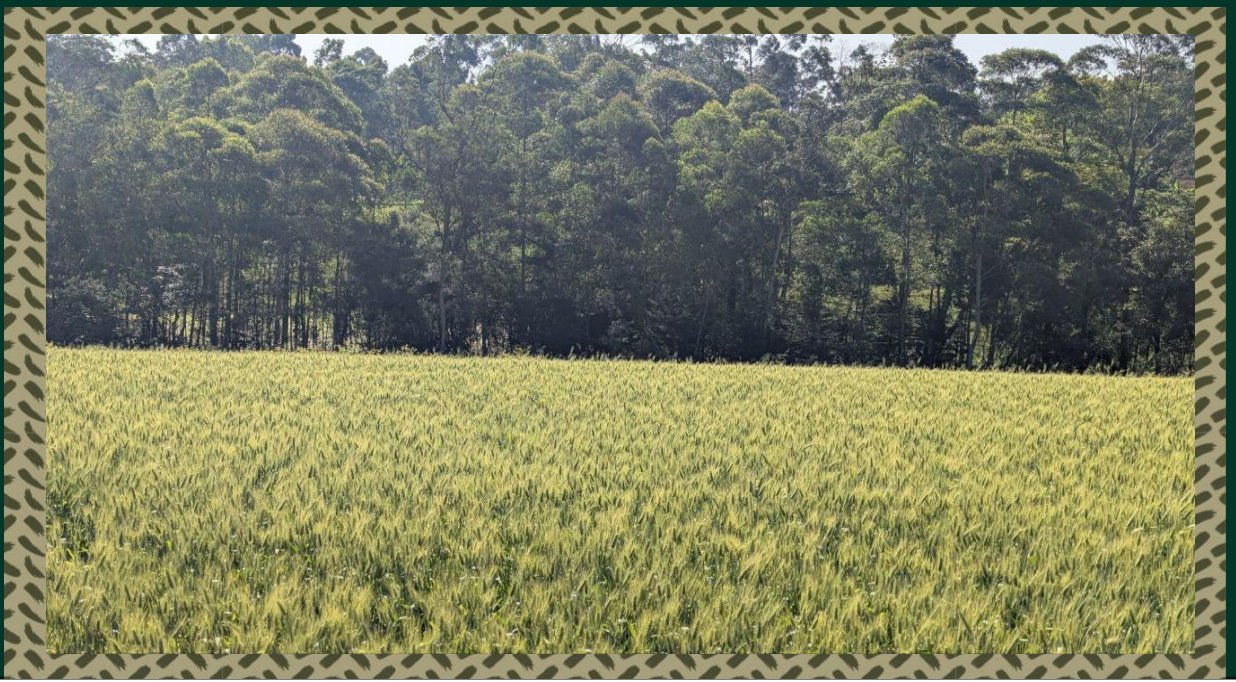
CGIAR SUSTAINABLE FARMING

Hyper-Localized Fertilizer Advisory System

Precision Nutrient Management for Ethiopian Smallholder Farmers

December 2025



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The Challenge: Blanket Fertilizer Recommendations

Current Fertilizer Use Situation

• Ethiopian agriculture uses uniform fertilizer recommendations; large areas are treated as homogeneous despite strong variation in soil, climate, and topography.

• Fertilizer is costly, and the climate is variable – farmers need field-level, data-driven guidance.

