Fuzzy Logic Sprinkler System

Team Members:

WAINAINA, NIXON MBURU – 665507

WILLIAM MUNGAI – 666494

BRACKCIDIS TEMKO – 666989

LEE KAMAU – 666591

STEPHEN KAHANYA 668435

Date: March 23, 2025

Introduction

This report presents an advanced fuzzy logic-based sprinkler control system designed to optimize irrigation based on environmental conditions. The system demonstrates the practical application of fuzzy logic in agricultural automation, providing intelligent and efficient water management.

The primary advantage of this fuzzy logic approach is its ability to handle imprecise input data and provide smooth, continuous output adjustments, unlike traditional binary systems. This results in more natural and efficient irrigation control.

System Description

The intelligent sprinkler system incorporates multiple components working in harmony:

Input Variables:

1. Soil Moisture (0-100%): Measures water content in soil
   - Dry (0-50%): Indicates urgent watering needs
   - Moist (20-80%): Optimal moisture range
   - Wet (50-100%): Sufficient water content

2. Temperature (0-50°C): Monitors environmental temperature
   - Cold (0-20°C): Low evaporation conditions
   - Warm (10-40°C): Moderate water requirements
   - Hot (30-50°C): High evaporation risk

Output Control:

- Water Sprinkling Level (0-100%): Automated adjustment based on conditions
  - Low (0-50%): Conservative water usage
  - Medium (20-80%): Balanced irrigation
  - High (50-100%): Intensive watering

Methodology

The system employs triangular membership functions for both inputs and outputs, providing a balanced approach to fuzzy set representation. The rule base is designed to prioritize water conservation while maintaining optimal growing conditions.

Key Implementation Features:

1. Continuous variable monitoring
2. Real-time adjustment capability
3. Smooth transition between states
4. Adaptive response to changing conditions

Implementation Screenshots

The following screenshots show the system implementation and key components:

```python
import numpy as np
import skfuzzy as fuzz
import skfuzzy.control as ctrl
import matplotlib.pyplot as plt
from fpdf import FPDF
import os
import textwrap
from datetime import datetime

# fuzzy system for an automatic sprinkler


# We define inputs: Soil Moisture and Temperature, and an output: Water Sprinkling Level
```

System Components and Variables

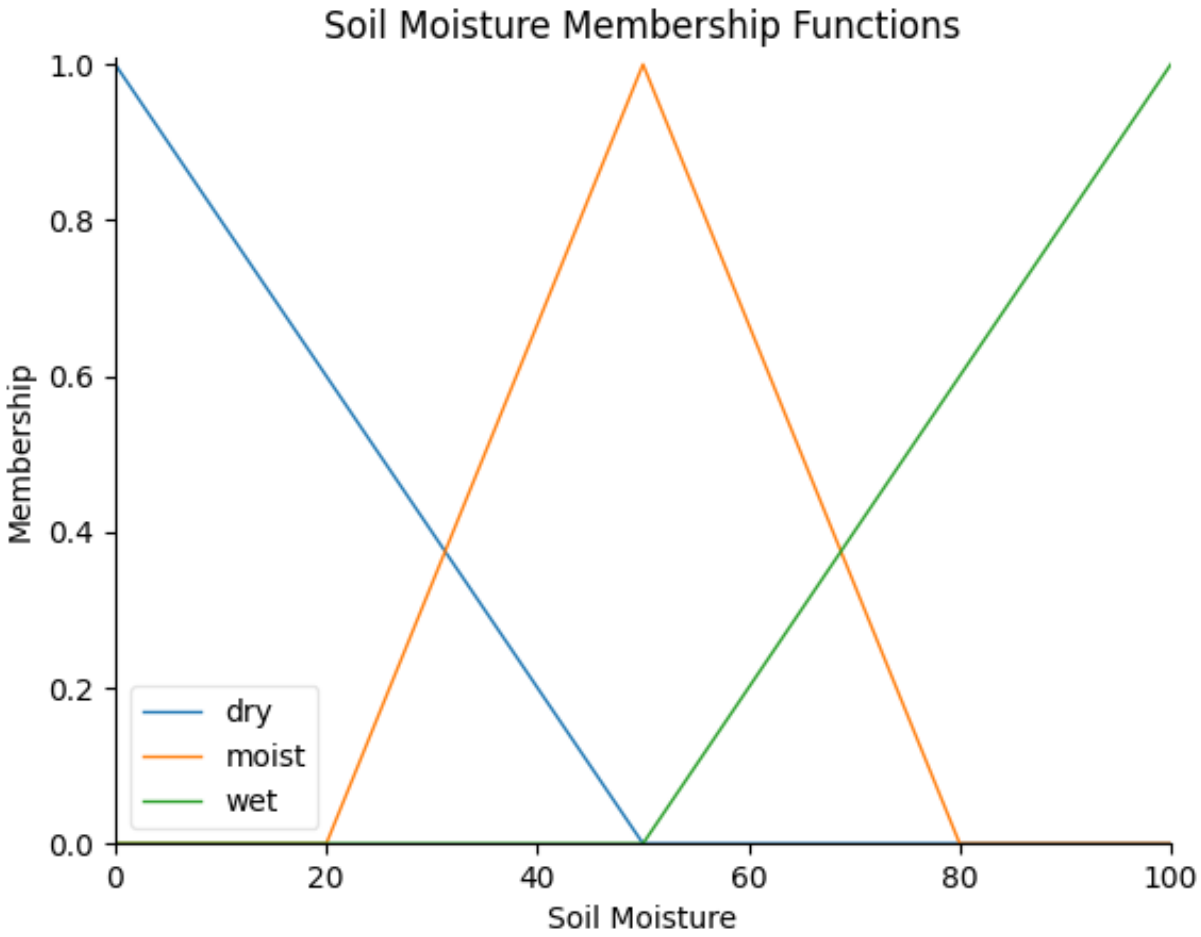
```python
soil_moisture = ctrl.Antecedent(np.arange(0, 101, 1), 'Soil Moisture')
temperature = ctrl.Antecedent(np.arange(0, 51, 1), 'Temperature')
water_sprinkle = ctrl.Consequent(np.arange(0, 101, 1), 'Water Sprinkling')

# Now each input can be categorized using membership functions
soil_moisture['dry'] = fuzz.trimf(soil_moisture.universe, [0, 0, 50])
soil_moisture['moist'] = fuzz.trimf(soil_moisture.universe, [20, 50, 80])
soil_moisture['wet'] = fuzz.trimf(soil_moisture.universe, [50, 100, 100])

temperature['cold'] = fuzz.trimf(temperature.universe, [0, 0, 20])
temperature['warm'] = fuzz.trimf(temperature.universe, [10, 25, 40])
temperature['hot'] = fuzz.trimf(temperature.universe, [30, 50, 50])
```

