

# Causality of Land Use Shifts and Water Availability Variability in the Liliba Oebobo Watershed of Kupang City

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## ABSTRAK

Liliba Watershed is one of the watersheds located in Kupang City that is also experiencing a shift in land use due to the logical consequences of being the center of government of NTT Province, industrial development and a high population growth rate that increases the need for land and land use change that has the potential to have an impact on water system conditions, namely watershed water availability. This study aims to analyze the causality of land use shifts on the variability of water availability in the Liliba watershed. The methods used are spatial analysis to obtain land use shift data, hydrological analysis to obtain water availability variability data and parametric to analyze the causality of land use shift on water availability variability with Liliba watershed as the unit of analysis. The data used is observational data within the last 10 years (2013 - 2022). Spatial data analysis was conducted through interpretation of Landsat TM 8 image processing results, hydrological analysis using the Mock model water balance analysis method, and parametric analysis using multiple linear regression models using the SPSS v.18 for Windows tool at a significance level of 95% ( $\alpha = 0.05$ ). The results showed that simultaneously (sig.=0.109) there was no significant effect of land use shifts on the variability of water availability in the Liliba watershed although partially land use shifts in settlements/built-up land (sig.=0.025), forests (sig.=0.037), and shrubs (sig.=0.016) had a significant effect while waters (sig.=0.052) and agriculture/plantations (sig.=0.377) had no significant effect. Settlement/built-up land (regression coef. = 0.044) had the most influence compared to the other four land use types on the variability of water availability in Liliba watershed.

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## 1. INTRODUCTION

Watershed, hereinafter referred to as watershed, can be considered as a unit of hydrological system with inputs in the form of rainwater so that the interaction between resource components in the watershed can be described through a cycle of water movement (Kodoatie and Widiarto, 2016). The hydrological process in a watershed can be described by the relationship between the input

elements, namely rain, process and output in the form of flow. Rain will produce a certain flow and this flow is not only influenced by the characteristics of the watershed, but also depends on the characteristics of the rain that falls (Asdak, 2014).

One parameter that theoretically and practically can be analyzed to measure the value of the quality level of a watershed is the river discharge that flows in several different rainfall conditions. This parameter is a description of the ecosystem and the characteristics of a watershed (Suripin, 2004). Discharge is an important factor in watershed water management and become one of the criteria for determining the classification of watersheds. River water discharge data serves to provide information about the amount of water flowing at any given time. This is useful to determine the adequacy of water supply for various purposes (Soewarno, 1991). Land use is any form of human intervention on the land in meeting their needs. In the hydraulics aspect, land use change can directly affect the characteristics of land cover so that it can affect the watershed water system, resulting in changes in watershed hydrological responses such as water production (Arsyad, 2009).

Liliba Watershed is one of the watersheds that covers Kupang City and Kupang Regency. It is administratively located in three sub-districts, namely Nekamese, Oebobo and Kelapa Lima. The area of Liliba watershed is 4,557.73 ha. Due to the condition of the Liliba watershed area, which is located within the city and regency areas, the consequences that must be accepted are experiencing urban development where population growth causes the demand for land to increase, resulting in land conversion or land use change in the watershed. The main factor causing changes in land cover/use in general is due to an increase in population (Kubangun, 2016). The rapid development of cities, especially changes in land use, can be detrimental to the city itself, such as the loss of water catchment (Widharyatmo, 2010). With the loss of water catchment areas, it can increase the flow of runoff water, reduce the infiltration of water into the soil which causes flooding (Widodo, 2020).

Land use change that ignores soil and water conservation measures will have an effect in the form of a lack of spring water discharge, one of the inputs of which is rainfall. Similar conditions also occur in the Liliba watershed (Pobas, et al., 2022), especially if it continues for a long period of time. This consciously or unconsciously threatens the sustainability of the Liliba watershed ecosystem, especially land conditions. On the other hand, land use change can affect the watershed's water system. The causal impact of land use shifts on the variability of water availability in the Liliba watershed is a problem that will be studied in this research. The significance of the study is part of the promotive efforts in maintaining the continuity of Liliba Oebobo watershed in Kupang City in a sustainable manner.

The specific objectives of this study were to assess land use shifts, water availability variability, and the causality of land use shifts on water availability variability in the Liliba Oebobo watershed in Kupang City over the last 10 years (2013 - 2022).

