

Title of Invention:

SoilScope360: An AI-Enabled, Multi-Sensor Soil Analysis Device with Heavy Metal Detection

Field of the Invention:

This invention relates to the field of soil analysis, specifically portable devices used for measuring soil health, detecting contaminants, and analyzing environmental factors through sensor integration and artificial intelligence (AI) processing.

Background of the Invention:

Current soil testing methods often require specialized equipment, laboratory access, or technical expertise, making them inaccessible to many farmers, particularly in rural and underserved regions. Traditional handheld soil testers typically measure only basic metrics (e.g., moisture, pH) and lack contaminant detection features. No affordable, AI-supported, multi-sensor device currently offers real-time, comprehensive soil health assessments including heavy metal contamination, VOC detection, and surface structure analysis.

Summary of the Invention:

The present invention provides a portable, low-cost, solar-powered soil analysis device designed for community-based environmental monitoring.

The device incorporates:

- A LiDAR sensor to map soil surface structure.
- A gas sensor array to detect volatile organic compounds (VOCs) associated with soil health and pollution.
- Traditional soil probes for moisture, pH, temperature, and electrical conductivity.
- A heavy metal detection subsystem, using either electrochemical sensors (anodic stripping voltammetry) or colorimetric strip analysis captured by an onboard camera.

- A wireless communication system (Bluetooth or WiFi) for transmitting data to an AI agent, hosted either locally or on cloud platforms like Replit.
- AI processing to interpret sensor data, predict contamination risks, and recommend actions.

The device is intended to function both online and offline, ensuring usability in areas with limited infrastructure.

Brief Description of the Drawings:

1. **Block Diagram:** Shows the interconnection between the solar panel, power system, ESP32 microcontroller, sensors, and wireless communication modules.



Detailed Description of the Invention:

Device Components:

- **Microcontroller (ESP32):** Central processing unit.
- **Power System:** Solar panel charging a lithium-ion battery through a battery management system (BMS).
- **Sensors:**
 - **LiDAR:** Maps surface roughness, slope, and soil compaction.
 - **Odor Sensors:** Detect VOCs linked to microbial activity and pollution.
 - **Moisture/Temperature/pH/EC Sensors:** Provide core soil health metrics.
 - **Heavy Metal Detection:**
 - **Electrochemical Sensor:** Detects metals like lead, arsenic, cadmium via voltammetric analysis.
 - **Alternative Colorimetric System:** Photographs chemical test strips and interprets results through AI image analysis.

Communication and AI Integration:

- Wireless module sends data to a Replit-hosted server or edge AI running locally.
- AI agent analyzes patterns for:
 - Soil fertility prediction.
 - Contaminant presence estimation.
 - Actionable recommendations for soil remediation or planting decisions.

Form Factor:

- Waterproof, rugged enclosure suitable for field use.
 - Modular sensor attachments for easy maintenance or upgrades.
-

Claims:

1. **A portable soil analysis device comprising:** a LiDAR sensor, a gas sensor array for VOC detection, traditional soil probes (moisture, pH, temperature, electrical conductivity), and a heavy metal detection subsystem, wherein the device transmits collected data to an external AI agent for real-time interpretation and recommendations.
2. **The device of Claim 1**, wherein the heavy metal detection subsystem comprises a screen-printed electrochemical sensor capable of performing anodic stripping voltammetry measurements.
3. **The device of Claim 1**, wherein the heavy metal detection subsystem comprises a colorimetric reagent strip read by an onboard optical sensor and processed by an AI model.
4. **The device of any preceding claim**, further comprising a solar panel and battery system enabling off-grid operation.
5. **The device of any preceding claim**, wherein the AI agent interprets sensor data to generate soil quality reports, contamination risk alerts, and agricultural guidance suitable for non-specialist users.
6. **A method for soil analysis comprising:**
 - (i) inserting the device into soil,
 - (ii) acquiring sensor readings,
 - (iii) transmitting the readings wirelessly to a cloud server,
 - (iv) analyzing the readings with an AI agent to detect soil health status and contamination risks, and
 - (v) outputting actionable advice to the user.