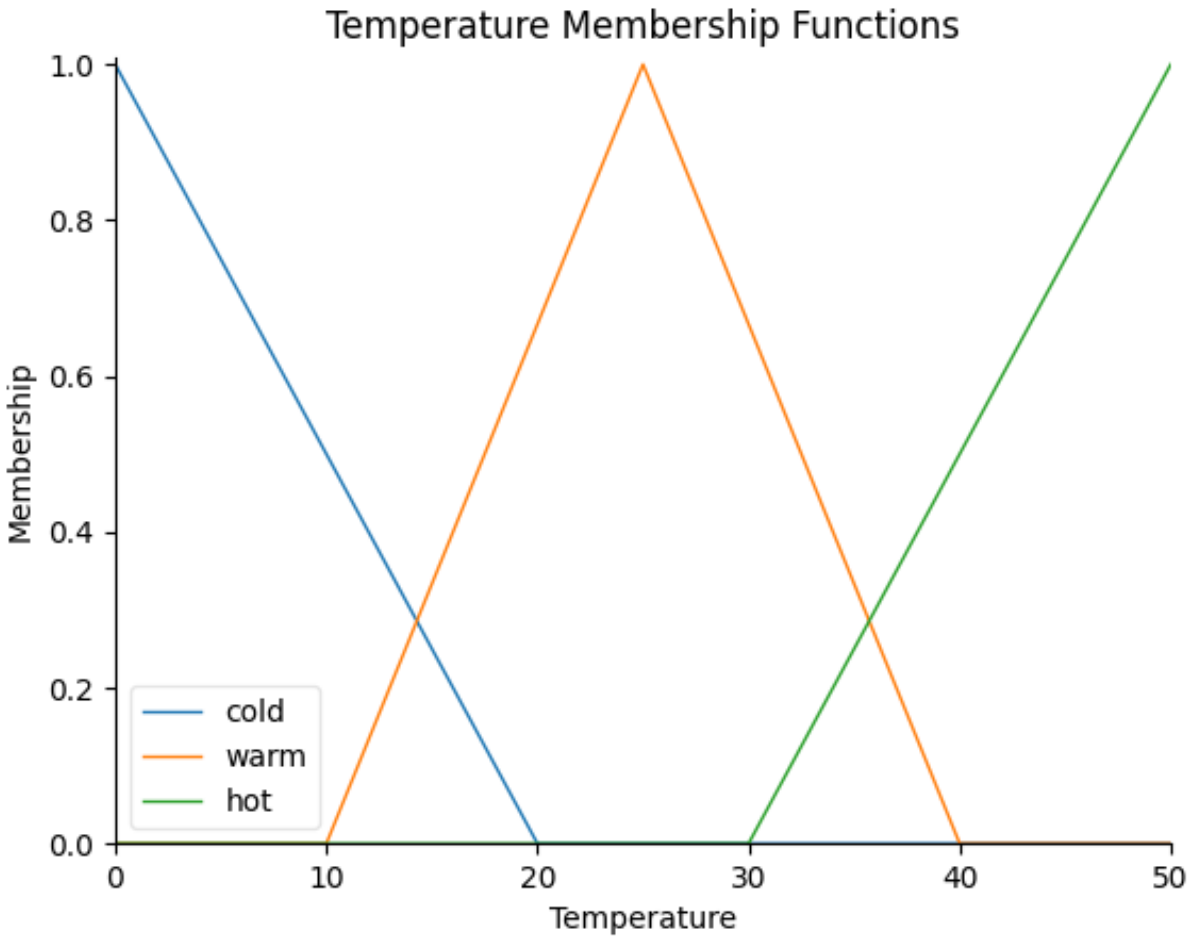
Membership Functions Implementation

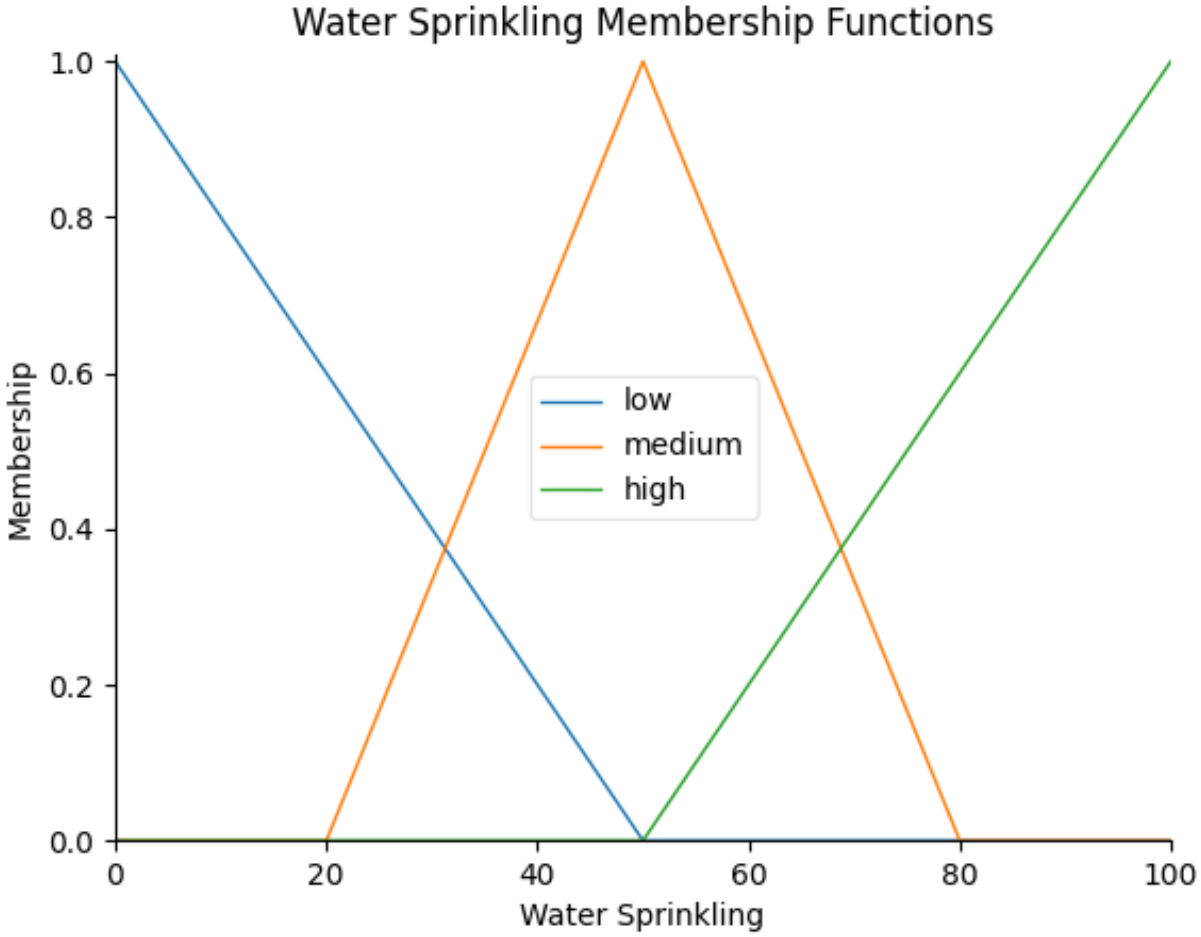
```python
#We define some rules for the system
rule1 = ctrl.Rule(soil_moisture['dry'] & temperature['hot'], water_sprinkle['high'])
rule2 = ctrl.Rule(soil_moisture['dry'] & temperature['warm'], water_sprinkle['medium'])
rule3 = ctrl.Rule(soil_moisture['moist'] & temperature['warm'], water_sprinkle['medium'])
rule4 = ctrl.Rule(soil_moisture['moist'] & temperature['cold'], water_sprinkle['low'])
rule5 = ctrl.Rule(soil_moisture['wet'], water_sprinkle['low'])

# Applying the rules
sprinkle_ctrl = ctrl.ControlSystem([rule1, rule2, rule3, rule4, rule5])
sprinkler = ctrl.ControlSystemSimulation(sprinkle_ctrl)
```