## 2. RESEARCH METHODS

### 2.1 Time and Location

The research was conducted from May to November 2023 in Liliba Oebobo watershed in Kupang City. The research area amounted to  $\pm$  4,557, 730 ha. The research location map can be seen in the figure below:

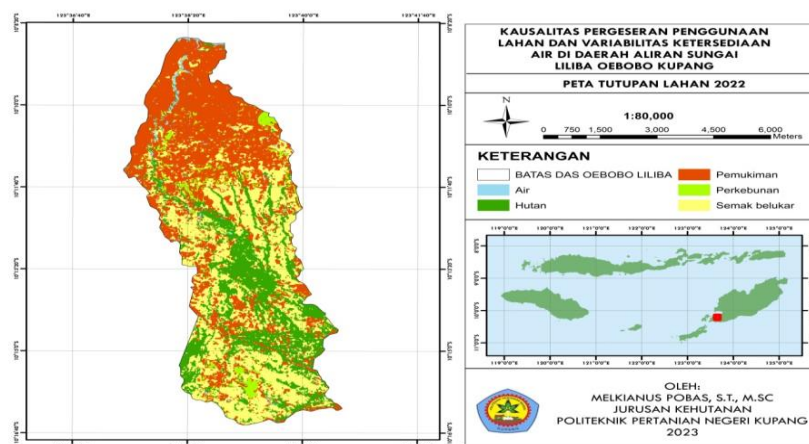


Figure 1. Research Location

## 2.2 Tools and Materials

The tools used are Global Positioning System (GPS) to determine the coordinates of points in the field and a computer equipped with ArcGis v.10.2 software, while the materials used are Landsat ETM+ 8 images from 2013 - 2022 and climate data.

## 2.3 Data Type and Collection

Primary data (Nazir, 2014) includes land use shift map data and water availability variability data processed from secondary data, direct observation of the physical appearance of land use types and environmental conditions in the Liliba watershed area. The physical appearance of the research object in 2023 is assumed to be representative for the data on the physical appearance of land use in the last year of the study time, namely 2022. Secondary data includes DEM data of Kupang city and surrounding areas, Landsat TM 8 images sourced from <http://Glovis.usgs.org> and Kupang City climate data for 2013-2022 sourced from <https://power.larc.nasa.gov/data-access-viewer/> and <https://www.ogimet.com>. The data used is observation data in the last 10 years (2013 - 2022).

## 2.4 Data Analysis

a. Land Use Shift, conducted using spatial analysis methods.

The processed data from the Landsat ETM 8 image is then analyzed by overlaying the types of land use in the initial observation year (T0) with the following year (T1) to find out both unchanged and changed objects. The calculation of the area of land use shift (PPL) is done using the equation:

$$PPL = T1 - T0 \quad (1)$$

b. Water Availability Variability, conducted by hydrological analysis.

The availability of water in the Liliba Oebobo watershed was calculated as the river discharge using the Mock model water balance analysis method, which is through the conversion of rainfall into discharge with three parts of the process, namely rainfall and evapotranspiration, water balance on the ground surface, and groundwater flow and storage (Mock, 1973). Potential evapotranspiration (ET<sub>o</sub>) is calculated based on the FAO modified Penman-Monteith method using data on temperature, wind speed, relative humidity, and solar brightness (Monteith, 1965).

c. Causality of Land Use Shifts to Water Supply Variability.

Analyzed parametrically using multiple linear regression models using the SPSS v.18 for Windows tool at a significance level of 95% ( $\alpha = 0.05$ ), which has a general equation:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + e \quad (2)$$

Description:

Y : Variable variability of water availability m<sup>3</sup> / dtk

a : Constant

b<sub>1,2,3,4,5</sub> : Regression coefficient of the independent variables of water land use, settlement / built-up land, forest, shrubs and agriculture / plantations

X<sub>1,2,3,4,5</sub> : Independent variables water land use, settlement/built-up land, forest, shrubs and agriculture/plantations

e : Estimation error

## 3. RESULTS AND DISCUSSION

### 3.1 Land Use Shift in Liliba Watershed in the last 10 years (2013 - 2022)

Based on the results of processed Landsat TM 8 images, in the last 10 years (2013 - 2022) there has been a shift in land use in the Liliba Oebobo watershed as shown in the table below

**Table 1.** Land Use Shift in Liliba Watershed in the Last 10 Years (2013 - 2022)

Land Use	Area (ha)			
	Year 2013	Year 2014	Year 2018	Year 2022
Waters	44,727	50,805	38,293	64,438
Settlement / Built-up Land	1.095,741	1,394,854	1,574,820	1,848,856
Forest	965,516	721,724	920,346	1,015,426
Shrubs	1.223,642	2,146,212	1,458,079	1,459,317
Plantation/Agriculture	1.228,104	244,135	566,191	169,693
Total	4.557,730	4.557,730	4.557,730	4.557,730

Source: Data Processing Results, 2023

From the table above, it can be seen that there are five categories of land use, namely waters, settlements/developed land, forests, shrubs and plantations/agriculture where there are fluctuations in the area of land use in the Liliba Oebobo watershed in Kupang city over a period of 10 years.

