UNDERGRADUATE'S THESIS

APPLICATION OF VENSIM SOFTWARE TO ANALYZE WATER – ENERGY – FOOD NEXUS OF SELOREJO RESERVOIR

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PERNYATAAN

Yang bertandatangan di bawah ini, saya dengan data diri sebagai berikut:

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Menyatakan bahwa skripsi ~~/ tesis / disertasi~~*) dengan judul:

Application of Vensim Software to Analyze Water – Energy – Food Nexus of Selorejo Reservoir adalah benar-benar karya saya sendiri di bawah bimbingan dosen pembimbing. Saya tidak melakukan penjiplakan atau pengutipan dengan cara-cara yang tidak sesuai dengan etika keilmuan yang berlaku dalam masyarakat keilmuan. Apabila di kemudian hari ditemukan adanya pelanggaran terhadap etika keilmuan dalam karya saya, atau jika ada tuntutan formal atau non formal dari pihak lain berkaitan dengan keaslian karya saya ini, saya siap menanggung segala resiko, akibat, dan/atau sanksi yang dijatuhkan kepada saya, termasuk pembatalan gelar akademik yang saya peroleh dari Universitas Katolik Parahyangan.

Dinyatakan: di Bandung

Tanggal: 7 Januari 2022

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ABSTRACT

A concept of water, energy, and food (WEF) nexus was introduced to study the interconnection among these three elements. The Nexus Approach can support a transition to sustainability by integrating the three sectors. Benefits include increased productivity of resources, excess as a resource in multi-use systems, stimulating development through economic incentives, and policy coherence. Selorejo Reservoir supplies water for three hydropower plants with a total capacity of 36.53 MW and 5,700 Ha irrigation, supplying energy and providing food for East Java Province. The use of water for these different purposes may cause a conflict between water for energy and water for food. A simultaneous simulation model is required to simulate and analyze the interconnection and feedback behavior of the elements. One of the available system dynamic computation models is the Vensim. According to the model, the current Konto River Basin system was unable to provide water, food, and energy to the entire Malang District throughout the year. Two hypothetical alternative scenarios are created in this study to improve the current system in Konto River Basin. The first alternative is to boost production and eliminate trade-offs on Selorejo Reservoir without making any changes to the current infrastructure or system. There is an increase in the domestic electricity supply after using the first alternative scheme in the WEF Nexus model. The goal of the second alternative is to boost resource productivity and to use trash as a resource in a multi-use system. Selorejo Powerplant capacity and water treatment plant capacity are updated or enhanced in this alternate. After applying the second alternative, there is an increase in supply for direct demand energy and water.

Keywords: Selorejo Reservoir, Dynamic System Modelling, Vensim Software, WEF Nexus.

APLIKASI PERANGKAT LUNAK VENSIM DALAM ANALISIS *WATER – ENERGY – FOOD NEXUS* PADA WADUK SELOREJO

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ABSTRAK

Konsep hubungan air, energi, dan makanan (WEF Nexus) diperkenalkan untuk mempelajari interkoneksi di antara ketiga elemen ini. Pendekatan Nexus dapat mendukung transisi menuju keberlanjutan dengan mengintegrasikan ketiga sektor tersebut. Manfaatnya termasuk peningkatan produktivitas sumber daya, limbah sebagai sumber daya dalam sistem multi guna, merangsang pembangunan melalui insentif ekonomi, dan koherensi kebijakan. Waduk Selorejo memasok air untuk tiga pembangkit listrik tenaga air dengan total daya bangkitan sebesar 36,53 MW dan irigasi 5.700 Ha, memasok energi dan menyediakan makanan untuk Provinsi Jawa Timur. Penggunaan air untuk tujuan yang berbeda ini dapat menimbulkan konflik antara air untuk energi dan air untuk makanan. Sebuah model simulasi simultan diperlukan untuk mensimulasikan dan menganalisis interkoneksi dan umpan balik. Salah satu model komputasi system dinamis yang tersedia adalah Vensim. Berdasarkan simululasi model, sistem DAS Konto saat ini tidak mampu menyediakan air, makanan, dan energi ke seluruh Kabupaten Malang sepanjang tahun. Dua skenario alternatif dibuat dalam studi ini untuk memperbaiki sistem yang ada di DAS Konto. Alternatif pertama adalah meningkatkan produksi dan menghilangkan pemborosan di Waduk Selorejo tanpa melakukan perubahan pada infrastruktur atau sistem saat ini. Terjadi peningkatan pasokan energi direct demand atau kebutuhan energi rumah tangga setelah menggunakan skema alternatif pertama pada model WEF Nexus. Tujuan dari alternatif kedua adalah untuk meningkatkan produktivitas sumber daya dan menggunakan sampah sebagai sumber daya dalam sistem multi guna. Beberapa infrastruktur dan sistem diperbarui atau ditingkatkan dalam alternatif ini. Setelah menerapkan alternatif kedua, terjadi peningkatan pasokan untuk kebutuhan langsung energi dan air.

