THESIS

DROUGHT FORECASTING MODEL FOR LIMBOTO-BOLANGO-BONE RIVER BASIN AND SUMBAWA RIVER BASIN

FLAVIA DOMITILLA FREDERICK
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ABSTRACT

Drought is one of the most frequent water-related disasters in Indonesia. Drought will have a significant impact on countries related to agriculture, which one of them is Indonesia. Drought disaster management needs to be done to reduce the impact of drought, considering that agriculture accounts for 70% of the total water needs in Indonesia. Drought forecasting is one of the components in Drought Disaster Management as one of the early warning systems. The Limboto-Bolango-Bone River Region and the Sumbawa River Region were selected in this study. The characteristics of drought calculated with the SPI method on a real-time monthly rainfall basis. Validation of the results of the drought index is done by calculating the paddy fields affected by drought area with drought intensity and drought duration. Forecast model was made for the dry months with a statistical approach using second-order polynomial and multilinear regressions equations which is a function of the teleconnection parameter, Oceanic Niño Index teleconnection (ONI). The drought forecasting model produces a drought index with the smallest error based on the Root Mean Square Error (RMSE) for the Limboto-Bolango-Bone river basin RMSE maximum of 0.444 for the drought forecast model for one month ahead and a maximum RMSE of 0.684 for the drought forecast model for six months ahead. For the Sumbawa river basin, the maximum RMSE is 0.620 for the drought forecast model for one month ahead and the RMSE is a maximum of 0.698 for the drought forecast model for six months ahead.

Keywords: Drought, Limboto-Bolango-Bone, Sumbawa, SPI Method, ONI, RMSE

MODEL PRAKIRAAN KEKERINGAN UNTUK WILAYAH SUNGAI LIMBOTO-BOLANGO-BONE DAN WILAYAH SUNGAI SUMBAWA

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ABSTRAK

Kekeringan adalah salah satu bencana keairan yang sering terjadi di Indonesia. Kekeringan akan memberikan dampak yang besar untuk negara yang bergantung dengan pertanian, salah satunya Indonesia. Perlu dilakukan manajemen bencana kekeringan untuk mengurangi dampak kekeringan mengingat pertanian menyumbang kebutuhan sebanyak 70% dari total kebutuhan air di Indonesia. Prakiraan kekeringan merupakan salah satu komponen dalam Manajemen Bencana Kekeringan, yakni bertindak sebagai elemen dari sistem peringatan dini. Wilayah Sungai Limboto-Bolango-Bone dan Wilayah Sungai Sumbawa dipilih pada studi ini. Karakteristik dari kekeringan akan dihitung menggunakan metode SPI dengan basis hujan bulanan yang bersifat real-time. Validasi hasil indeks kekeringan dilakukan dengan cara menghitung korelasi antara luas wilayah sawah yang terkena kekeringan dengan intensitas kekeringan dan durasi kekeringan. Pemodelan prakiraan kekeringan dibuat untuk bulan kering dengan pendekatan statistik menggunakan persamaan polinomial orde dua dan regresi linear berganda yang merupakan fungsi dari parameter telekoneksi Oceanic Niño Index (ONI). Model prakiraan kekeringan menghasilkan indeks kekeringan dengan kesalahan terkecil yaitu berdasarkan *Root Mean Square Error* (RMSE) untuk Wilayah Sungai Limboto-Bolango-Bone RMSE maksimum 0,444 untuk model prakiraan kekeringan satu bulan ke depan dan RMSE maksimum 0,684 untuk model prakiraan kekeringan enam bulan ke depan. Untuk Wilayah Sungai Sumbawa RMSE maksimum 0,620 untuk model prakiraan kekeringan satu bulan ke depan dan RMSE maksimum 0.698 untuk model prakiraan kekeringan enam bulan ke depan.

Kata Kunci: Kekeringan, Limboto-Bolango-Bone, Sumbawa, Metode SPI, ONI, RMSE

PREFACE

This thesis is made as a requirement to complete the bachelor degree education in Civil Engineering from Faculty of Engineering at Parahyangan Catholic University. This thesis has been a great adventure for the writer because the writer has been through many phases of emotion when writing this Thesis. There are a lot of people around the writer that gave the writer technically guidance and mentally support in the making of this Thesis.

Therefore, this page is specially dedicated to thank those people who always be on the writer's side while making on this thesis. First of all the writer want to thank God because of His grace and guidance, the writer can finish this thesis. The writer would like to express the gratitude to:

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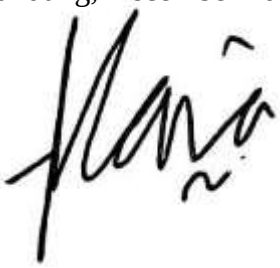
The writer realizes that this thesis may contain many limitations and far from perfection. Therefore, the writer would greatly appreciate any suggestions and critiques in terms of enhancing this thesis. The writer wish that this thesis can be the initiation of the drought topics for thesis in Water Engineering at Parahyangan Catholic University and this thesis can be useful for any reader.