### 3.2 Variability of Water Availability in Liliba Watershed over the last 10 years (2013 - 2022)

Based on the results of hydrological analysis with the *Mock* model *water balance* analysis method, the variability of water availability in the Liliba watershed in the last 10 years (2013 - 2022) is obtained as shown in the table below:

**Table 2.** Variability of Water Availability in Liliba Watershed over the Last 10 Years (2013 - 2022)

Year	Total (m <sup>3</sup> /dtk)	Average (m <sup>3</sup> /dtk)
2013	19,15	1,60
2014	13,15	1,10
2018	11,77	0,98
2022	17,18	1,43

Source: Data Processing Results, 2023

### 3.3 Causality of Land Use Shifts on Water Availability Variability in Liliba Watershed in the last 10 years (2013 - 2022)

Based on the results of the multiple regression linear model analysis, it was found that 82.7% of the variation in water availability in the Liliba watershed in the last 10 years (2013-2022) can be explained by shifts in land use of waters, forests, settlements / built-up land, shrubs and agriculture / plantations, while the remaining 17.3% is explained by other factors outside this research model. The results of the model accuracy test can be seen in the table below

**Table 3.** Model Accuracy Test Results

	Average	Standard Deviation	R-Square	Std. Error of the Estimate
Variability of water availability (discharge)	14,42	6,43	0,827	4,01

Source: Data Processing Results, 2023

Shifts in land use of waters, forests, settlements/built-up land, shrubs and agriculture/plantations simultaneously have no significant effect ( $\text{sig.}=0.109$ ) on the variability of water availability in the Liliba watershed over the last 10 years (2013 - 2022). Simultaneously or together, shifts in land use of water, forest, settlement/built-up land, shrubs and agriculture/plantations that occur in the Liliba watershed area do not have a significant impact on the variability of water availability in the Liliba watershed. The results of the F-Test can be seen in the table below

**Table 4.** F-test Results

Source of Variation	df	Sum of Squares	Mean Square	F Count	Sig.
Regression	5	307,597	61,519	3,820	0,109
Residuals	4	64,414	16,103		
Total	9	372,011			

Source: Data Processing Results, 2023

The variation in water availability in the Liliba watershed is not solely determined by fluctuations in the area of the five land use classifications, although 82.7% of the variation in water availability can be explained by fluctuations in the area of the five land use classifications.

The results of this study are in line with the results of Fa'ah's research (2021) which found that changes in the area of secondary forest land cover, settlements, dry land agriculture, and grass simultaneously ( $\text{sig.}=0.178$ ) had an insignificant effect on the availability of water in the Osmo Batung Kupang watershed.

Partially, shifts in land use of settlements/built-up land ( $\text{sig.}=0.025$ ), forests ( $\text{sig.}=0.037$ ) and shrubs ( $\text{sig.}=0.016$ ) have a significant effect while waters ( $\text{sig.}=0.052$ ) and agriculture/plantations ( $\text{sig.}=0.377$ ) have no significant effect on the variability of water availability in the Liliba watershed in the last 10 years (2013-2022). Shifts in the area of each type of land use, including settlements/built-up land, forests and shrubs, had a significant effect on the variability of water availability in the Liliba watershed during this period. In contrast, shifts in the area of aquatic land use and agriculture/plantations did not have a significant impact on the variability of water availability in the Liliba watershed during this period. The results of the T-Test can be seen in the table below:

**Table 5. T-test Results**

Variables	Regression Coefficient	Thitung	Sig.
Constant	15,465	8,616	0,001
Waters	0,031	2,739	0,052
Settlement/built-up land	-0,044	-3,482	0,025
Forest	0,022	3,084	0,037
Shrubs	0,020	4,024	0,016
Agriculture/plantation	0,004	0,993	0,377