Kata kunci: Waduk Selorejo, Model sistem dinamik, Vensim, WEF Nexus.

PREFACE

This thesis is made as a requirement to complete a bachelor's degree in Civil Engineering from the Faculty of Engineering at Parahyangan Catholic University. There are a lot of people around the author that gave technical guidance and mental support in the making of this thesis. Therefore, this page is specially dedicated to give appreciation for those who always be on the writer's side while making this thesis. The writer would like to express the gratitude to:

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Bandung, 28 January 2022

Amelia Andriani

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CHAPTER 1
INTRODUCTION

1.1 Background

Water, energy, and food (WEF) are fundamental for human beings. Food provides humans with energy and nutrition to perform their life processes. Humans need water for various reasons and activities, from the fundamental activities such as for drinking and showering to other activities like washing, cleaning, gardening, etc. (Carpenter et al., 2021). Water is also used in industry and manufacturing, even to generate energy and electricity for being used in many ways. It produces heat used to manufacture goods, process food, and transportation. Recently, water, energy, and food security issue have been rising globally (Hoff, 2011). The scarce water, energy, and food are facing increasing demand driven by a rising global population, rapid urbanization, changing diets, economic growth, and climate change (Hoff, 2011). These tightening constraints and challenges continue to push WEF demand yet lower supply. Therefore, ensuring the availability and sustainability of these three elements are essential works that should be concerned. Furthermore, water, food, and energy have invisible interconnection among each other. It takes water and energy to produce food, energy is used to transfer water from a source to houses, and water is required to produce energy in power plants (Hoff, 2011).

A concept of water, energy, and food (WEF) nexus was introduced to study the interconnection among these three elements. In the WEF nexus approach, the three sectors, water security, energy security, and food security, are inextricably linked, and that actions in one area often impact one or both others (Hanlon, 2014). This means there is a significant potential to increase overall resource use efficiency and benefits in production and consumption.

The Nexus Approach can support a transition to sustainability by integrating the three sectors. Hence, many could be benefited from the WEF Nexus concept. These benefits include increased productivity of resources, excess as a resource in multi-use systems, stimulating development through economic incentives, governance, institutions, and, policy coherence, benefiting from productive

ecosystems, integrated poverty alleviation and green growth, capacity building and awareness-raising, and achieving a Green Economy Such support should appeal to national interest and encourage governments to engage (Hoff, 2011). The Nexus Approach can support a transition to sustainability by integrating the three sectors. Hence, reducing trade-offs and generating additional benefits. Such support should appeal to national interest and encourage governments to engage.

A challenge in integrating the three sectors is their interconnection itself. The availability change of a particular element will directly or indirectly affect the availability or production of other elements. Therefore, a simultaneous simulation model is required to simulate and analyze the interconnection and feedback. A system dynamics model is a suitable approach for understanding the feedback behavior of interconnected elements. One of the available system dynamic computation models is the Vensim. Vensim has simulated several simultaneous behaviors, including the nationwide WEF Nexus simulation (Wicaksono & Kang, 2019). This study has shown a successful calculation of availability, demand, and required of water, energy, and food on a nation-scale. However, the nation scale model is not applicable to establish any policy, especially in an archipelago or spatially various countries such as Indonesia. Based on its success story, this study will modify and implement this nation-scale model into the river basin-scale model. The Konto river basin, specifically at Selorejo Reservoir, is chosen as the study area for this study.