Consequences

• Over-application in nutrient-rich areas → wasted resources

• Under-application in deficient areas → limited yields

• Environmental degradation from nutrient runoff

• Economic losses for smallholder farmers

Need: Site-specific recommendations that account for local conditions

Our Solution: Two-Stage Recommendation Process

Stage 1: Site-specific Fertilizer Advisory

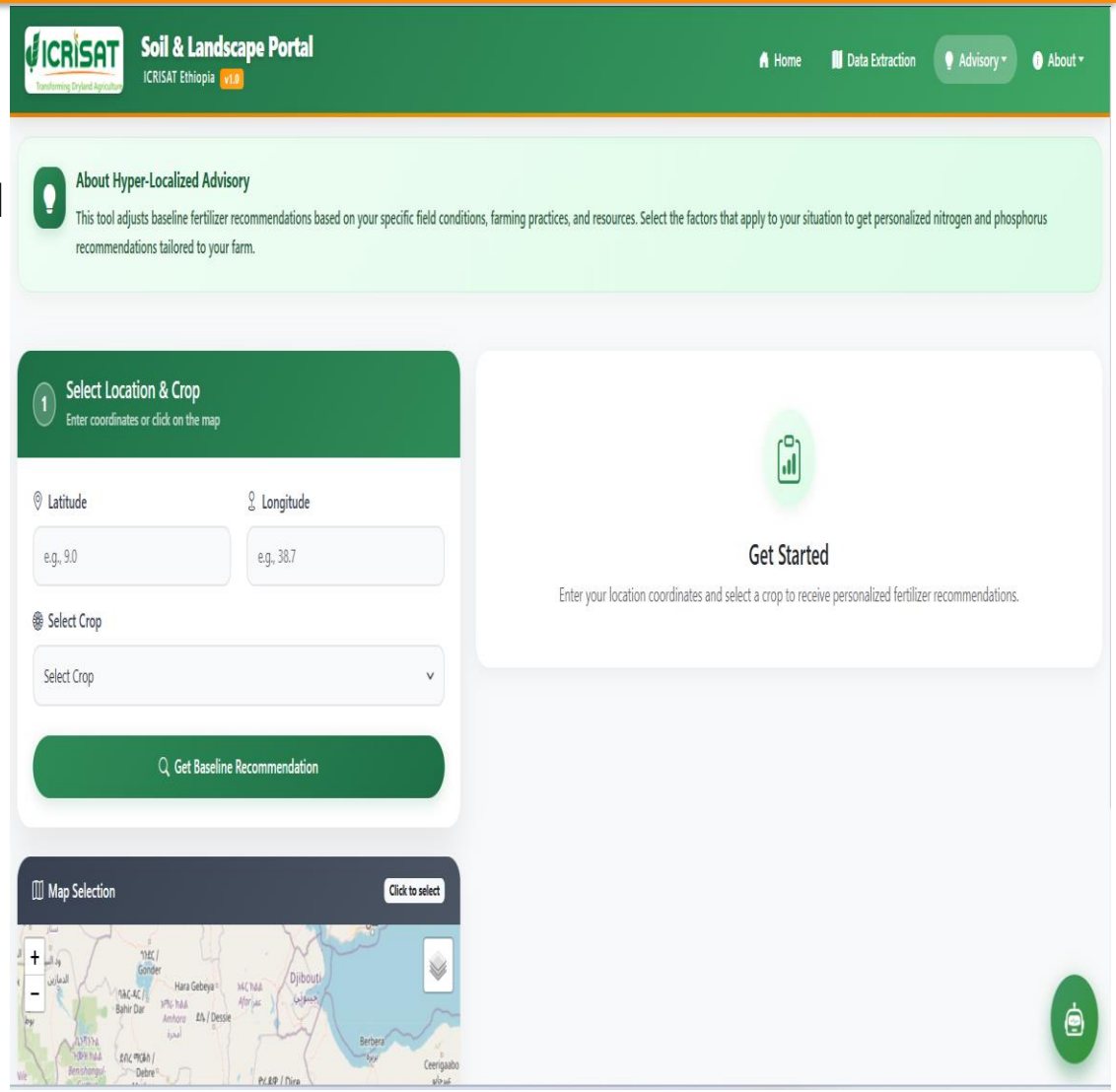
- User selects location on interactive map
- For a chosen farmer field, query Machine Learning (ML) driven N and P_2O_5 raster layers for the selected crop.
- Raster values are optimal fertilizer rates at ≈30 m resolution from the ML Decision Support Tool (DST).

Stage 2: Farmer Context-Based Fertilizer Adjustment

- Farmer reports site-specific conditions
- System applies percentage adjustments to baseline recommendations

Result

- Personalized fertilizer recommendation
- Transparent breakdown of each farmer context, farmer and extension knowledge, improving adoption and trust.



