CHAPTER V
CONCLUSION AND RECOMENDATION

5.1. Conclusion

Based on the results of the conducted research, several conclusions can be drawn to address the formulated research problems as follows:

1. The IoT-based Type-2 Fuzzy system was successfully designed to monitor and control the environmental parameters of the aquascape. The system is capable of integrating temperature, light intensity, and water turbidity sensors with the ESP32 microcontroller, as well as relay-based actuators. Based on the functional testing results of each component, all devices operate properly in accordance with the design and are able to display data in real time.
2. The developed system is capable of maintaining the stability of the main aquascape parameters, where water temperature, light intensity, and turbidity can be kept within the desired ranges. Based on the testing results and in reference to the standards applied in this study, the water temperature ranges between 28–30°C, the light intensity falls within the requirements of low-tech aquascape plants at approximately 13–16 watts, and the water turbidity level remains within the range of 0–50 NTU. These results indicate that the system is able to maintain environmental parameters in accordance with the ideal conditions required by the aquascape ecosystem.
3. Based on system testing under various conditions, the system’s performance in maintaining stable water conditions can be considered good. The system is able to respond automatically to changes in environmental parameters in accordance with the predefined fuzzy rules, ensuring that the aquascape remains within the optimal range. The testing results show that changes in conditions can be responded to promptly by the actuators, allowing parameter fluctuations to be controlled more effectively compared to a system without control.
4. The designed microcontroller- and IoT-based system is capable of performing real-time and remote monitoring and control of aquascape environmental conditions. Sensor data can be displayed through an IoT platform, and changes in conditions can be directly controlled by the system, thereby facilitating users in monitoring without the need to be physically present at the location.

5.2. Recomendation

Based on the research results and the conclusions obtained, the developed Type-2 Fuzzy Logic-based IoT system still has opportunities for further improvement and development. In future research, the system can be enhanced by incorporating additional environmental parameters that influence the aquascape ecosystem, such as pH, dissolved oxygen levels, and total dissolved solids, thereby enabling more comprehensive and accurate environmental control of the aquascape.

In addition, the Type-2 Fuzzy Logic method used in this study can be compared with other control methods, such as Type-1 Fuzzy, PID, or artificial intelligence-based approaches, in order to identify the advantages and limitations of each method in maintaining the stability of the aquascape environment. Further development on the software side is also recommended, particularly in the user interface, by incorporating features such as historical data visualization, automatic notification systems, and more flexible parameter settings through application- or web-based platforms.

In addition to improvements in parameters and methods, enhancements can also be made in terms of hardware and system reliability. The use of sensors with higher accuracy and more optimal calibration processes can improve the quality of the generated data. On the other hand, the system can be further developed by incorporating security and redundancy features, such as backup power systems or notifications in the event of device failure, allowing the system to operate more reliably over the long term. Testing on a larger-scale aquascape or with different types of plants is also recommended to evaluate the effectiveness and flexibility of the system under various usage conditions.