Selorejo Reservoir is located in East Java Province and a part of Brantas River Basin. Currently, Selorejo Reservoir supplies water for Selorejo, Mendalan, and Siman hydropower plants with a total capacity of 36.53 MW and 5,700 Ha irrigation (Triweko et al., 2010), supplying energy and providing food for Malang District. The use of water for these different purposes may conflict between water for energy and water for food. Implementing this river basin scale WEF Nexus model to Selorejo Reservoir is expected to verify the model's capability and evaluate the feedback of water, energy, and food during their supply and production process. An evaluation of WEF Nexus would be advantageous to establish any policy and action to increase productivity and reduce trade-offs on Selorejo Reservoir.

1.2 Problem Statement

According to the background that has been mentioned before, a few problems could be identified. The invisible interconnection and feedback of water, energy, and food may affect the allocation and supply of water. The current model that is capable to simulate this connection was developed for a nation-scale policy, which may not suitable for a smaller area such as a river basin or reservoir. Therefore, an adjustment of the model is required before it could be utilized in a smaller scale area.

The use of water from Selorejo Reservoir for supplying hydropower plants and irrigation may cause a conflict. Currently, the water supply for irrigation is depending on excess water from hydropower plants. Therefore, the interconnection of them should be evaluated to reduce any possible conflicts and establish suitable action to ensure a reliable supply.

1.3 Aim and Objectives

The aim of writing this thesis is to evaluate WEF Nexus implementation on Selorejo Reservoir with system dynamic modeling. To achieve this aim, several objectives are set as follow:

1. Implement and/or conform an existing nation-scale nexus model to a river-basin scale model
2. Calculate and analyze water, energy, and food production in Selorejo Reservoir
3. Evaluate the nexus between water, energy, and food on Selorejo Reservoir
4. Suggest alternatives according to maximize water, energy, and food production.

1.4 Scope of Study

A limitation of the problem is needed so that the research could be carried out in a clear direction of the purpose of this research. The limitations of the problem in this study are as follows:

1. The data for conducting the WEF Nexus analysis was taken from the literatures, previous studies, and secondary data,
2. The scope of this research was carried out in the Selerejo Reservoir,
3. The river basin scale model was developed from an existing nation-scale model that was constructed using the Vensim software,
4. This study does not consider yet the climate change effect, detailed hydrology analysis, and future predictions

1.5 Research Methodology

The research methodology for this thesis consists of:

1. Data Collecting

   In this step, necessary data to construct the WEF Nexus model are collected. These data include water distribution scheme and historical time data series of the Konto River Basin, technical data, average inflow and outflow, and evapotranspiration data of Selorejo Reservoir, and hydropower and irrigation water demand.

2. Developing System Dynamic Modelling

   This step is carried out to construct the system dynamic model using Vensim and calculate water availability, and electricity, and food production using the constructed model.

3. WEF Nexus Evaluation

   This step is carried out to find the correlation between water for food and water for energy nexus and to find conflicts between the three sectors.

The research process could be visualized as a schematic diagram shown in Figure 1.1

