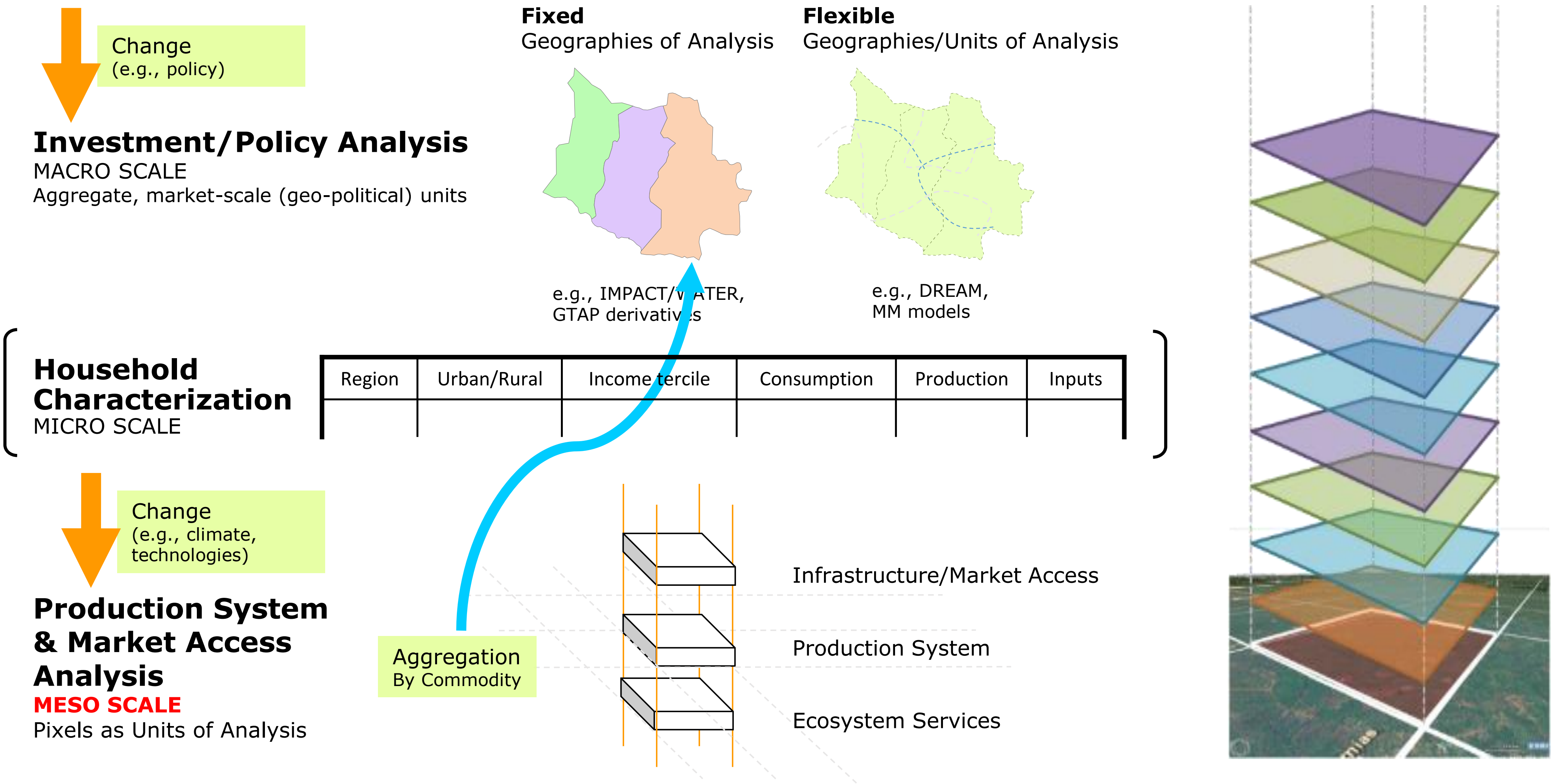