System Architecture

Technology Stack

- **Frontend**: JavaScript + Leaflet.js maps
- **Backend**: Python Flask REST API
- **Spatial Data**: GeoTIFF rasters (30m)
- **Processing**: Rasterio, PyProj, Pandas
- **Deployment**: Web-based, mobile-friendly

Data Flow

1. User clicks the location on the map
2. Coordinates sent to backend API
3. Raster values extracted at the point
4. User selects local adjustment conditions
5. Backend calculates adjusted values
6. Results are displayed with a breakdown

User Interface: Stage 1 - Site-specific Fertilizer Advisory (Baseline)

Interactive Map

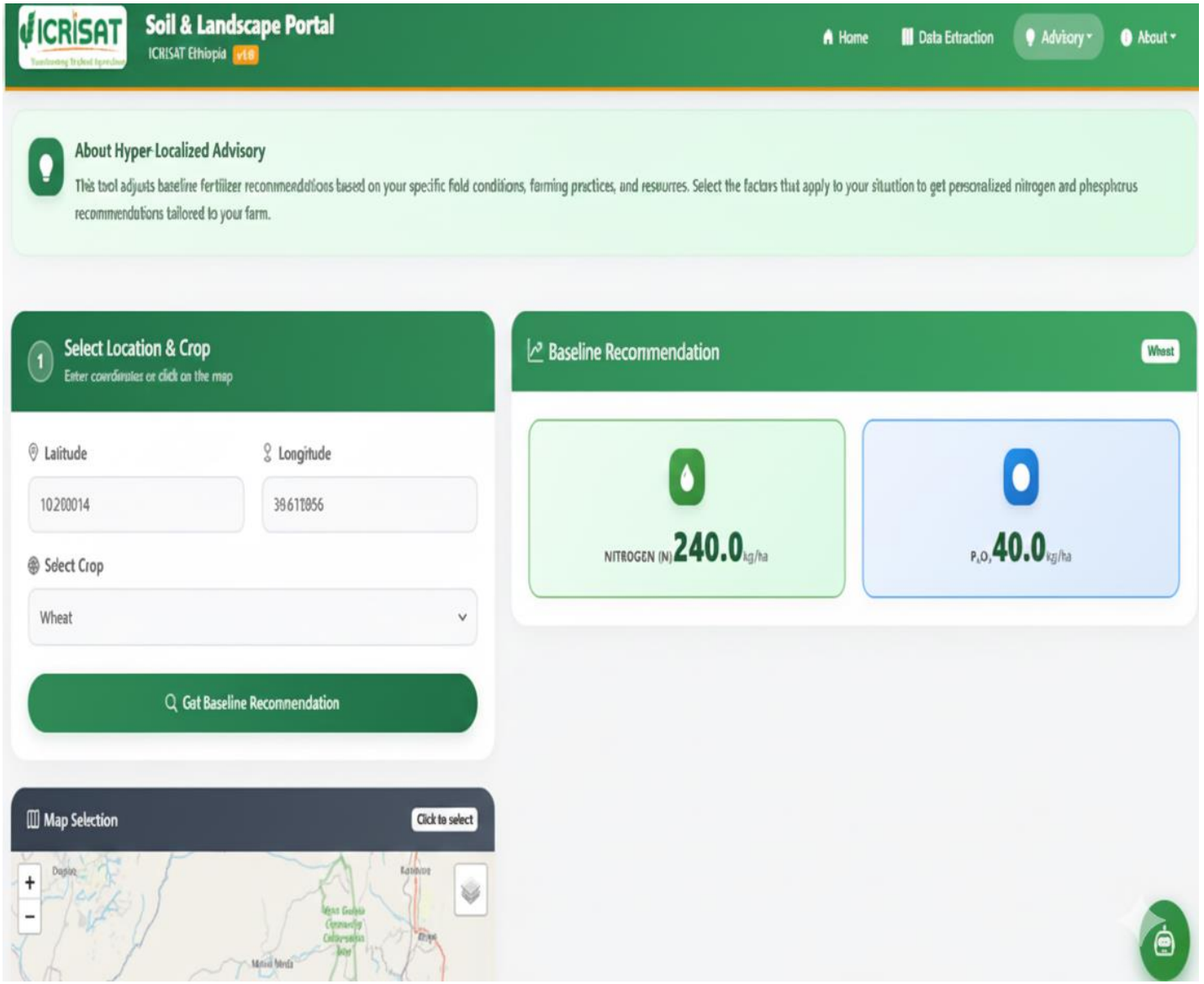
- Map centered on Ethiopia
- Click to select field location
- Coordinates auto-populate input fields