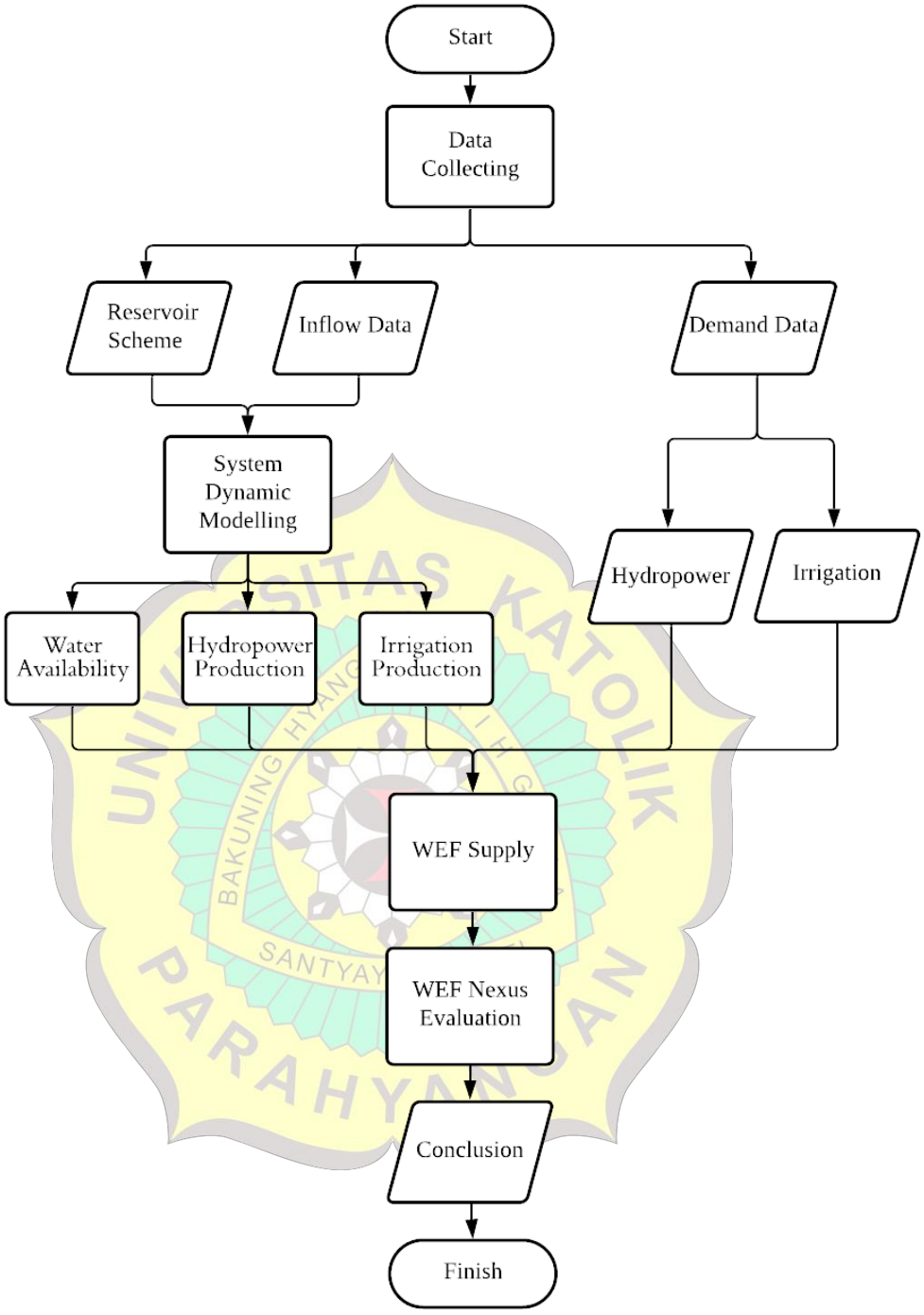

Figure 1.1 Study Flow Chart

1.6 Writing Systematic

CHAPTER 1 INTRODUCTION

This chapter describes the background of the problem, problem statement, aim and objectives, the scope of the study, research methodology, and writing systematics.

CHAPTER 2 LITERATURE STUDY

This chapter explains the theoretical approach about The WEF Nexus, and available models, also Dynamic System Modelling and Vensim.

CHAPTER 3 STUDY AREA AND DATA AVAILABILITY

Chapter 3 summarizes the Konto River and Selorejo Reservoir, including hydropower and irrigation demand. Besides that, other necessary data to construct the WEF Nexus Model will be explained in this chapter.

CHAPTER 4 MODEL DEVELOPMENT

This chapter explains the scheme and development of the WEF Nexus model. This chapter also consists of formulas that are used to build the dynamic system model.

CHAPTER 5 DATA ANALYSIS AND DISCUSSION

This chapter presents the results from the simulation process and analysis of the WEF model for the Selorejo reservoir. Then, the results will be discussed to explore and evaluate the nexus in the Selorejo reservoir.

CHAPTER 6 CONCLUSION AND RECOMMENDATION

This chapter is the end of the research, presenting the conclusions from the obtained results and the aforementioned discussion and recommendations that could be done to improve the results in future research.