# CHAPTER I
# INTRODUCTION

## 1.1 Background

Climate change is one of the major threats that has become a primary focus in various global policies due to its extensive impacts on the environment, economy, and human life. One of the causes of climate change is the increasing concentration of greenhouse gases in the atmosphere, which leads to global warming (Nastiti & Hardiningsih, 2022). The rise in greenhouse gas concentrations is caused by various factors, one of which is the activities of mining companies (Hariswan et al., 2022). Greenhouse gases are atmospheric gases that can absorb and re-emit infrared radiation from the Earth's surface, leading to global warming. These gases include carbon dioxide ($CO_2$), methane ($CH_4$), chlorofluorocarbon (CFC), ozone ($O_3$), and nitrous oxide ($N_2O$) (Didik & Nining, 2022). The mining sector, particularly the coal subsector, is one of the main contributors to carbon emissions. Coal generates 66% higher emissions compared to other energy sources in terms of carbon dioxide ($CO_2$) per unit of energy produced. These emissions result from various activities, including mining extraction processes and the operations of coal-fired power plants (PLTU) that use coal as their primary fuel (Akmalia et al., 2022).

Indonesia, through PT PLN (Persero), has set an ambitious target to achieve Net Zero Emissions by 2060. One of PLN's initiatives to reach this goal is implementing the Accelerated Renewable Energy Development (ARED) program, which aims to reduce coal usage in coal-fired power plants (PLTU). Additionally, PLN plans to increase the capacity of renewable energy-based power plants by 51.6% as part of a more sustainable energy transition strategy (PLN, 2024).

Another mitigation method to reduce the carbon footprint from coal combustion in PLTUs is the co-firing method. Co-firing is the process of burning two types of fuel simultaneously. PLTUs use co-firing to incorporate biomass into electricity generation (Nasution et al., 2022). The fuel for co-firing comes from wood chips, tree debris, energy crops, certain types of waste, or processed waste, with a mixture percentage ranging from 1% to 5% (Aditya et al., 2022).

To optimize the implementation of co-firing, accurate monitoring and estimation of biomass availability are required. One approach that can be utilized is the use of satellite imagery and machine learning techniques to analyze biomass distribution across various regions. With the availability of remote sensing data, which is easily accessible and comes with diverse spatial, temporal, and spectral resolutions, the use of satellite information has become increasingly effective in supporting biomass resource mapping and estimation (Khaki et al., 2021).

One of the remote sensing technologies used for biomass estimation is Sentinel-2 imagery, which is part of the Copernicus remote sensing program by the European Space Agency (ESA). The Sentinel-2 satellites are divided into Sentinel-2A (launched in 2015) and Sentinel-2B (launched in 2017). These satellites operate together in a phased manner, positioned 180 degrees apart from each other. They provide 13 spectral bands covering a swath width of 290 km at various resolutions (Chen et al., 2021).

Machine learning approaches can be used to predict biomass distribution based on Sentinel-2 satellite imagery. In recent years, machine learning techniques such as decision trees, random forest (RF), and extreme gradient boosting (XGBoost) have been increasingly applied in biomass estimation, integrated with satellite data usage (Li et al., 2021). XGBoost is a relatively new machine learning algorithm that has been proven to be more accurate in predicting the spatial-temporal patterns of biomass, as demonstrated in a biomass estimation study in eastern Mongolia (Jia et al., 2022). Meanwhile, random forest is a machine learning algorithm based on decision tree methods, characterized by its random sampling approach for feature extraction from a set of training data and building classification or regression models based on that data (Li et al., 2022).

From the explanation above, the main challenge in biomass estimation to support the co-firing program in PLTUs is ensuring the availability of accurate and up-to-date data. By leveraging satellite imagery approaches, a more adaptive and precise method for biomass estimation can be obtained. The combination of Sentinel-2, which provides high-resolution imagery for smaller areas, becomes an optimal choice for biomass distribution analysis. Utilizing Sentinel-2 satellite data with XGBoost and random forest machine learning algorithms enables comprehensive mapping of biomass availability. This study is expected to assist in the planning of biomass feedstock distribution and logistics for PLTUs by making a heatmap distribution of biomass to support the decision making for PLTU to achieve PLN goal of Net Zero Emission in 2060.

## 1.2 Problem Identification

Based on the background that has been outlined, several issues need to be considered in biomass estimation as a feedstock for co-firing in PLTUs, including:

1. There are still limitations in monitoring and estimating biomass availability accurately and in up-to-date across various regions.
2. Limited research discusses the utilization of Sentinel-2 satellite imagery in biomass distribution analysis for co-firing needs in PLTUs.
3. The optimization of machine learning algorithms such as XGBoost and Random Forest in biomass estimation modeling still needs further development.

## 1.3 Research Scope

To address the issues that have been explained, this research requires limitations to clarify the scope of the study. The limitations of this research are as follows:

1. This study focuses solely on biomass estimation using Sentinel-2 satellite imagery and machine learning techniques.
2. The algorithms used in this research are XGBoost and Random Forest to predict biomass distribution based on remote sensing data.
3. The data used in this study consists of multispectral data from Sentinel-2 and GEDI Satellite with relevant variables for biomass estimation.
4. This study does not discuss the technical aspects of the biomass combustion process in the co-firing method but rather focuses on biomass availability estimation and mapping.

## 1.4 Research Question

Based on the background that has been explained, the research questions formulated are as follows:

1. How well can Sentinel-2 vegetation indices combined with GEDI data capture variations in Above Ground Biomass (AGB) in the Central Kalimantan region?
2. How accurate are Random Forest and XGBoost in predicting biomass distribution using Sentinel-2 and GEDI data in Central Kalimantan?
3. What additional data or model improvements are needed to make biomass estimation more accurate and useful for planning biomass supply in PLTU co-firing programs?

## 1.5 Research Objective

Based on the research questions described, the objectives of this study are as follows:

1. To find out how well Sentinel-2 vegetation indices combined with GEDI data can show differences in Above Ground Biomass (AGB) in the Central Kalimantan region.
2. To evaluate the predictive accuracy of Random Forest and XGBoost in estimating biomass distribution using Sentinel-2 and GEDI data in Central Kalimantan.
3. To identify additional data sources and model improvements that can enhance the accuracy and usefulness of biomass estimation for planning biomass supply in PLTU co-firing programs.

## 1.6 Research Significance

The expected benefits of this research based on the research objectives are as follows:

1. **Theoretical Benefits**

   This study is expected to contribute to the understanding of utilizing Sentinel-2 satellite imagery and machine learning algorithms, such as XGBoost and Random Forest, for biomass estimation. The findings of this research can also serve as a reference for other studies related to remote sensing and spatial data analysis, particularly in supporting the transition to renewable energy.

2. **Practical Benefits**

   This research can provide valuable information for PT PLN and relevant stakeholders in managing biomass distribution and logistics to support the co-firing program in PLTUs. Additionally, the developed model is expected to assist in monitoring biomass availability more efficiently, thereby supporting clean energy policies and carbon emission reduction efforts in Indonesia.

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