Input Options

- Manual latitude/longitude entry
- Crop selection: Wheat, Sorghum, Tef, or Maize
- 'Get Baseline' button triggers raster extraction

Baseline Display

- Shows extracted N (kg/ha) and P_2O_5 (kg/ha)
- Values come directly from pre-computed raster maps



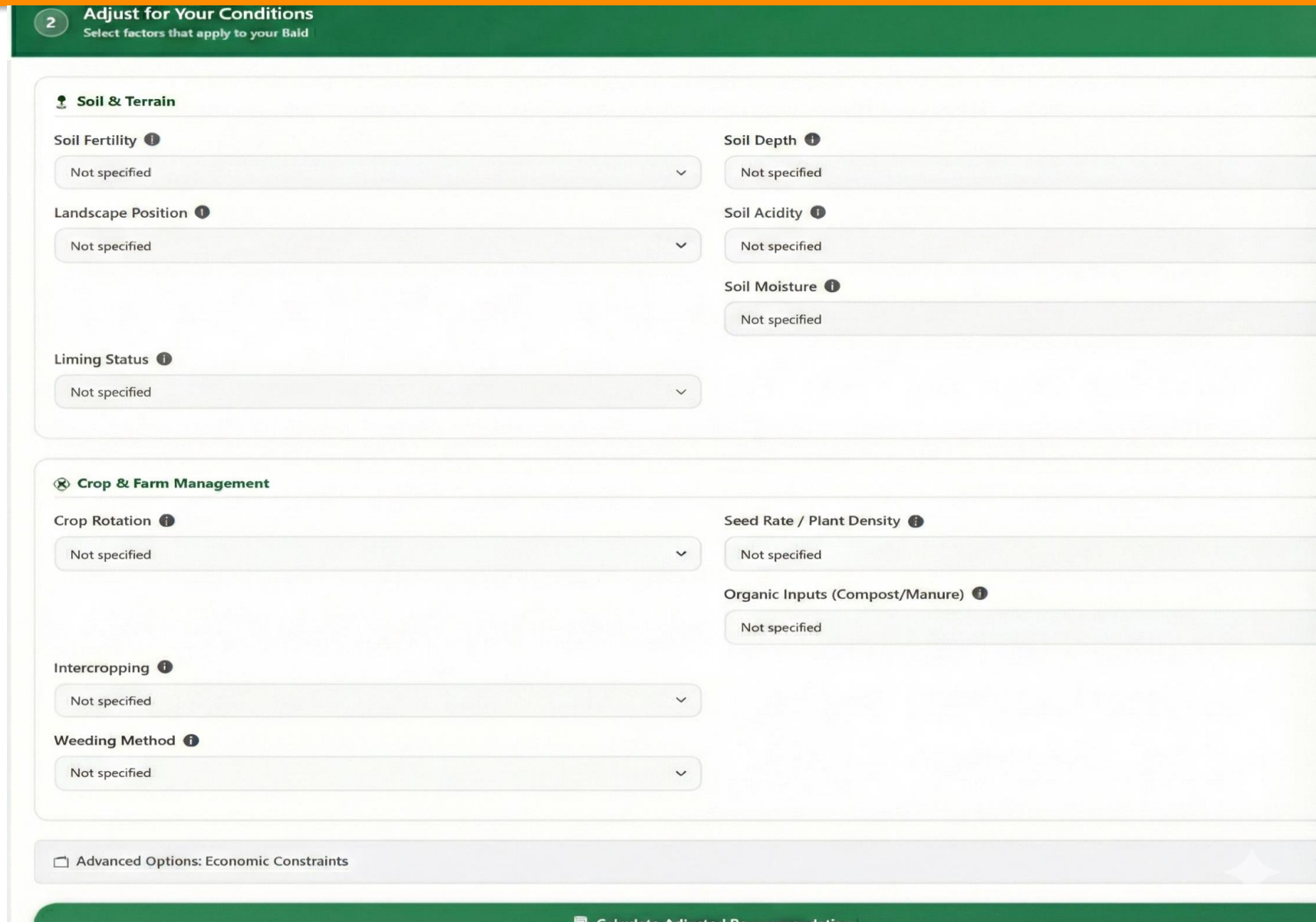
User Interface: Stage 2 - Farmer Context-Based Fertilizer Adjustment