Source: Data Processing Results, 2023

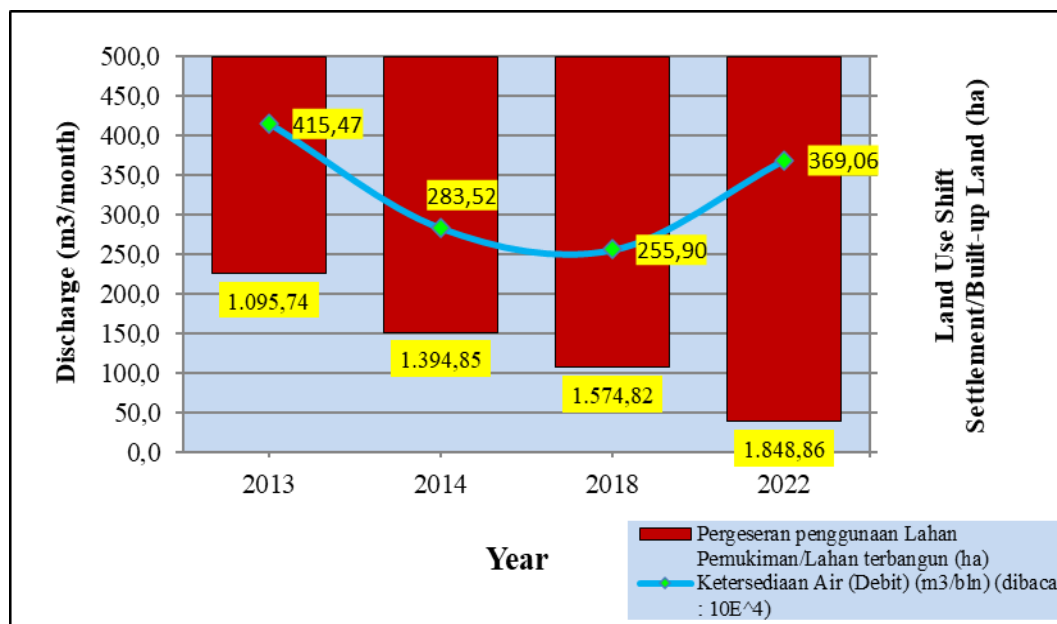
The partial impact of fluctuations in the area of the five land use classifications on water availability in the Liliba watershed varies as evident from the regression equation formed from this measurement model, namely:

$$Y_2 = 15.465 + 0.031X_1 - 0.044X_2 + 0.022X_3 + 0.020X_4 + 0.004X_5 \quad (3)$$

An increase in the area of land use of water, forest, shrubs and agriculture/plantations by 1 ha each will increase the water availability of the Liliba watershed by 0.031 m<sup>3</sup>/s, 0.022 m<sup>3</sup>/s, 0.020 m<sup>3</sup>/s and 0.004 m<sup>3</sup>/s, respectively. Conversely, an increase in the area of residential land use/built-up land by 1 ha will reduce the water availability of the Liliba watershed by 0.044 m<sup>3</sup>/s. Shifts in residential land use/built-up land have the most influence on the variability of water availability in the Liliba watershed.

The results of this study are slightly different from the results of Fa'ah's (2021) research which shows that partially, there is no significant effect of secondary forest (sig.=0.231>0.05), settlements (sig.=0.337>0.05), dry land agriculture (sig.=0.337>0.05), and grass (sig.=0.124>0.05) on water availability in the Osmo Batugang Kupang watershed in 2007-2017.

The results of this study are in line with the statement that land use activities that change the type or types of land cover in a watershed can often increase or decrease water yield (Asdak, 2014), as shown in Figure 2 below.



**Figure 2.** Graph of Variability of Water Availability (Discharge) and Shifting Land Use of Settlement/Built-up Land in Liliba Watershed 2013-2022

Soemadiredja and Asyiwati (2022) stated that the conversion of agricultural land into built-up land will cause the absorption capacity of the soil to water to decrease because it has been covered by built-up land. This is in line with Suhendar's (2005) statement in Fa'ah (2021) that changes in land use from green open space (agriculture, moorland) to built-up areas result in the availability of water resources, especially groundwater, from year to year, which continues to change, where the wider the built-up land, the rainwater that seeps into the ground which becomes groundwater reserves decreases.

Forests in hydrology have a very large influence so that if forest functions are disturbed, it can have a major impact on hydrological functions. The influence of forests on hydrological functions

includes increasing river flow discharge, regulating fluctuations in river flow discharge, and improving the quality of water supply (Suripin, 2004).

#### 4. CONCLUSIONS

There has been a shift in land use and variation in water availability in the Liliba watershed over the last 10 years (2013-2022). Changes in land use from green open space to built-up areas will increase runoff water so that the infiltration of rainwater into the soil decreases. A more specific study is needed on the conversion of land use from green open space to built-up areas and its relationship to the availability of groundwater and water needs in the Liliba watershed.

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