CHAPTER 1

INTRODUCTION

1.1 Background

Land subsidence is a significant geological phenomenon, especially in urban areas such as Yogyakarta and Bandung. Excessive groundwater extraction, construction loads, and the natural consolidation of soil strata are the principal causes of subsidence. This increases the likelihood of flooding, disruption of drainage systems, and damage to infrastructure, such as cracks in buildings and roads. Local communities have experienced significant economic and social detriments due to these consequences[1].

The integration of deep learning with GNSS (Global Navigation Satellite System) technology enhances the accuracy of land subsidence forecasting and enables the detection of geographical and temporal patterns of land subsidence in extensive urban regions. Through the analysis of elevation variations and temporal data, deep learning algorithms can identify nuanced trends that conventional methods may overlook. In regions such as Bandung and Yogyakarta, where intricate and localized factors such as diverse soil compositions, groundwater levels, and anthropogenic activities influence subsidence, this expertise is especially vital. This integrated technique facilitates precise mapping of subsidence hotspots, enabling targeted actions and effective allocation of mitigating resources[2].

In order to achieve Sustainable Development Goal (SDG) 11, which aims to make cities and human settlements inclusive, safe, resilient, and sustainable, land subsidence presents a significant obstacle that must be overcome. Efforts to improve urban resilience and sustainability are hampered by the effects of subsidence, which include an increased risk of flooding, damaged infrastructure, and disruptions to urban services. Through the promotion of sustainable urban development, the improvement of catastrophe risk reduction, and the guarantee of resilient infrastructure, monitoring and mitigating subsidence through the use of sophisticated technology and methods correspond closely with SDGs 11[3].

The GNSS technology has been extensively employed to monitor and analyze ground subsidence. This approach enables precise measurement of the Earth's surface position, facilitating the accurate detection of elevation changes caused by land subsidence. GNSS data indicates that ground subsidence rates in the Bandung Basin varied from 1.4 to 13 millimeters per year between 2016 and 2023[1].

Land subsidence is additionally monitored by several methods, including InSAR (Interferometric Synthetic Aperture Radar). This method uses high-resolution radar satellite data to detect alterations in the terrestrial surface. The integration of GNSS and InSAR data enhances the comprehension of subsidence trends and spatial patterns, providing a more comprehensive perspective on the characteristics of subsidence in a specific region[2].

Utilizing deep learning methodologies such as the Temporal Fusion Transformer (TFT) can enhance the predictive accuracy of land subsidence. TFT is an attention-based architecture designed for multi-horizon time series forecasting with high interpretability[4]. TFT can forecast temporal dynamics and identify the components that most significantly influence land subsidence by utilizing previous GNSS and InSAR data.

Consequently, in areas like as Bandung and Yogyakarta, the integration of GNSS and InSAR data processed using the Temporal Fusion Transformer can serve as an effective approach for monitoring and predicting land subsidence. This method enhances prediction accuracy and provides a deeper understanding of subsidence causes, facilitating the development of targeted mitigation strategies[5]. In addition, this research contributes to the achievement of Sustainable Development Goal 11 by ensuring the sustainability and viability of urban environments through improved monitoring, planning and resource allocation. Moreover, aligning SDG 11 with national policies and regulatory frameworks in Indonesia can further strengthen efforts to mitigate land subsidence. By incorporating scientific advancements into governance structures, urban planning, and resource management, policymakers can establish a comprehensive approach that integrates legal, environmental, and technological perspectives. This alignment ensures that land subsidence mitigation strategies are effectively implemented, fostering more sustainable and resilient urban areas.

1.2 Problem Identification

In geotechnical and environmental research, the investigation of land subsidence is essential, necessitating precise monitoring to mitigate its effects on infrastructure, groundwater management, and urban development. Both disciplines pertain to the environment. Numerous traditional methods, such as satellite radar interferometry (InSAR) and elevation surveys, face several significant limitations. These approaches often exhibit restricted temporal and spatial coverage, hence impeding their ability to provide comprehensive and real-time data. As a result, they are less effective than possible alternatives. Moreover, the manual analysis inherent in these traditional techniques is labor-intensive and susceptible to human error, leading to diminished efficiency in both large-scale and dynamic contexts. An illustrative example of this is that InSAR techniques are highly reliant on coherence and geometric alignment, rendering them less effective in environments that are densely vegetated or subject to constant change [6], [7].

Global Navigation Satellite Systems (GNSS) offer a potentially valuable option for monitoring ground subsidence due to their continuous data acquisition and high temporal resolution. The processing of GNSS data, however, poses considerable challenges, primarily due to the vast volume and intricacy of the generated datasets. Geographical Navigation Satellite System (GNSS) data, unlike prior methodologies, includes three-dimensional positioning information that varies over time. Consequently, sophisticated analytical instruments are necessary to examine the dynamic patterns. Moreover, global navigation satellite systems (GNSS) are susceptible to various noise effects, such as multipath errors and atmospheric delays, necessitating the application of advanced filtering and correction algorithms. Addressing this complexity by conventional methods would be problematic, especially in scenarios necessitating real-time insights and predictive capabilities[8].