Soil & Terrain Factors

- Soil Fertility (poor to fertile)
- Soil Depth (shallow to deep)
- Soil moisture level (low to high)
- Landscape position (steep hill to bottomland)

Crop Management Factors

- Seed rate/plant density
- Crop rotation
- Organic inputs (compost/manure)



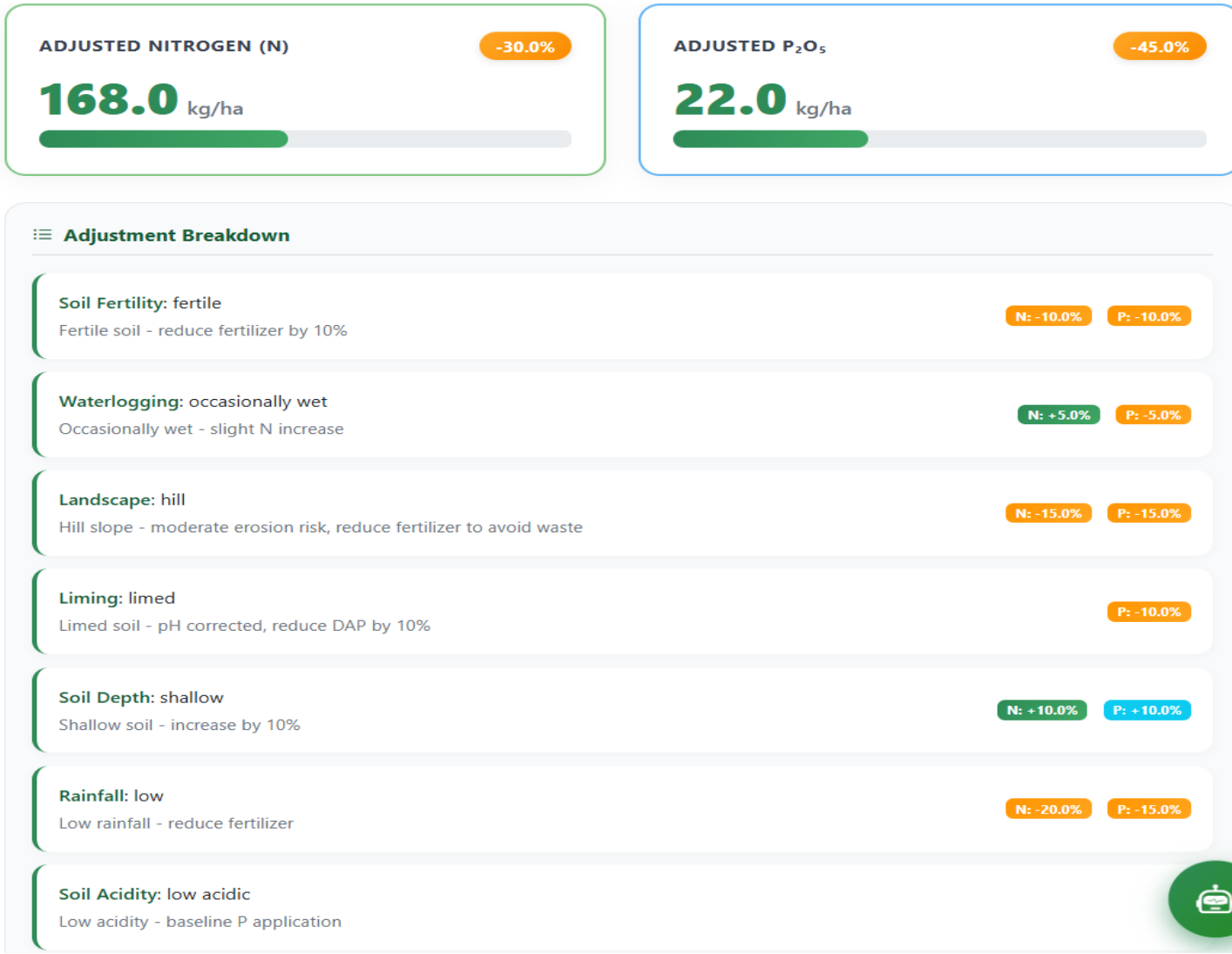
Personalized Recommendation

Final Recommendation Display

- Adjusted Nitrogen (N) in kg/ha with % change badge
- Adjusted P_2O_5 in kg/ha with % change badge
- Color-coded badges: green (+), orange (-), gray (0)