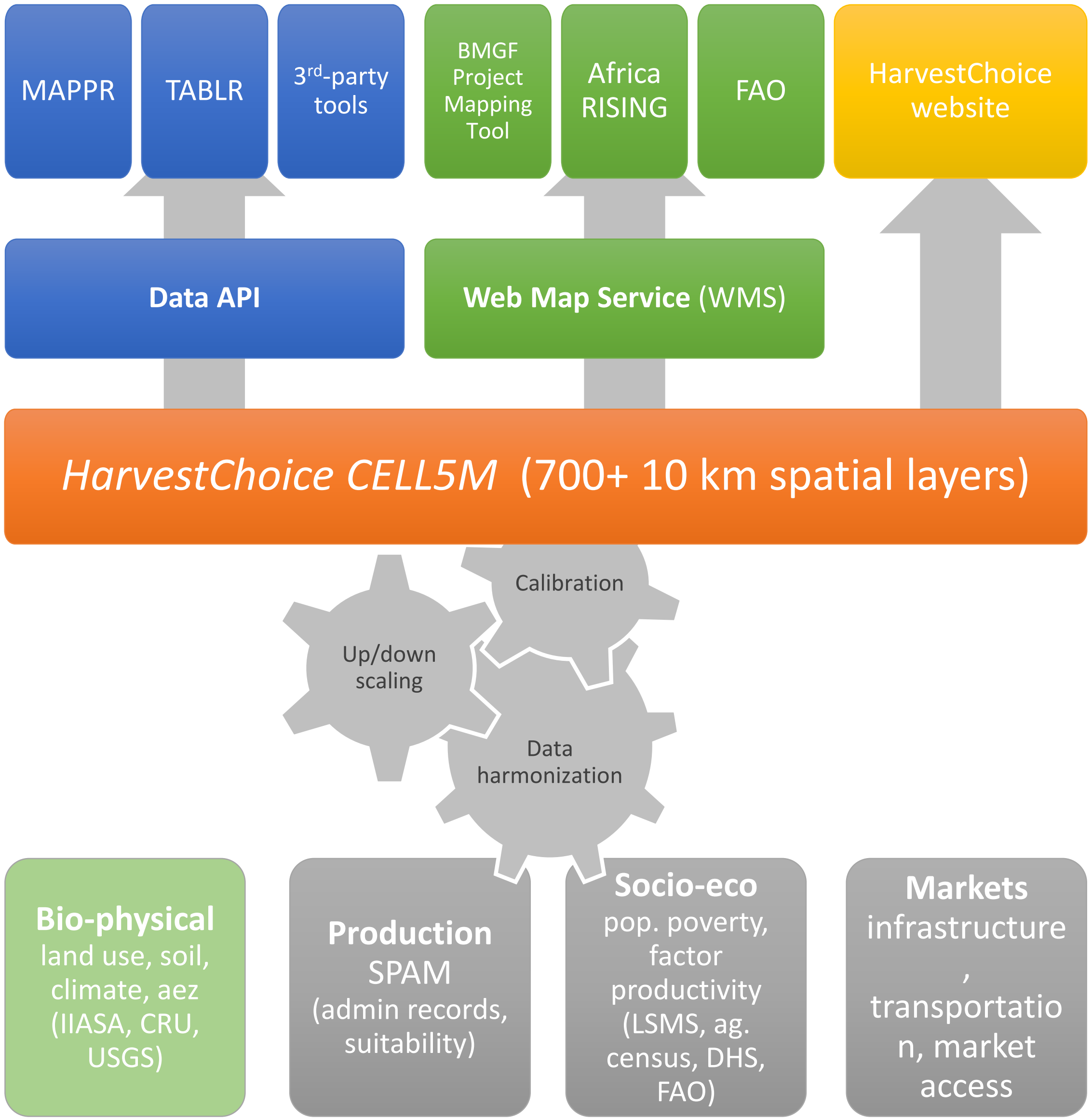
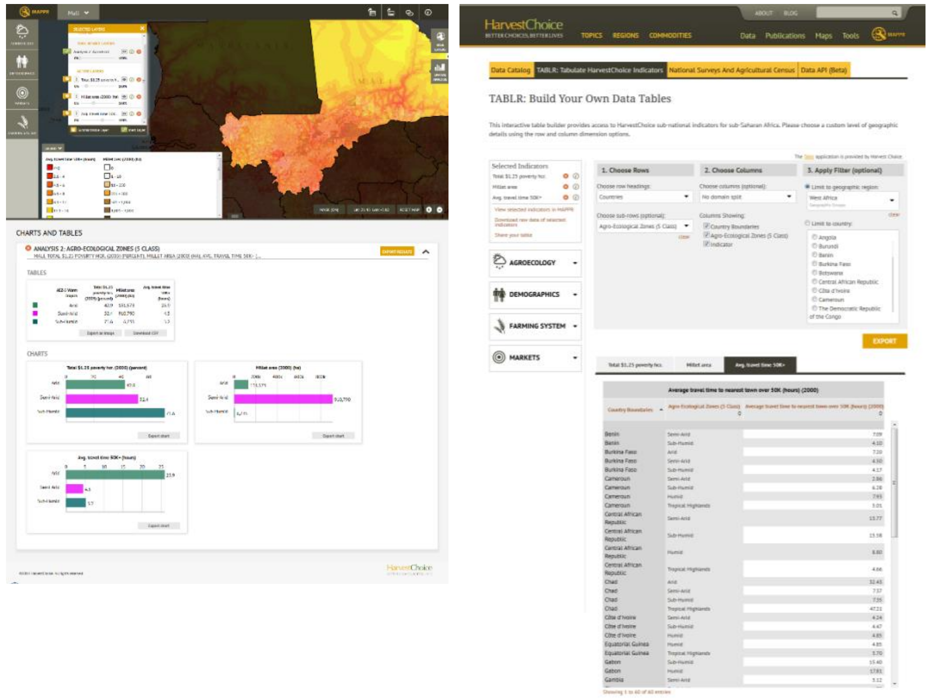
SOIL HEALTH, PRODUCTIVITY, and PROFITABILITY