Rule Base and Control System

System Membership Functions




Temperature Membership Functions
Membership
Temperature
cold
warm
hot
0.0
0.2
0.4
0.6
0.8
1.0
0
10
20
30
40
50


Water Sprinkling Membership Functions
Membership
Water Sprinkling
low
medium
high
0.0
0.2
0.4
0.6
0.8
1.0
0
20
40
60
80
100

Fuzzy Rule Base Design

Rule 1
IF soil is dry AND temperature is hot
THEN sprinkle high
Explanation: High temperature combined with dry soil requires maximum irrigation

Rule 2
IF soil is dry AND temperature is warm
THEN sprinkle medium
Explanation: Warm conditions with dry soil need moderate watering

Rule 3
IF soil is moist AND temperature is warm
THEN sprinkle medium
Explanation: Optimal moisture maintenance during warm weather

Rule 4
IF soil is moist AND temperature is cold
THEN sprinkle low
Explanation: Cold weather reduces evaporation need

Rule 5
IF soil is wet
THEN sprinkle low
Explanation: Wet soil needs minimal watering regardless of temperature

Test Results and Analysis

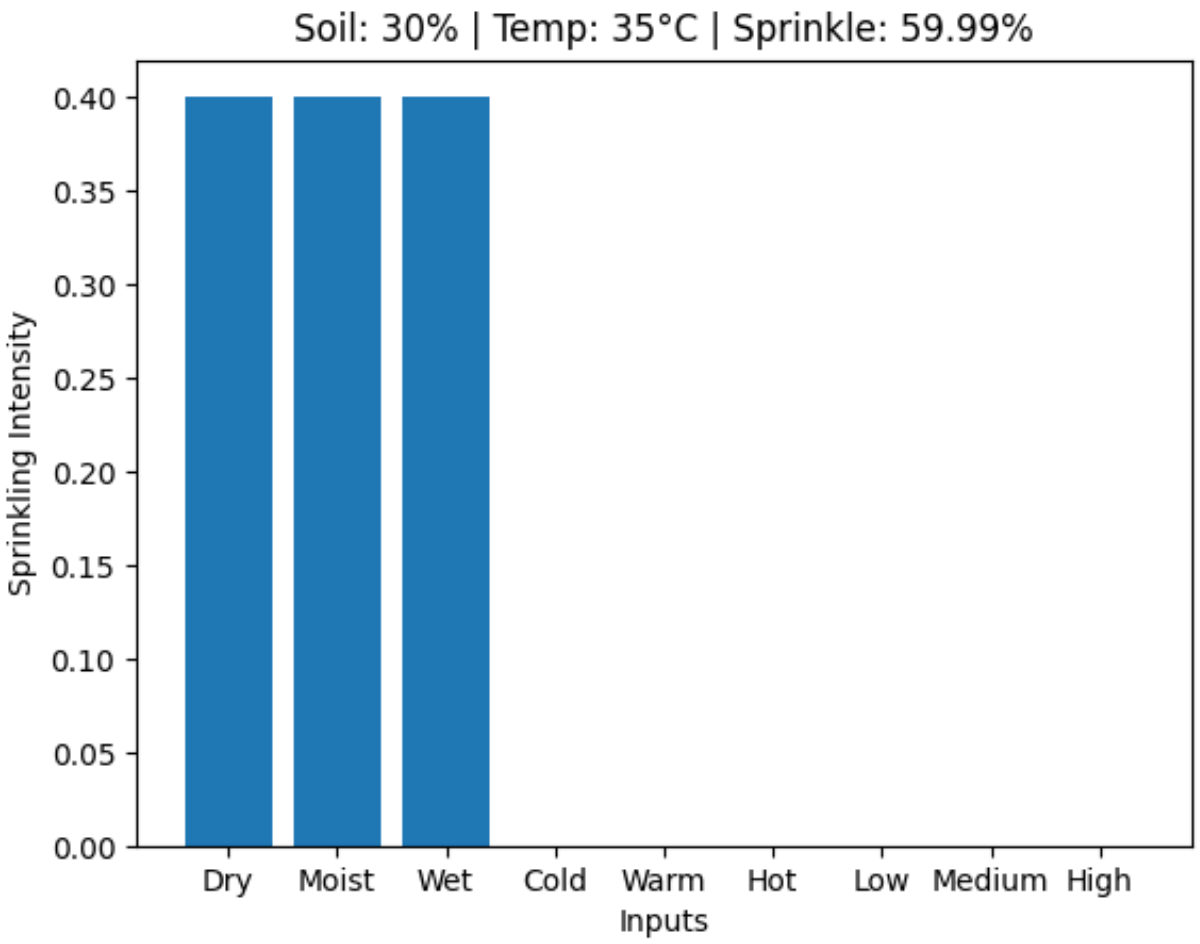
Test Case 1

Environmental Conditions:

- Soil Moisture: 30% - Dry
- Temperature: 35°C - Hot

System Response:

- Sprinkling Level: 60.0%
- Reasoning: High water need due to dry soil and high temperature



Test Case 2

Environmental Conditions:

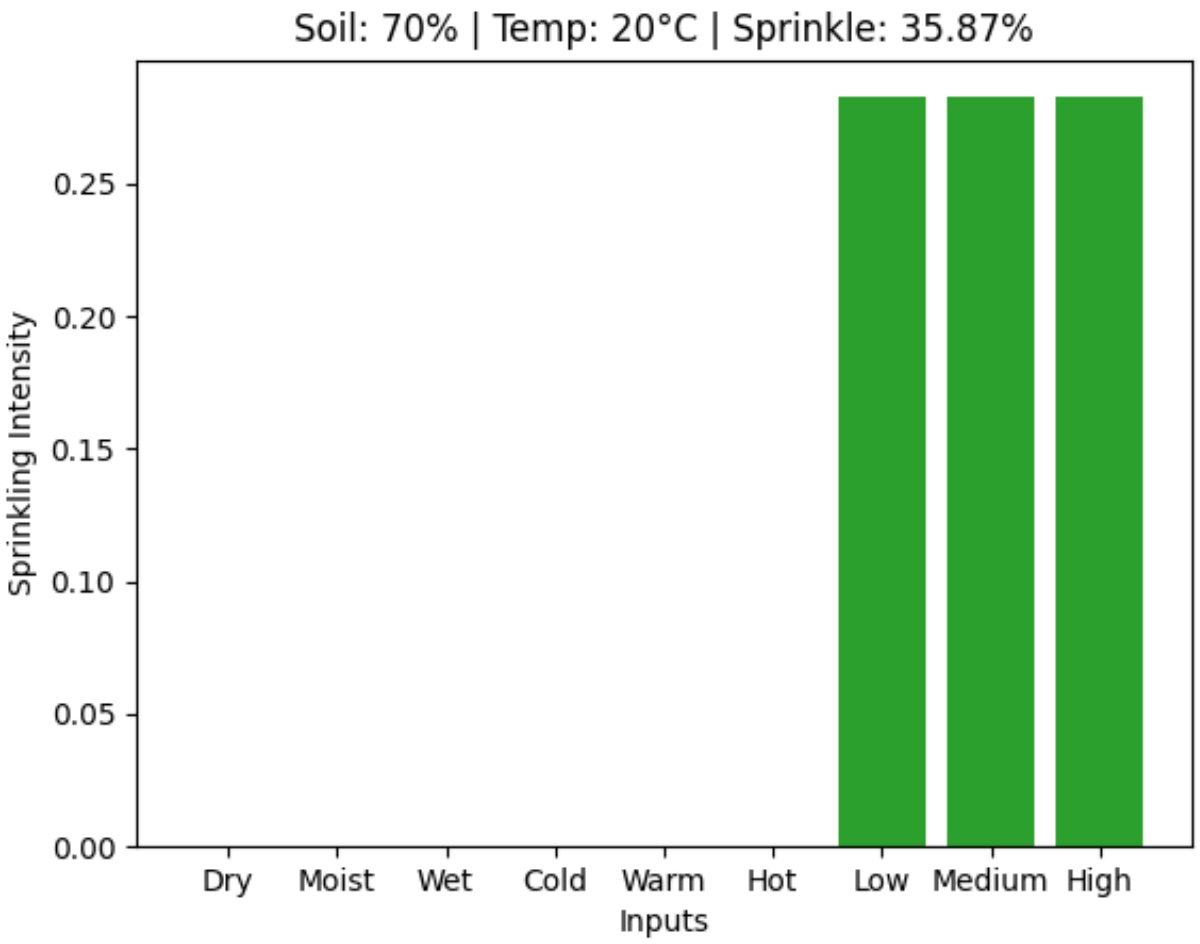
- Soil Moisture: 70% - Wet

• Temperature: 20°C - Cool

System Response:

• Sprinkling Level: 35.9%

• Reasoning: Minimal watering needed due to sufficient soil moisture



Test Case 3

Environmental Conditions:

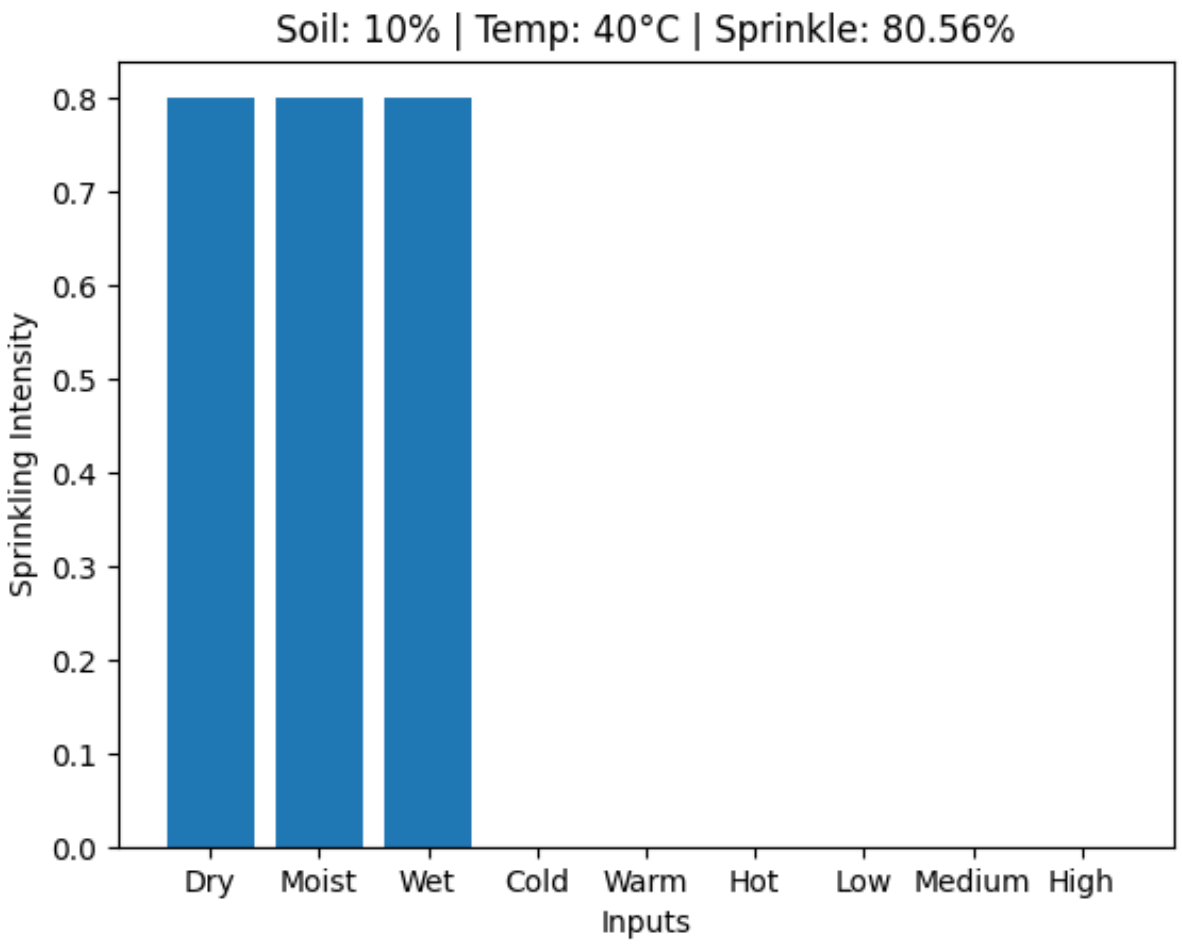
• Soil Moisture: 10% - Very Dry

• Temperature: 40°C - Hot

System Response:

• Sprinkling Level: 80.6%

• Reasoning: High water need due to dry soil and high temperature



Test Case 4

Environmental Conditions:

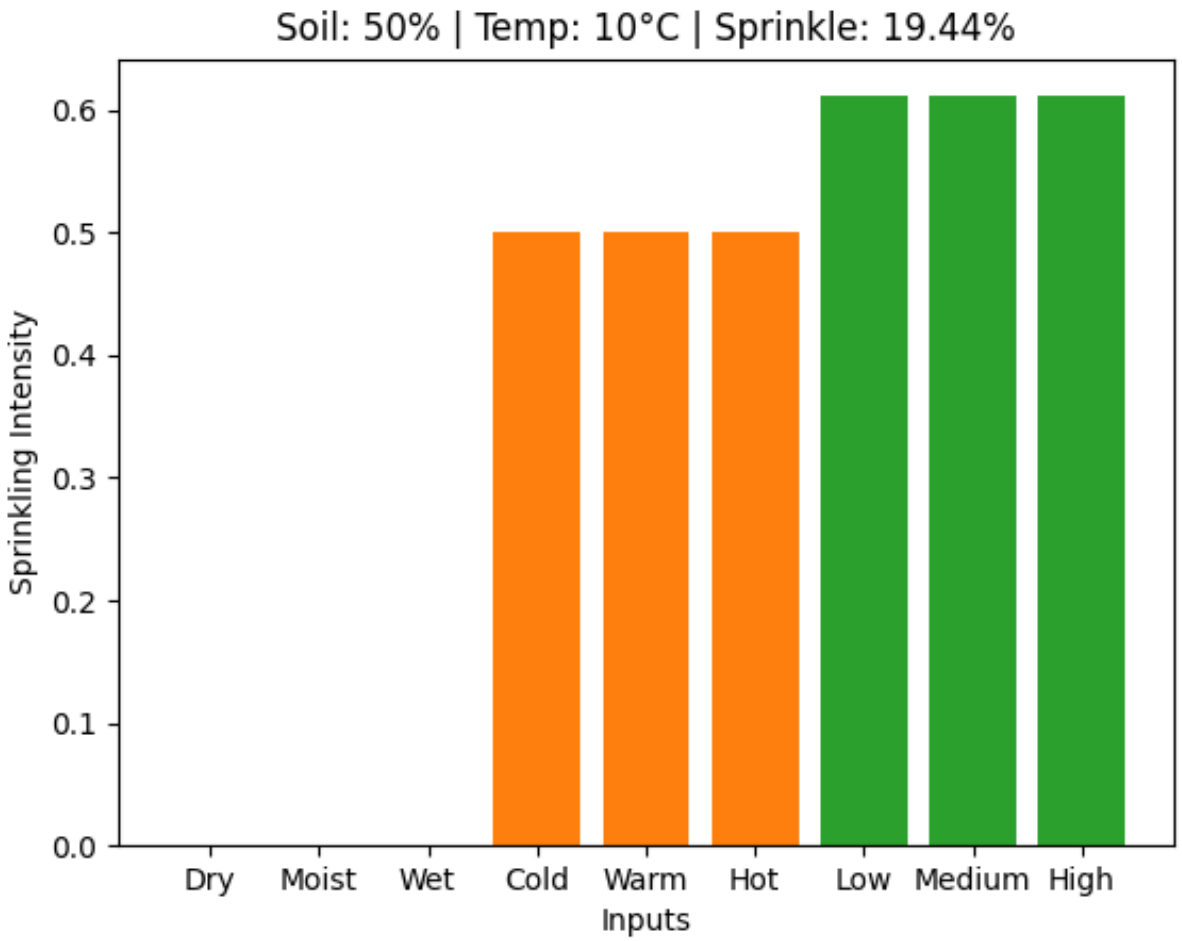
• Soil Moisture: 50% - Moderate

• Temperature: 10°C - Cold

System Response:

• Sprinkling Level: 19.4%

• Reasoning: Moderate watering to maintain moisture



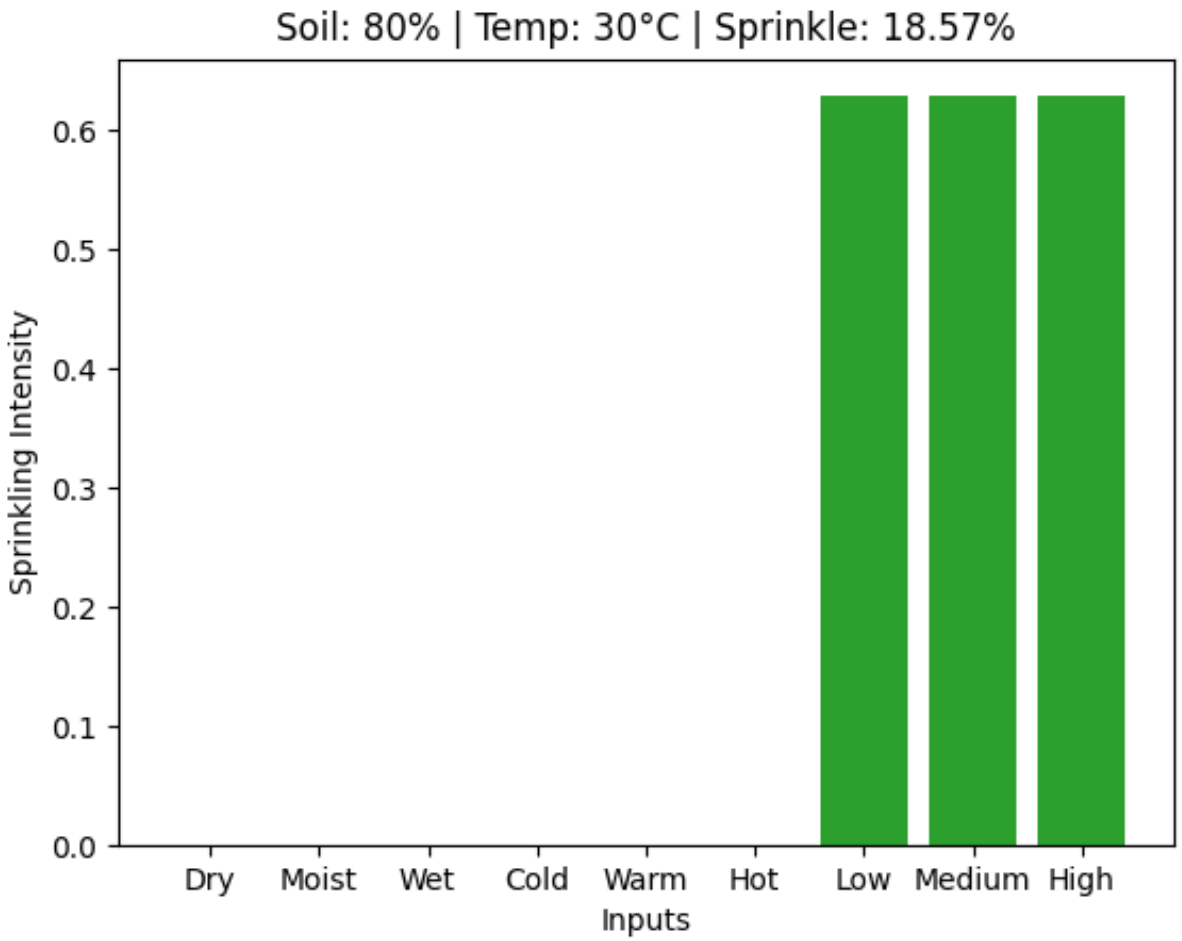
Test Case 5

Environmental Conditions:

- Soil Moisture: 80% - Very Wet
- Temperature: 30°C - Warm

System Response:

- Sprinkling Level: 18.6%
- Reasoning: Minimal watering needed due to sufficient soil moisture



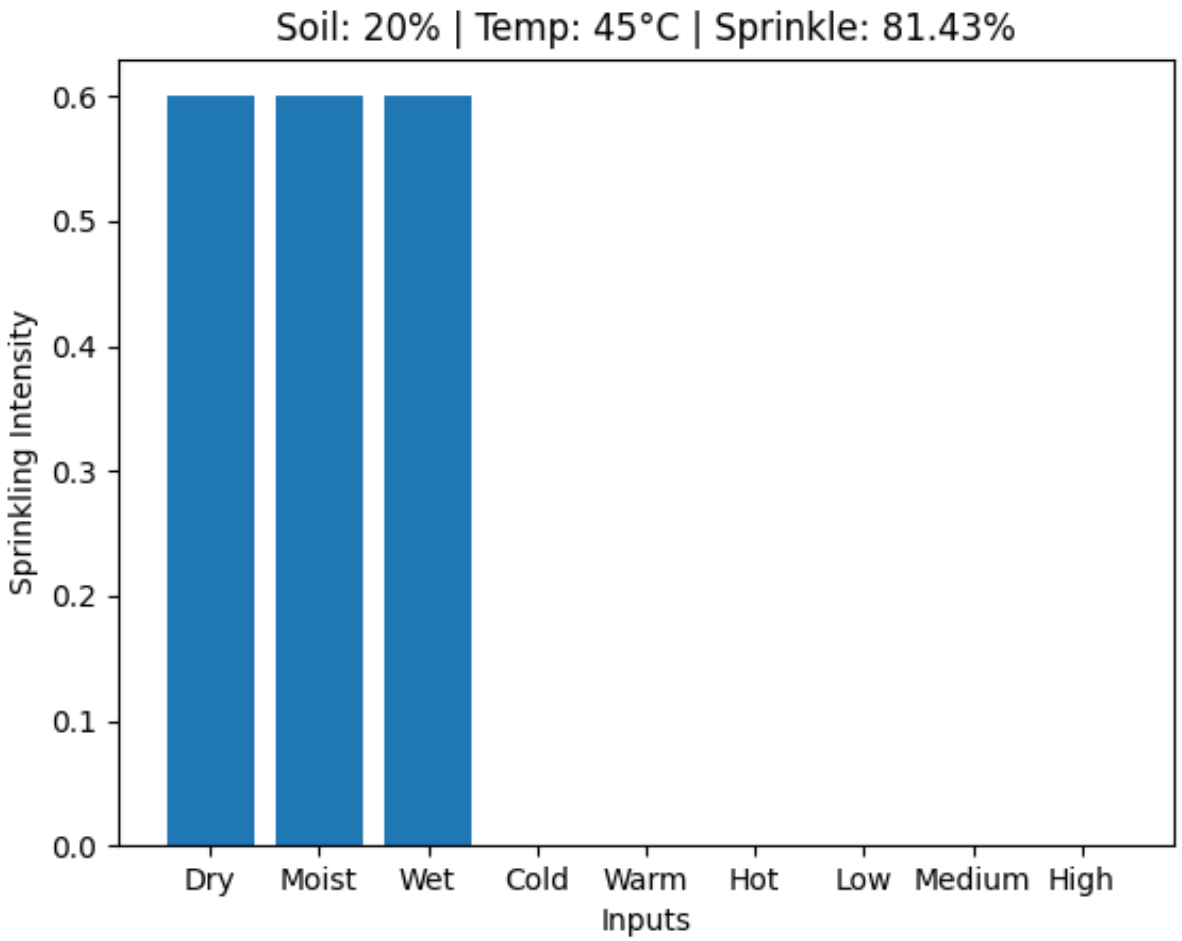
Test Case 6

Environmental Conditions:

- Soil Moisture: 20% - Dry
- Temperature: 45°C - Hot

System Response:

- Sprinkling Level: 81.4%
- Reasoning: High water need due to dry soil and high temperature