Adjustment Breakdown

- Lists each factor that was applied
- Shows individual N and P adjustments
- Includes explanatory descriptions



Core Implementation (Python Backend)

```
# script/routes/advisory.py

FERTILIZER_ADJUSTMENT_RULES = {
    "soil_fertility": {
        "very_fertile": {"N": -0.15, "P": -0.15, "description": "Reduce by 15%"},
        "poor": {"N": 0.10, "P": 0.10, "description": "Increase by 10%"},
        "very_poor": {"N": 0.20, "P": 0.20, "description": "Increase by 20%"}
    },
    "rainfall": {
        "very_low": {"N": -0.25, "P": -0.20},
        "high": {"N": 0.10, "P": 0.10}
    }
}

MAX_ADJUSTMENT = 0.50  # Safety cap at ±50%

# Apply adjustments
for factor, value in factors.items():
    rule = FERTILIZER_ADJUSTMENT_RULES[factor][value]
    total_adj_n += rule['N']
    total_adj_p += rule['P']
```

Expected Impact & Conclusion

Quantified Benefits

- Improved fertilizer-use efficiency and reduced costs for farmers.
- More equitable, field-specific fertilizer recommendations across heterogeneous landscapes.
- Higher and more stable yields due to better targeted N and P_2O_5 application.
- Reduced environmental pressure from over-application of fertilizers.
- Transparent and explainable recommendations that build trust among farmers and extension agents.

Key Innovations

- Combines geospatial precision with local knowledge
- A transparent, context-specific analysis for each farmer, explainable adjustments
- Safety-capped recommendations
- Mobile-friendly field deployment
- Bridges science and practical farming

The Hyper-Localized Fertilizer Advisory System transforms blanket recommendations into precision guidance, empowering farmers with actionable, site-specific insights.

Citation:

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Acknowledgements

The CGIAR Sustainable Science Program forms a part of CGIAR's new Research Portfolio, addressing key challenges in agri-food systems by fostering efficient production of nutritious foods and safeguarding the environment to create fair employment opportunities, as we simultaneously tackle climate change, soil degradation, pests, diseases, and desertification. Its research is being implemented by CGIAR researchers from ICRISAT and ALLIANCE Bioversity International CIAT in close partnership with the Ministry of Agriculture, Ethiopian Institute of Agricultural Research, Regional Agricultural Research Institutes (Amhara, Oromia, South, Central, South West), Self Help Africa (SHA), Catholic Church South Synod, Sasakawa Africa Association (SAA), People in Need, Enhanced Rural Self Help Association (ERSHA), Precision Development (PxD), and Digital Green.

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About CGIAR Sustainable Science Program Report

This research was conducted as part of the CGIAR Sustainable Farming Science Program. This research is being implemented by CGIAR researchers from ICRISAT in close partnership with the Ministry of Agriculture, Ethiopian Institute of Agricultural Research, Regional Agricultural Research Institutes (Amhara, Oromia, South, Central, South West), Self Help Africa (SHA), Catholic Church South Synod, Sasakawa Africa Association (SAA), People in Need, Enhanced Rural Self Help Association (ERSHA), Precision Development (PxD), and Digital Green. CGIAR is a global research partnership for a food-secure future. Its science is carried out by 15 Research Centers in close collaboration with hundreds of global partners. www.cgiar.org

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Key Words:

Hyper-Localized Advisory, Precision Nutrient Management, Site-Specific Fertilizer, Two-Stage Advisory Solution

Partners

Ministry of Agriculture, Self Help Africa (SHA), Catholic Church South Synod, Sasakawa Africa Association (SAA), People in Need, Enhanced Rural Self Help Association (ERSHA), Ethiopian Institute of Agricultural Research, Precision Development (PxD), Digital Green

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