Bandung, December 2019



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ANNOTATIONS

$\overline{rg_X}$: The mean of the independent variable rg_X rank

$\overline{rg_Y}$: The mean of the dependent variable rg_Y rank

$\hat{y}_i$: The fitted values of the dependent variable Y for the i^{th} case

$\bar{X}$ (t,m) : Average value of selected rainfall data series on m-month, t-year

$cov(_{rg_X,rg_Y})$: covariance or the rank variables

$\bar{y}$: Data Mean

ρ_{rg_X,rg_Y} : Pearson correlation coefficient for the rank variables

σ_{rg_X} and σ_{rg_Y} : standard deviations of the ranks variables

A (t,m) : deficit or surplus indicators on m-month, t-year

D_n : Amount of deficit from m – month until m+i – month

Fx : Cumulative Probability Distribution

LBB : Limboto Bolango Bone

L_n : Duration of drought from m – month until m+i – month

n : number of observation

ONI : Oceanic Niño Index

P : Rainfall data

P* : Bias corrected rainfall

P_0 : Reference monthly rainfall (1 mm per month)

q : The probability of zero rain occurrence in τ-month

r : Correlation coefficient

rg_{Xi} : The independent variable rank

rg_{Yi} : The dependent variable rank

RMSE	: Root Mean Square Error
SPI	: Standardized Precipitation Index
TRMM	: Tropical Rainfall Measuring Missions
X (t,m)	: Selected rainfall data series on m-month, t-year
x	: Independent Variable
$X_{v,\tau}$	: Monthly Rainfall Data on v-year and τ-month.
y	: Dependent Variable
y_i	: Observed Data
z	: Standardized Precipitation Index - SPI
z_f	: Forecasted data (expected values or unknow results)
z_o	: Original data (known results)
μ_τ	: Average $X_{v,\tau}$ on τ-month
σ_τ	: Standard Deviation on τ-month

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CHAPTER 1
INTRODUCTION

1.1 Background

Flood and drought are the most frequent water-related disasters in Indonesia in the period of 1815-2019, where flood is ranked first, and drought ranked fifth after waterspout, landslides, and fires (BNPB , 2019). The repercussion of flooding is more visible and countable hydraulically and hydrologically than drought. According to the 5th Assessment Report of the Intergovernmental Panel on Climate Change, one of the key words is the increasing risk of drought-related water and food shortage. Drought begins to reveal its effects when it has spread and developed on a large scale in an area (Adidarma, 2015). A general definition of drought is "An extended period of rainfall deficit" (Şen, 2015). Rising temperatures is one of the significant factors causing drought because it disrupt the hydrological cycle, which makes the rain patterns change (Adidarma, 2015). For the past 30 years, the temperature in Indonesia is getting warmer at 0.9°C (BMKG , 2018).

Drought will lead to enormous impacts for countries that rely upon agriculture, which one of them is Indonesia. Agriculture is one of the vital sectors in Indonesia because the water used for agriculture reaches 70% out of the total water uses in Indonesia (Indonesian Agency for Agricultural Research and Development, 2003). UN-ESCAP reported Indonesia's potential loss due to natural disasters and drought reached USD 50 billion, which makes Indonesia ranked 4th of the Asia Pacific countries, below India, Japan, and China (ESCAP, 2019). UN-ESCAP have also reported that there are 3 million Indonesians lived below the poverty line in severely drought-impacted districts, of whom 1.2 million relies on rainfall for food production" (ESCAP, 2019). It can be concluded that the people who suffer the most when drought occurs in Indonesia are people who lived below the poverty line. There are two locations that will be discussed as case studies, Limboto-Bolango-Bone River Basin, Gorontalo Province and Sumbawa River Basin, Nusa Tenggara Barat Province. On July 2019 BPS published the Indonesian's Statistic Report. In that report stated, Gorontalo province ranked 5th,

and Nusa Tenggara Barat Province ranked 8th in Indonesia for their percentage of people live below poverty with the respective rate of 15.52% and 14.56%.

Regarding the substantial losses suffered by Indonesia, it indicates that Indonesia still uses Disaster Crisis Management to handle drought. It means that waiting for the drought to occur and affected the people first before handling it. Regardless that drought is immensely impacting the people that live below the poverty line. Therefore, to reduce the impact of drought, mitigation based on Disaster Risk Management should be performed. The drought mitigation is aiming to anticipate the impact of the drought (Levina, Adidarma, Martawati, & Seizarwati, 2011). The drought mitigation requires analysis with specific parameters to determine the severity of the drought. The Ministry of National Development Planning of the Republic of Indonesia on RAN-MAPI Report strongly recommended the enabling of drought early warning system for disaster risk management (National Development Planning/National Development Planning Agency, 2014). Therefore the Early Warning System is needed. Early Warning System for drought obtained from drought forecasting results.

This study is conducted to monitor the drought with SPI method and produce the Drought Forecasting Model for Limboto-Bolango-Bone (LBB) river basin and Sumbawa river basin with the statistical approach.

