hulu Sungai District," *SSRG Int. J. Civ. Eng.*, vol. 10, no. 2, pp. 25–31, 2023, doi: 10.14445/23488352/IJCE-V10I2P103.

[8] X. Qing *et al.*, "Research Progress of Soil Water Infiltration," *E3S Web Conf.*, vol. 189, p. 01006, Sep. 2020, doi: 10.1051/e3sconf/202018901006.

[9] Sunjoto, "Infiltration well and urban drainage concept," in *Future Groundwater Resources at Risk*, 1994, pp. 527–532.

[10] A. A. Hanuf, S. Prijono, and S. Soemarno, "Improvement of soil available water capacity using biopore infiltration hole with compost in a coffee plantation," *J. Degrad. Min. Lands Manag.*, vol. 8, no. 3, p. 2791, 2021.

[11] D. Kabelka, D. Kincl, J. Vopravil, J. Brychta, and J. Bačovský, "Measuring of infiltration rate in different types of soil in the Czech Republic using a rainfall simulator," *Soil Water Res.*, vol. 18, no. 2, pp. 128–137, May 2023, doi: 10.17221/132/2022-SWR.

[12] J. D. Derek, J. Husain, J. E. Lengkong, and Y. E. B. Kamagi, "Laju Infiltrasi Pada Areal Pertanaman Wortel di Wilayah Rurukan Kecamatan Tomohon Timur Kota Tomohon," *Soil Environ. J.*, vol. 1, no. 1, pp. 1–5, 2021, doi: 10.35791/se.21.3.2021.36649.

[13] Sunjoto, *Pembangunan Sumberdaya Air Dalam Dimensi Hamemayu Hayuning Bawono*. Yogyakarta: Hasta Cipta Mandiri, 2009.

[14] R. Har, Aprisal, W. Darta Taifur, and T. Haria Aditia Putra, "The effect of land uses to change on infiltration capacity and surface runoff at latung sub watershed, Padang City Indonesia," *E3S Web Conf.*, vol. 331, p. 08002, Dec. 2021, doi: 10.1051/e3sconf/202133108002.

[15] N. Novitasari and H. Kurdi, "Flood Mitigation in Banjar Regency, South Kalimantan, Indonesia in 2021: Between Hydro-meteorological factor and Anthropogenic factor," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 999, no. 1, p. 012010, Mar. 2022, doi: 10.1088/1755-1315/999/1/012010.

[16] S. Supriatna, F. Hashilah, M. K. Mukhtar, and K. K. Wardani, "Determinant of Land Use Change in South Kalimantan: An Evidence from Banjarbaru City and Banjar Regency," *For. Soc.*, vol. 6, no. 1, pp. 422–435, Apr. 2022, doi: 10.24259/fs.v6i1.18469.

[17] L. S. Tatura, "Kajian Perubahan Tata Guna Lahan dalam Rencana Tata Ruang Wilayah Kota Gorontalo," *J. Inov.*, vol. 7, no. 1, pp. 176–185, 2010.

[18] Novitasari, Y. Sari, Y. F. Arifin, M. R. Faisal, A. R. Baskara, and R. Ridhani, "Improving Land Cover Classification Accuracy with UAV Images and YOLOv5 Deep Learning Model," *Int. J. Emerg. Technol. Adv. Eng.*, vol. 13, no. 5, pp. 106–112, 2023, doi: 10.46338/ijetae0523_11.

[19] Badan Pertanahan Nasional, *Peraturan Menteri Negara Agraria/Kepala Badan Pertanahan Nasional Nomor 1 Tahun 1997 Tentang Pemetaan Penggunaan Tanah Perdesaan, Penggunaan Tanah Perkotaan, Kemampuan Tanah Dan Penggunaan Simbol/Warna Untuk Penyajian Dalam Peta*. 1997.

[20] E. Suharto, "Kapasitas Simpanan Air Tanah pada Sistem Tataguna Lahan LPP Tahura Raja Lelo Bengkulu," *J. Imlu-Ilmu Pertan. Indones.*, vol. 8, no. 1, 2006, doi: 10.31186/jipi.8.1.44-49.

[21] Suripin, *Sistem Drainase Perkotaan yang berkelanjutan*. Yogyakarta: Andi Offset, 2004.

[22] C Asdak, *Hidrologi dan Pengelolaan Daerah Aliran Sungai*. Yogyakarta: Gadjah Mada University Press, 2010.

[23] Dinas PUPR Kota Banjarbaru, *Peta Luasan Hutan Lindung Liang Anggang*. Banjarbaru: Dinas PUPR Kota Banjarbaru, 2022.

[24] BMKG, "Data Hujan Online," BMKG. Accessed: Jun. 30, 2022. [Online]. Available: http://dataonline.bmkg.go.id

[25] Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia, *Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia Nomor 8 Tahun 2021 Tentang Tata Hutan dan Penyusunan Rencana Pengelolaan Hutan, serta Pemanfaatan Hutan di Hutan Lindung dan Hutan Produksi*. 2021.

[26] Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia, "Kawasan Hutan Lindung," Dishut Kalsel.

[27] S. Harto, *Hidrologi, Teori, Masalah dan Penyelesaian*. Yogyakarta: Nafiri Offset, 2009.