All the components needed for the project are as mentioned as follows with their specifications –

**Hardware Components ⚙️**

**ESP32 Microcontroller**

The central processing unit of the system.

* **Processor**: Features an Xtensa® Dual-Core 32-bit LX6 microprocessor, running at speeds from 160MHz up to 240MHz.
* **Connectivity**: Has integrated 2.4 GHz dual-mode Wi-Fi and Bluetooth (Classic and BLE 4.2).
* **Memory**:
  + **Internal**: 448 KB ROM, 520 KB on-chip SRAM, 8 KB RTC SLOW Memory, and 8 KB RTC FAST Memory.
  + **External**: Supports up to 4 x 16 MBytes of external QSPI flash and SRAM.
* **Peripherals**: Includes ADC, DAC, Touch Sensor, UART, I2C, SPI, Ethernet MAC interface, and PWM, among others.
* **Package**: Comes in a 48-pin QFN package (6mm x 6mm).

**pH Sensor (PCB Type)**

This versatile module measures the acidity or alkalinity of a solution and other environmental parameters.

* **Primary Function**: Measures pH levels on a scale of 0 to 14 by evaluating hydrogen ion activity.
* **Integrated Sensors**: Also equipped with a light intensity sensor, a water level sensor, and a temperature sensor.
* **Communication**: Uses UART for data transmission with a baud rate of 9600.
* **Power**: Requires a 5V power supply for operation.
* **Data Pins**:
  + **D5**: pH sensor output.
  + **D6**: Light sensor output.
  + **D7**: Temperature sensor output.

**Soil Moisture Sensor (FC-28)**

Used to measure the water content in the soil.

* **Working Principle**: Utilizes capacitance to gauge the volumetric water content of the soil.
* **Pin Configuration**:
  + **VCC**: For power supply.
  + **A0**: Analog output.
  + **D0**: Digital output.
  + **GND**: Ground.
* **Specifications**:
  + **Operating Voltage**: 5V.
  + **Operating Current**: <20mA.
  + **Interface**: Analog.
  + **Working Temperature**: 10°C to 30°C.

**NPK Sensor**

Measures the concentration of three essential macronutrients in the soil.

* **Function**: Designed to measure Nitrogen (N), Phosphorus (P), and Potassium (K) levels.
* **Technology**: Operates using various methods such as electrochemical (ion-selective electrodes), optical (near-infrared spectroscopy), or infrared sensors.

**I2C LCD**

A liquid crystal display used for real-time data visualization.

* **Communication**: Uses the I2C protocol, which requires only two wires (SDA and SCL) for data transfer.
* **Connections**: Typically needs four pins: VCC, GND, SDA, and SCL.
* **Features**: Includes an integrated I2C controller to simplify programming and often comes with backlighting for better visibility. Common sizes are 16x2 and 20x4 characters.

**MAX485 TTL to RS485 Module**

A transceiver for converting logic signals for long-distance communication.

* **Function**: Converts single-ended TTL signals into differential RS-485 signals, which are more resilient to noise.
* **Type**: Low-power, half-duplex transceiver.
* **Performance**:
  + **Transmission Distance**: Up to 4000 feet (approximately 1200 meters).
  + **Baud Rate**: Up to 2.5 Mbps.

**Power Supply**

Provides the necessary electrical power to all components.

* **Function**: Converts AC power from an outlet to a stable DC voltage required by the electronic components.
* **Core Components**:
  + **Transformer**: Steps down the AC voltage.
  + **Rectifier**: Converts AC to pulsating DC.
  + **Capacitor**: Smooths the DC output.
  + **Voltage Regulator**: A 78XX series regulator (e.g., 7805 for 5V) provides a constant output voltage.

**Software and Programming 💻**

**Python**

A high-level programming language used for data analysis and machine learning.

* **Role**: Used to process sensor data and provide crop recommendations via a machine learning algorithm.
* **Features**: It is an interpreted, object-oriented, and cross-platform language with a large standard library, making it ideal for rapid application development.

**Embedded C**

The language used for programming the ESP32 microcontroller.

* **Role**: To write the firmware that reads data from the sensors, displays it on the LCD, and sends it to the cloud.
* **Characteristics**: It is less tedious to write and more portable across different microcontrollers compared to assembly language.

**Arduino IDE**

The integrated development environment for writing and uploading code.

* **Function**: An open-source software used to write, compile, and upload the Embedded C code to the ESP32 board.
* **Features**: It is user-friendly, contains example codes for beginners, and simplifies the process of microcontroller programming.