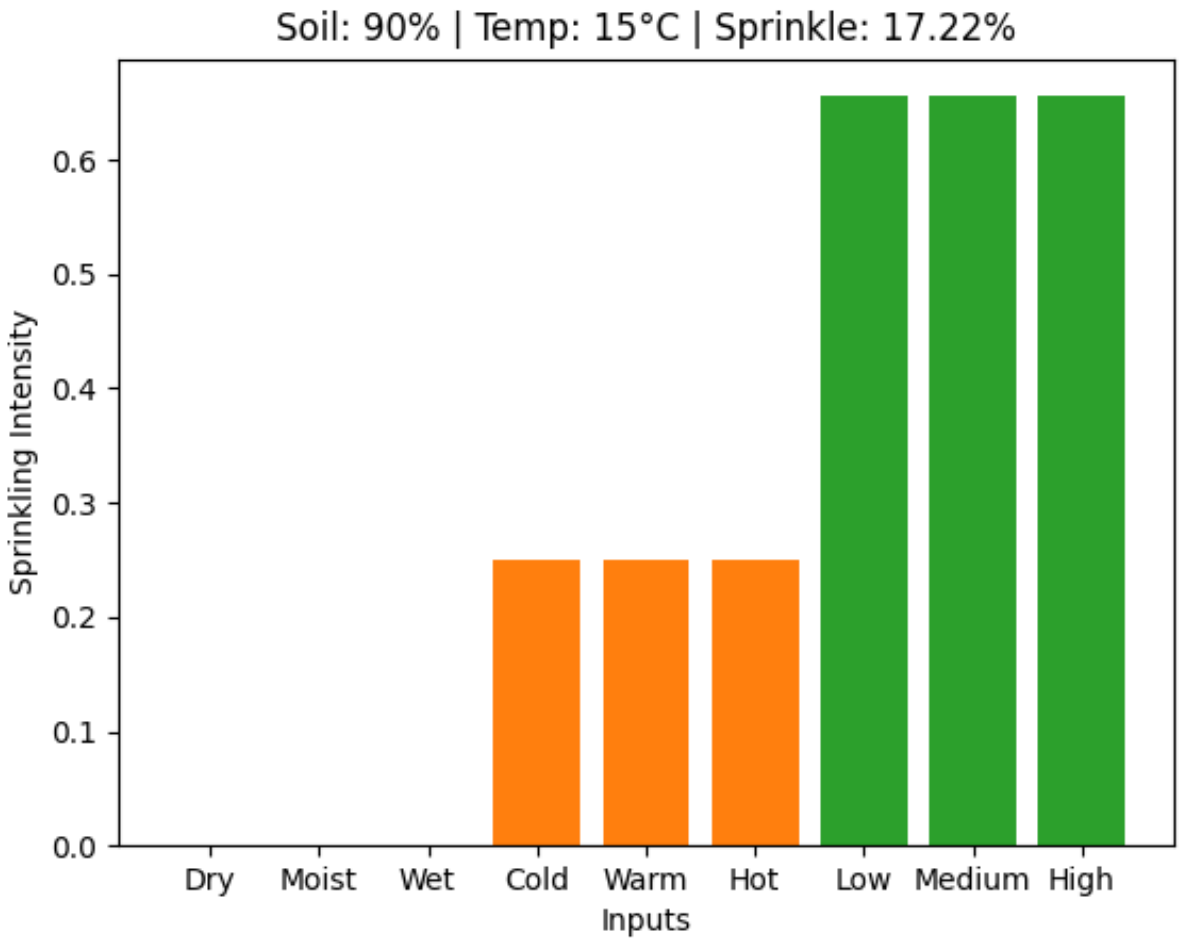
Test Case 7

Environmental Conditions:

- Soil Moisture: 90% - Very Wet
- Temperature: 15°C - Cool

System Response:

- Sprinkling Level: 17.2%
- Reasoning: Minimal watering needed due to sufficient soil moisture



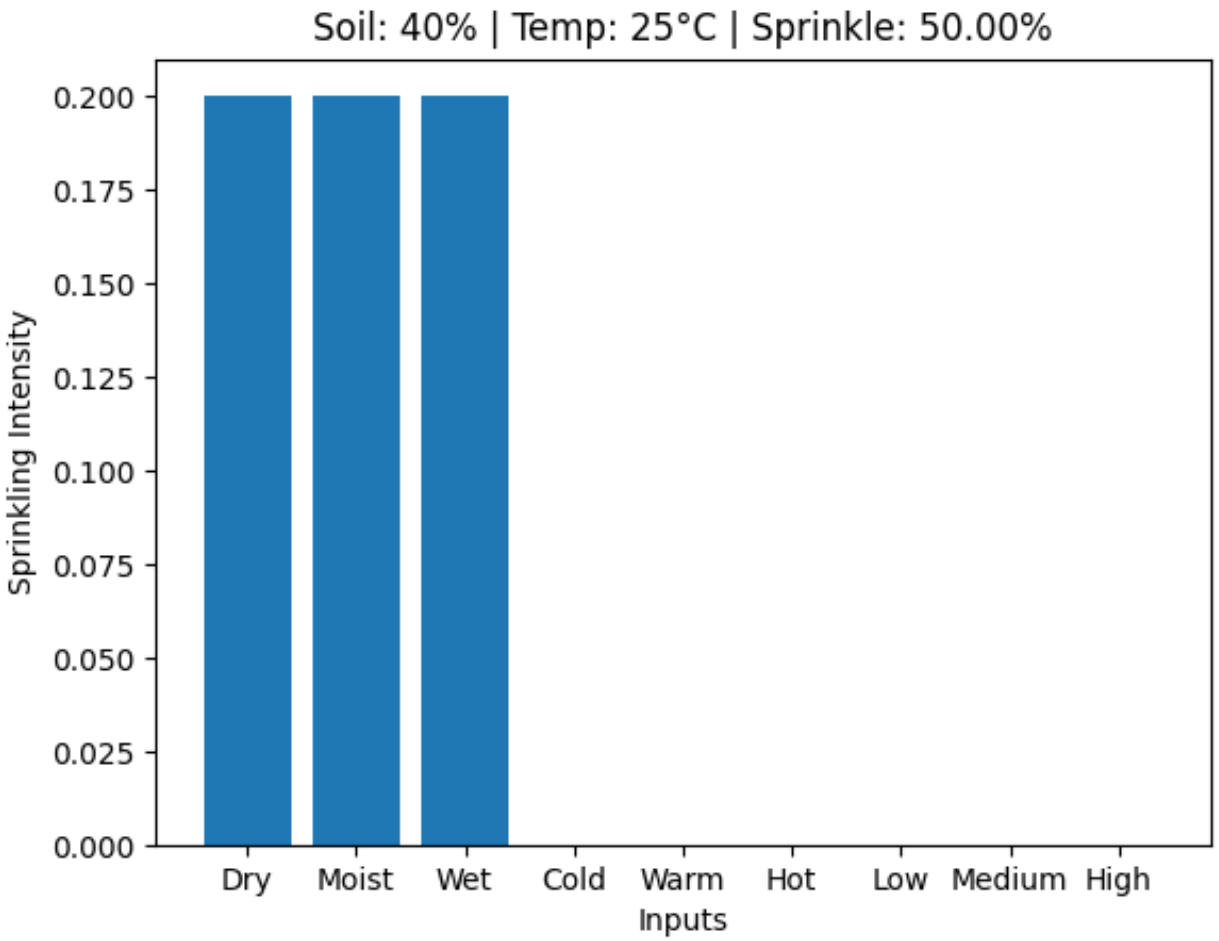
Test Case 8

Environmental Conditions:

- Soil Moisture: 40% - Moderate
- Temperature: 25°C - Warm

System Response:

- Sprinkling Level: 50.0%
- Reasoning: Moderate watering to maintain moisture



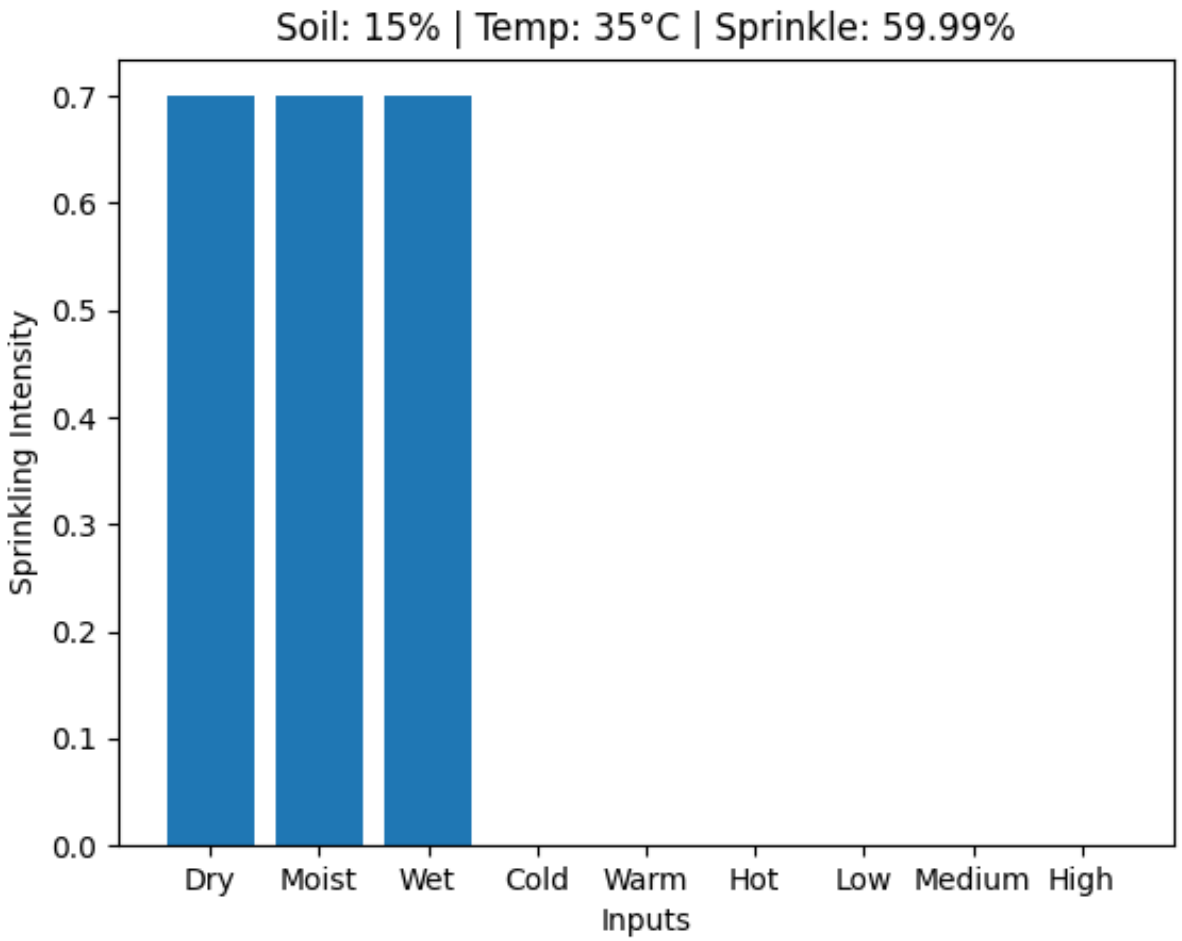
Test Case 9

Environmental Conditions:

- Soil Moisture: 15% - Very Dry
- Temperature: 35°C - Hot

System Response:

- Sprinkling Level: 60.0%
- Reasoning: High water need due to dry soil and high temperature



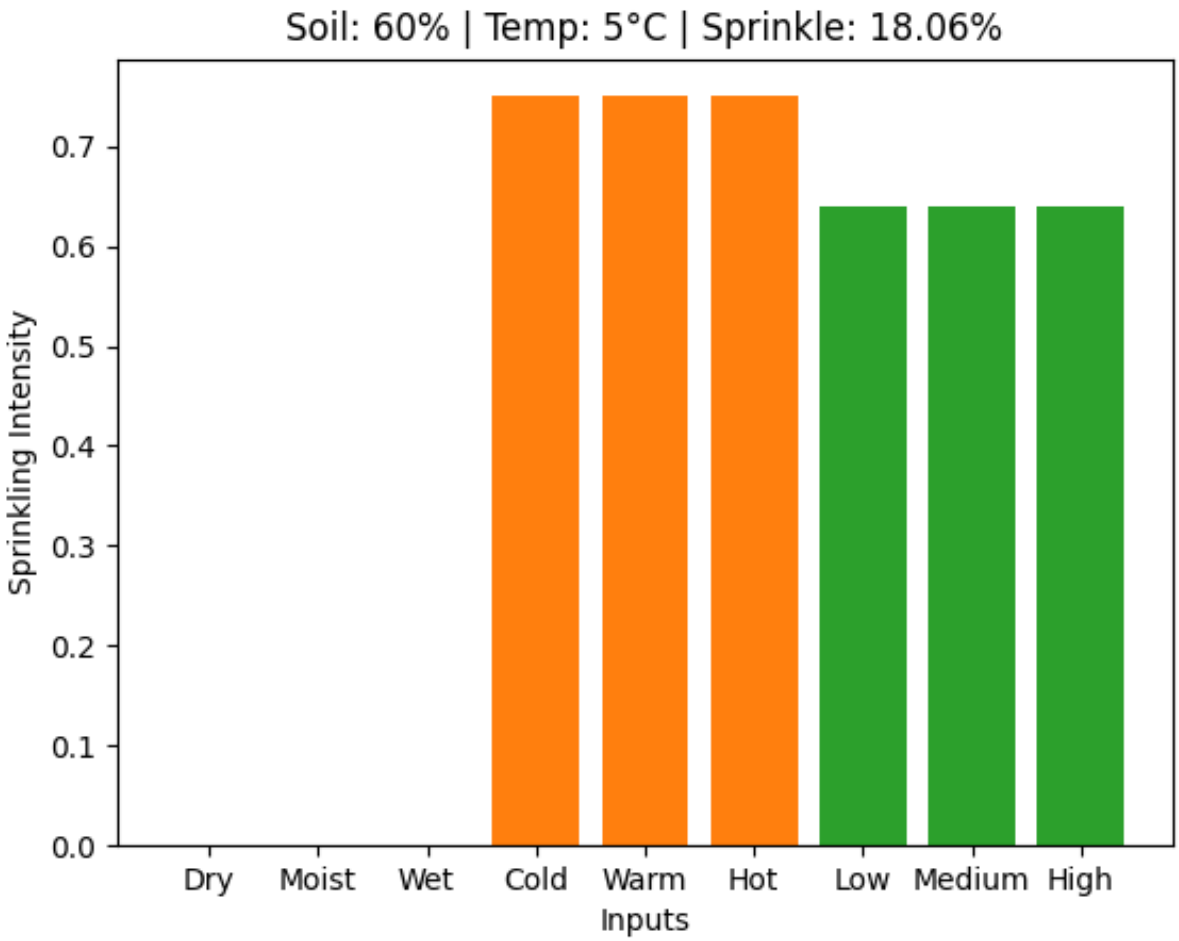
Test Case 10

Environmental Conditions:

- Soil Moisture: 60% - Wet
- Temperature: 5°C - Cold

System Response:

- Sprinkling Level: 18.1%
- Reasoning: Moderate watering to maintain moisture


Soil: 60% | Temp: 5°C | Sprinkle: 18.06%
Sprinkling Intensity
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Dry
Moist
Wet
Cold
Warm
Hot
Low
Medium
High
Inputs

Conclusion

The fuzzy logic sprinkler system demonstrates effective decision-making capabilities in determining appropriate water sprinkling levels based on environmental conditions. The system successfully adapts to various combinations of soil moisture and temperature, providing an intelligent solution for automated irrigation control. The membership functions and rule base ensure smooth transitions between different sprinkling levels, avoiding abrupt changes that could stress the plants or waste water.