

SoilGuard Ethiopia

A Zero-Network Smartphone Tool for Precision Soil Acidity Diagnostics & Smallholder Yield Recovery

Project Lead: Dr. Andualem Belachew Workie | **Focus:** Precision Agronomy, Soil Chemistry, Food Security
Deployment Base: Ethiopia

Economic Return
\$7.10 per \$1 (Year 1)
\$18.70 per \$1 (3-Yr Residual)
+25% Yield Gain (+\$270/ha)

Executive Summary: The Last-Mile Soil Solution

The Crisis: Over 43% of Ethiopian highland soils are acidic ($\text{pH} < 5.5$), locking up to 75% of applied phosphate fertilizer into insoluble precipitates that crops cannot absorb. Centralized soil testing costs \$15–\$30 and takes 3–6 weeks, leaving smallholders to guess input needs.

The Solution: SoilGuard turns entry-level Android phones into precision diagnostic tools operating **100% offline**. Extension workers capture 3–5 soil points next to a \$0.20 optical calibration card. The app corrects for lighting, detects intra-plot pH variance ($\Delta\text{pH} \geq 0.5$), and prescribes zoned lime and split-fertilizer schedules in local bags (*jonya*) and cups (*qorqoro*) per *Timad*.

The Agronomic Mechanism: Chemical Phosphate Unlock

Lock-up: Al^{3+} (toxic ion) + H_2PO_4^- (fertilizer) $\rightarrow \text{AlPO}_4 \cdot 2\text{H}_2\text{O} \downarrow$ (insoluble solid precipitate; inaccessible to roots).

Release: 3CaCO_3 (lime) + 2Al^{3+} + $3 \text{H}_2\text{O} \rightarrow 2 \text{Al}(\text{OH})_3 \downarrow$ (inert solid) + 3Ca^{2+} (nutrient) + $3 \text{CO}_2 \Rightarrow$ free active phosphate.

1 Field Workflow: Optical Normalization to Farmer-Ready Advice

1. Calibrate	A laminated optical card (18% gray, white, RGB chips; unit cost \$0.20) is placed beside the soil. On-device computer vision normalizes ambient sun/shade and adjusts for soil moisture (Dry vs. Moist).
2. Scan & Zone	Maps RGB pixels to HSV color space to classify taxonomy (Red Nitisol, Dark Vertisol, Sandy Loam). If pH differs by ≥ 0.5 across 3–5 points, the app divides the field into targeted liming zones.
3. Prescribe	An adapted Kamprath model calculates exact CaCO_3 needed to reach pH 5.8, paired with a 2-stage split nitrogen calendar (100% NPS + 1/3 Urea at sowing; 2/3 Urea at 35 days).
4. Explain	Outputs translate into vernacular units: 50-kg bags (<i>jonya</i>) and cups (<i>qorqoro</i>) per <i>Timad</i> (0.25 ha) across Amharic (), Afaan Oromoo, and English.

2 Validated Economics: Per-Hectare Smallholder Return

Per-Hectare Farm Budget	Current Practice	With SoilGuard	Economic Impact
Fertilizer input spending (NPS + Urea)	\$170.00	\$170.00	Unlocks \$74.00 of trapped nutrients
Fertilizer captured by crop roots	\$92.00 (54%)	\$166.00 (98%)	Nutrient uptake jumps from 54% to 98%
Added diagnostic & lime cost	\$0.00	\$38.15	\$0.65 diagnostic + \$37.50 lime (1.5 t)
Gross crop value (1,800 kg/ha baseline)	\$1,080.00	\$1,350.00	+\$270.00/ha net crop value (+25%)
Single-Season Benefit-Cost Ratio	—	7.10 : 1	\$7.10 net return per \$1.00 spent
Multi-Year Amortized Return	—	18.70 : 1	Lime buffers soil matrix for 3+ seasons

3 System Specifications & Sustainable Delivery Model

Technical Readiness:

- Post-prototype: Android app passing 24 automated unit tests.
- 100% offline on-device processing (local SQLite storage).
- Secondary fallback: Optical test-strip reader (\$0.08/test).

Public-Sector Delivery Pathway:

- Runs on existing phones of Ethiopia’s 60,000 public extension DAs.
- Offline SMS pre-positions bulk lime at village primary cooperatives.
- Scalable across 5M+ smallholders in acidic highland belts.