CHAPTER V
CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This study has successfully designed and implemented an Internet of Things (IoT) based automatic submersible pump irrigation control system using type-2 fuzzy logic. Based on the research carried out, the following conclusions have been drawn:

1. The system was successfully implemented as an integrated whole, ranging from the hardware, ESP32 programming, web server/API, to the android application. The type-2 fuzzy logic system (Interval Type-2 Fuzzy Logic System) implemented on the server using PHP, with 36 rules, type-2 membership functions (Upper and Lower Membership Functions), and the Karnik-Mendel (KM) type reduction method, has functioned effectively. The system is capable of handling the uncertainty in sensor data.
2. Two soil moisture sensors, a rain sensor and a PZEM-004T sensor can read data in real time and transmit it to the server for processing. The decision to switch the pump on or off is made automatically based on soil moisture levels and rainfall. Testing has shown that the system is capable of accurately detecting variations in soil conditions (dry, moist, wet) and weather conditions (from no rain to heavy rain).
3. Test results show that the type-2 fuzzy logic based system is capable of delivering significant efficiency gains compared to manual methods, based on a 24 hour test sample. It achieved a 40% reduction in electricity consumption and a 41% reduction in water usage. Furthermore, the sensors demonstrated high accuracy is the soil moisture sensor recorded 99,45% accuracy, the second soil moisture sensor recorded 99,59% accuracy, and the rain sensor showed no errors during testing, achieving 100% accuracy. There was no chattering (repeated on-off cycling) in the pump, and all data was synchronised effectively between the IoT devices, the server and the Android app.

5.2. Recommendation

Based on the findings of the research, here are some recommendations for further development:

1. To improve the system's scale and resilience, it is recommended that trials be conducted on larger areas of rice paddy, namely over 1,000 m², and over a longer period covering a full growing season. The purpose of these trials is to validate the stability of the system's performance, test its scalability, and evaluate the reliability of type-2 fuzzy logic in the face of more complex and dynamic environmental conditions.
2. To improve the system's accuracy and functionality, it is recommended that a water flow sensor (flow meter) be added to measure the volume of water discharged by the pump directly and in real time, thereby making calculations of water usage efficiency more precise. Optimise the membership function and the set of type-2 fuzzy rules by reducing the number of redundant rules, thereby reducing the computational load without compromising the system's accuracy. To improve system performance and security, an offline fallback mode mechanism can be developed, whilst strengthening authentication, data encryption and protection against attacks on the API and IoT communications.
3. It is recommended that the mobile app be developed not only for the android platform, but also for the iOS platform, so that it can be used by more farmers. In addition, various features should be added, such as push notifications, irrigation requirement forecasts, analysis of water and electricity consumption, and a more comprehensive web dashboard.