Example on the spatial patterns of fertilizer profitability in maize production systems in East Africa

Zhe Guo, Jawoo Koo, Stanley Wood, Carlo Azzarri, and Ho-Young Kwon
International Food Policy Research Institute, Washington, DC

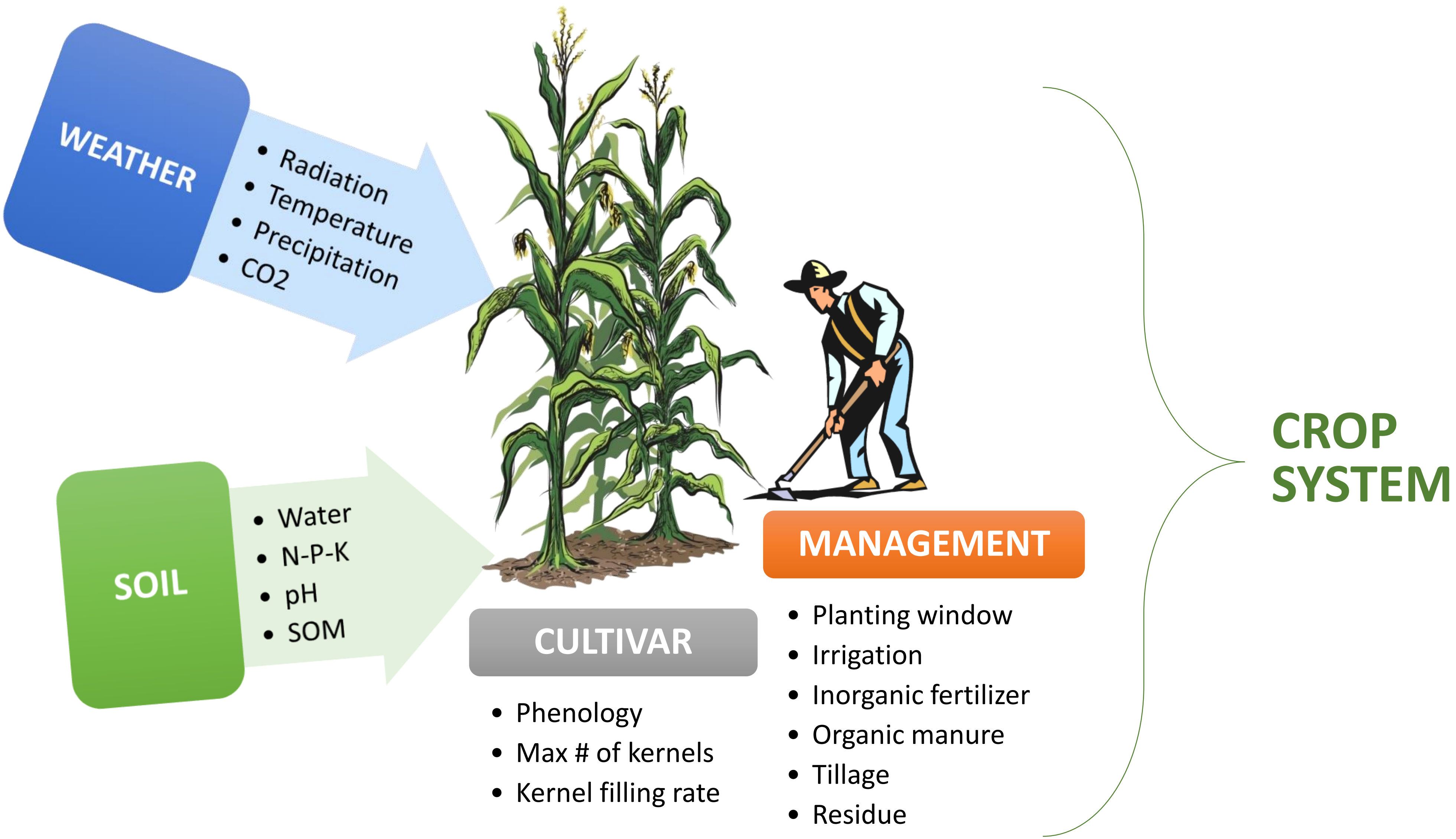

Change
(e.g., policy)
Investment/Policy Analysis
MACRO SCALE
Aggregate, market-scale (geo-political) units
Fixed
Geographies of Analysis
Flexible
Geographies/Units of Analysis
e.g., IMPACT/WATER,
GTAP derivatives
e.g., DREAM,
MM models
Household
Characterization
MICRO SCALE
Region
Urban/Rural
Income tercile
Consumption
Production
Inputs
Change
(e.g., climate,
technologies)
Production System
& Market Access
Analysis
MESO SCALE
Pixels as Units of Analysis
Aggregation
By Commodity
Infrastructure/Market Access
Production System
Ecosystem Services





Try:
*harvestchoice.org/**mappr***
*harvestchoice.org/**tablr***

Bio-physical data layers are used to run process-based **crop models**



CROP MODEL SIMULATES A LOT **MORE THAN YIELDS**

- Productivity
- Nutrient balances
- Water balance
- Soil organic carbon

→ **SOIL HEALTH** (or **SOIL QUALITY**) INDICATOR

YIELD **LEVELS** (esp. low-input)
YIELD **VARIABILITY** (esp. water stress)
YIELD **RESPONSES** to interventions

Continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans

USDA-Natural Resources Conservation Service

WHAT
HEALTHY SOIL DOES

- Tighten soil nutrient cycles
- Increase nutrient and water use efficiency
- Suppress diseases and pests, including weeds
- Resist degradation
- Buffer environmental constraints
- Produce healthy plants, people and animals

Illustration from National Geographic

How important is Soil?

