CHAPTER I
INTRODUCTION

1. 1. Background of the Study

Rice (Oryza sativa L.) is a strategic commodity that underpins food security for half the world's population, particularly in Indonesia [1], [2]. Unfortunately, the agricultural sector currently faces challenges such as extreme climate fluctuations and water scarcity during the dry season [3]. Conventional irrigation, which relies on farmers' intuition, often leads to water wastage and has a low efficiency of around 30-50%, or indeed results in a shortage of supply during critical phases of rice growth, leading to reduced productivity and high operational costs. However, efficient water use at the right time can increase crop productivity by up to 20-25% [4], [5].

The use of submersible pumps for groundwater extraction has become a popular solution, however their operation is still predominantly controlled by manual systems or simple on-off controls [6]. Such systems are not yet capable of handling the uncertainty of environmental parameters such as soil moisture and rainfall intensity which are dynamic and non-linear in nature [7]. type-1 fuzzy logic is often used to address this problem, but it has limitations in handling high levels of uncertainty in sensor data resulting from environmental disturbances or hardware degradation [8].

The solution to this problem lies in the use of the Interval type-2 Fuzzy Logic System (IT2FLS). IT2FLS offers more robust modelling as it utilises a Footprint of Uncertainty (FOU), which is capable of mapping uncertainty more accurately than type-1 [9]. Integration with Internet of Things (IoT) technology enables real-time data collection from rice paddies or agricultural land to a cloud server [10]. Supported by a mobile ecosystem such as android, farmers can monitor and control pumps remotely, thereby transforming traditional farming into efficient smart agriculture.

This study proposes a submersible pump control system for rice field irrigation using an IoT and android based type-2 fuzzy logic system. This research aligns with the smart farming program, which supports smart agriculture through the utilisation of digital technology, the Internet of Things (IoT), and automated applications to enhance agricultural productivity, particularly amongst millennial farmers [11]. Digitalisation within the agricultural sector can improve the efficiency of both production and distribution, as well as data management, to create a sustainable food system [12].

The system uses an ESP32 microcontroller as the main controller due to its ability to read sensors, its built-in Wi-Fi connectivity, and its ability to facilitate communication between devices via a web server [13], [14]. The system also integrates various sensors, including two soil moisture sensors for dual readings, a rain sensor for weather detection to determine irrigation requirements, and a PZEM-004T sensor to monitor electricity consumption, which contributes to energy cost efficiency. The data collected by this hardware system is then transmitted and displayed in real time via a mobile application developed and supported by a web server with a backend, which farmers can use to monitor and control the system remotely.

1. 2. Problem Formulation

Based on the background described above, the research question is formulated as follows:

1. How can an automatic irrigation control system for paddy fields, utilising a submersible pump and an ESP32 microcontroller, be designed and implemented using type-2 fuzzy logic?
2. How can a system be designed that is capable of reading and utilising data from two soil moisture sensors, a rain sensor and a power consumption sensor to support automatic pump control?
3. How can a system be designed and built to conserve water resources and reduce electricity costs by automatically controlling the operation of submersible pumps?

1. 3. Research Objectives

Designing and implementing a smart IoT-based irrigation system using an ESP32 microcontroller with type-2 fuzzy logic processing on the server for automatic decision making to control whether the pump is switched on or off based on real-time data from two soil moisture sensors and a rain sensor, which can be monitored via a mobile app (android), enabling users to monitor the system remotely. Users can determine the power consumption of the PZEM-004T sensor based on the pump’s operating duration and the volume of water used, in accordance with the pump’s specifications.

1. 4. Significance of the Study

The research carried out offers benefits to farmers in terms of labour efficiency, as the pumps can be monitored remotely and controlled automatically by the system, as well as in terms of electricity efficiency through a pump control system that is more precise and adaptive to environmental conditions. This research provides a practical solution that has the potential to help farmers reduce the wastage of water resources, minimise electricity operating costs, and improve the effectiveness of rice field management.

1. 5. Scope and Limitations

To ensure this research remains focused and can be carried out effectively, the following limitations have been established:

1. The scope of the system's application is limited to rice paddies with irrigation systems using submersible pumps powered by the national electricity grid (PLN) or a generator, it does not include gravity irrigation, solar-powered pumps, or drip irrigation.
2. The control system utilises a type-2 fuzzy logic approach, whereby type-2 fuzzy logic is used to determine irrigation requirement categories based on environmental variable inputs. The system does not regulate pump speed (Variable Speed Drive/VFD) as the pumps used are of the on/off type.
3. This system is designed and tested in locations or areas with affordable internet access. Implementation does not cover fully offline environments or areas with very limited or no internet connectivity.
4. The system does not use a water flow sensor.
5. The mobile application has been developed exclusively for the android platform using android studio. It has not been developed for iOS.
6. System testing was carried out on small-scale real rice fields (≤ 1000 m^2), not on a large commercial scale or in corporate farms.