1.2 Study Urgency

Drought has a huge impact on society, especially in Indonesia. However, there has not been any real action to overcome this problem. Therefore, this study was conducted to overcome the problem of drought in Indonesia especially using the non-structural apporach/measure as a Civil Engineer.

1.3 Study Objectives

Objectives of this study:

1. Perform the Meteorological drought analysis
2. Produce the drought forecast model for study areas for the dry months

1.4 Scope Study

In this study, the scope limitation of the discussions are:

1. Rainfall data using TRMM.
2. Correction factor of TRMM rainfall data using literature studies from recent studies in Limboto-Bolango-Bone River Basin and for Sumbawa River Basin using the correction from Verminnen
3. Meteorological drought analysis using SPI Method
4. Drought Forecasting using ONI index as one of the input

1.5 Research Methodology

The research methodology uses in this study are:

1. Literature Study

   A literature study is conducted to understand the Meteorological Drought and its analysis and to compose the Drought Forecasting Model.
2. Data Analysis

   Data Analysis is conducted to determine the drought's starting time, severity level, and termination time.
3. Forecast Modeling

   Forecast modeling is conducted to predict the drought condition in the study areas.

   The research methods conducted are also displayed in the flowchart in Figure 1.1.

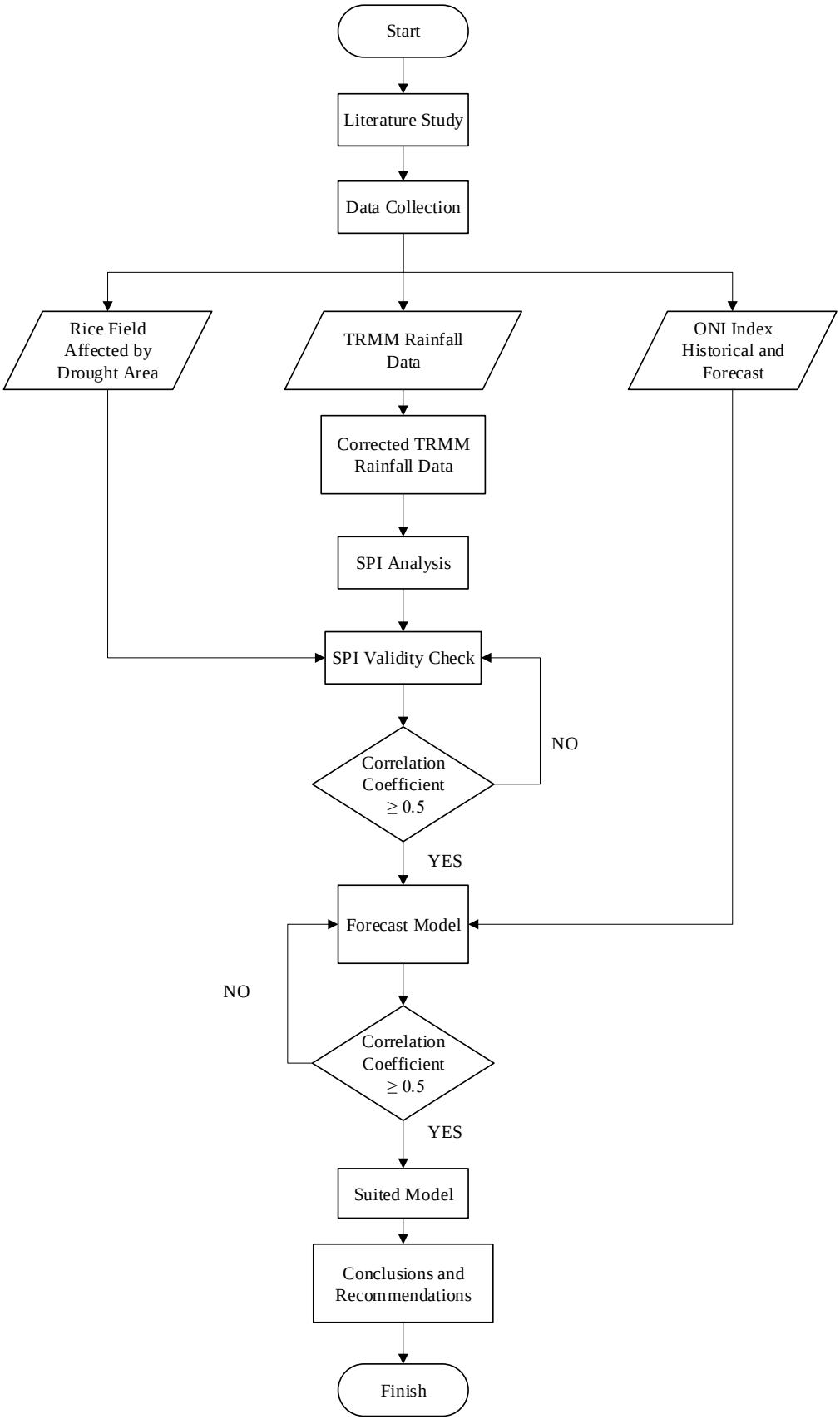

Figure 1.1 Flow Chart