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The Soil Renaissance: Knowledge to Sustain Earth's Most Valuable Asset

The Soil Renaissance seeks to reawaken the public to the importance of soil health in vibrant, profitable and sustainable natural resource systems. It seeks to make maintenance and improvement of soil health the cornerstone of land use management decisions.

A Soil Renaissance Strategic Plan has been developed with input from thought leaders working in production agriculture, agribusiness, the academic community, NGOs and government agencies. The Soil Renaissance Strategic Plan outlines goals and work plans in four key areas: Measurement, Economics Research and Education.

"This Strategic Plan is a starting point that will evolve and expand as work is completed, new challenges are identified and more

Project Activities

December 2013
The Soil Renaissance: Knowledge to Sust
Earth's Most Valuable Asset

March 2013
Solutions From the Land

SOIL RENAISSANCE | THE SOILS FACT SHEET

Soils are ...

THE **DYNAMIC SKIN** OF THE EARTH, FORMED BY THE INTERACTION OF MINERALS, ORGANIC MATERIAL, ORGANISMS, WATER AND AIR.

A **NONRENEWABLE** RESOURCE. IT CAN TAKE **HUNDREDS** TO **THOUSANDS OF YEARS** TO CREATE 1 INCH OF TOPSOIL.

Soils provide ...

THE SURFACE ON WHICH WE LIVE AND BUILD.

FERTILITY TO GROW THE PLANTS AND FORESTS THAT NURTURE AND SHELTER HUMANS AND ANIMALS.

STORAGE FOR WATER AND CARBON. JUST **1 PERCENT** OF ORGANIC MATTER IN THE TOP 6 INCHES OF SOIL WOULD HOLD APPROXIMATELY **27,000** GALLONS OF WATER PER ACRE.

RECYCLING AND PURIFICATION FOR AIR, WATER AND NUTRIENTS. HEALTHY SOILS CAN REDUCE NUTRIENT LOADING AND SEDIMENT RUNOFF, INCREASE EFFICIENCIES, AND SUSTAIN WILDLIFE HABITAT.

HOUSING FOR A DIVERSITY OF MICROBES, ORGANISMS AND ANIMALS.

Why the need for a Soil Renaissance?

IF THE EARTH WERE AN APPLE, THE ARABLE LAND WOULD BE EQUIVALENT TO THE PEEL FROM ONE/THIRTY-SECOND OF A SLICE OF THAT APPLE.

THE WORLD'S **7 BILLION PEOPLE** TODAY ARE FED BY ARABLE LAND THAT **COMPRISES 10.6%** OF THE WORLD'S LAND AREA.

HALF OF THE TOPSOIL ON THE PLANET HAS BEEN LOST IN THE LAST 150 YEARS.

EXPERTS FORECAST THE WORLD'S **FOOD DEMAND WILL DOUBLE BY 2050.**

POPULATION IS FORECAST TO INCREASE BY 50%, REDUCING THE RATIO OF ARABLE LAND TO PEOPLE AND PLACING MORE DEMANDS ON SOILS.

SOIL IS BEING LOST AT 10 TO 40 TIMES THE RATE AT WHICH IT CAN BE NATURALLY REPLENISHED.

THE AVERAGE RATE OF SOIL EROSION ON U.S. CROPLAND IS **7 TONS/ACRE/YEAR.**

GLOBALLY, ABOUT **40% OF THE SOIL** USED FOR AGRICULTURE IS CLASSIFIED AS DEGRADED OR SERIOUSLY DEGRADED. AT CURRENT DEGRADATION RATES, **THE WORLD HAS ABOUT 60 YEARS OF TOPSOIL LEFT.**

Why the need for a Soil Renaissance?

LOSS OF SOIL AND WATER FROM U.S. CROPLAND DECREASES PRODUCTIVITY BY ABOUT **$37.6 BILLION** PER YEAR.