The utilization of deep learning in GNSS data processing offers a revolutionary method for addressing these difficulties. Deep learning algorithms can effectively manage extensive, multidimensional datasets and discern significant patterns that are frequently undetectable by conventional statistical techniques. Moreover, deep learning models can adjust to diverse data distributions, rendering them resilient for real-time surveillance and forecasting of land subsidence. Notwithstanding these benefits, the implementation of deep learning necessitates meticulous attention to algorithm design, feature selection, and model training to guarantee dependability and precision. The amalgamation of deep learning with Global Navigation Satellite Systems offers a prospect for improving subsidence analysis; nonetheless, the absence of methodological standards and the high processing requirements pose considerable obstacles to wider implementation[9].

Bandung and Yogyakarta are excellent choices for studying land subsidence using AI due to their unique geological, urban, and socioeconomic factors. Bandung, situated in a volcanic basin, experiences significant land subsidence due to excessive groundwater extraction and rapid urbanization, making it a critical hotspot for such studies. Similarly, Yogyakarta, located near active tectonic zones and characterized by its heavy reliance on groundwater, faces subsidence risks compounded by its dynamic urban expansion. Employing AI in these regions allows for sophisticated analysis of spatiotemporal patterns, prediction of future subsidence trends, and mitigation planning. These cities' challenges offer opportunities to develop adaptable AI models to address geological factors and human-induced stresses.

Land subsidence poses considerable obstacles to the attainment of Sustainable Development Goal (SDG) 11, which seeks to provide inclusive, safe, resilient, and sustainable urban environments. Consequences such as compromised infrastructure, heightened flood risks, and disturbed urban systems resulting from subsidence hinder the objective of resilient urban development. Accurate and effective surveillance of ground subsidence with advanced technologies like GNSS and deep learning directly supports SDG 11 by aiding in catastrophe risk mitigation, resilient infrastructure development, and sustainable urban management[10]. The integration of deep learning with Global Navigation Satellite Systems presents an opportunity for enhancing subsidence analysis; nevertheless, the lack of methodological standards and significant processing demands present substantial challenges to broader application. Furthermore, weak regulatory enforcement and the lack of stringent policies in Indonesia exacerbate the issue of land subsidence. Current laws and regulations often fail to adequately monitor and control excessive groundwater extraction and unsustainable urban expansion, leading to unchecked subsidence rates. Strengthening these regulations and ensuring proper enforcement are critical steps in aligning with SDG 11's vision for resilient and sustainable cities.

1.3 Objective

The objectives can be described as follows based on the background and identification of the problems underlying this thesis research

1. To design a system capable of predicting land subsidence in the cities of Bandung and Yogyakarta for the year 2024 using deep learning techniques.
2. To align the developed predictive system with the goals of Sustainable Development Goal (SDG) 11, ensuring that the research contributes to creating more inclusive, safe, resilient, and sustainable cities by enabling effective land subsidence monitoring.

1.4 Scope of Work

In order to improve the thesis study, a number of restrictions will be put in place. The following are the limitations and presumptions of the research scope:

1. This research was only conducted in two cities, namely Bandung and Yogyakarta.
2. After the system is completed, we will discuss the regulation.
3. This study doesn’t discuss transmission in depth.

1.5 Expected Results

1. Makes it easier for several parties to make decisions.
2. Find out land subsidence more accurately using deep learning methods.

1.6 Research Methodology

In this thesis, we use fundamental studies and experiments based on work packages. here are the WPs for this thesis:

1. Literature Study

   The theories required to comprehend and bolster the implementation research are examined in this method. research on implementation. Books, conferences, and research journals were the sources of relevant theory.
2. Data Collection

   The source of the GNSS data used comes from the Indonesian geospatial information agency (BIG)
3. Technical Analysis

   The use of temporal fusion transformer, a transformer-based deep learning technique, to forecast land subsidence.
4. Regulatory Analysis

   The approach of the research embraces the ideas of Sustainable Development Goal 11, which focuses on the creation of cities that are sustainable, safe, and inclusive for all people. The research makes a contribution to the enhancement of urban resilience, the improvement of strategies for catastrophe risk reduction, and the guarantee of sustainable infrastructure planning. This is accomplished by analyzing the implications of land subsidence and offering solutions that use predictive and monitoring methods.

1.7 Methodology

The following chapters will include the technique used to compile this thesis:

1.7.1 CHAPTER I – INTRODUCTION

This chapter will address the introduction, problem identification, objective, scope of work, expected results, research methodology, and methodology

1.7.2 CHAPTER II – BASIC CONCEPT

This chapter will describe the theoretical investigations that will strengthen and support this research. The theories that will be discussed are land subsidence, global navigation satellite system, data collection, temporal fusion transformer, and regulatory review.

1.7.3 CHAPTER III – SYSTEM MODEL ANALYSIS

This chapter will explain the analysis model system starting from the dataset used, system flowchart, technical analysis, performance parameters and regulatory analysis.

1.7.4 CHAPTER IV – RESULT AND DISCUSSION

This chapter will explain the results of the technology result and regulatory result.

1.7.5 CHAPTER V – CONCLUSION, RECOMMENDATION, & FUTURE WORK

This chapter describes the conclusions of the technical analysis and regulations. Then, conclusions, recommendations, and further research will be drawn.