MORE THAN 90% OF THE **FRUITS AND 78% OF THE VEGETABLES** PRODUCED IN THE U.S. ARE GROWN ON FARMS LOCATED CLOSEST TO CITIES – DIRECTLY IN THE PATH OF DEVELOPMENT.

SOIL EROSION GLOBALLY COSTS AN ESTIMATED **$400 BILLION PER YEAR.**

EVERY YEAR, THE U.S. **LOSES MORE THAN 1 MILLION ACRES OF LAND** IDEALLY SUITED TO GROW FOOD **TO DEVELOPMENT.**

MOST **FARMERS CAN INCREASE SOIL** ORGANIC MATTER IN **THREE TO 10 YEARS** IF MOTIVATED TO ADOPT CONSERVATION PRACTICES.

Threats to soils include ...

POPULATION GROWTH

URBAN DEVELOPMENT

KNOWLEDGE GAPS THAT IMPACT PRODUCTION PRACTICES AND PUBLIC POLICIES

SOIL EROSION

DEGRADATION AND CONTAMINATION

The Soil Renaissance will ...

- MAKE SOIL HEALTH A PRIORITY AMONG ALL STAKEHOLDERS.
- IDENTIFY A STANDARD APPROACH TO MEASURING SOIL HEALTH.
- DEVELOP TOOLS TO DEMONSTRATE THE RETURN GENERATED BY SOIL HEALTH INVESTMENTS.
- SUPPORT SOIL HEALTH EDUCATION AND OUTREACH PROGRAMS FOR ALL STAKEHOLDERS.
- IDENTIFY KNOWLEDGE GAPS AND LAY THE GROUNDWORK FOR NEEDED RESEARCH.
- CELEBRATE THE MIRACLE OF SOILS.

How to be a part of the Renaissance ...

Neil Conklin, president, Farm Foundation, NFP, neil@farmfoundation.org
William Buckner, president, Noble Foundation, wbuckner@noble.org
Tim Brennan, Farm Foundation, NFP, tim@farmfoundation.org

“No civilization has outlived the usefulness of its soils. When the soil is destroyed, the nation is gone.”

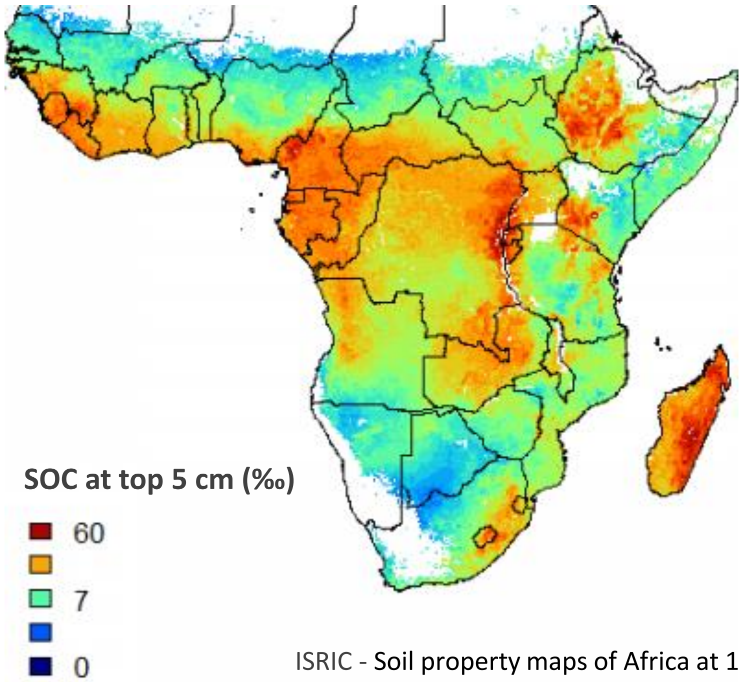
– Lloyd Noble, Nov. 18, 1949

Farm Foundation

THE SAMUEL ROBERTS NOBLE FOUNDATION

WHERE ARE THE HEALTHY SOILS, AND WHAT ARE THEIR YIELD IMPACTS? **IT'S COMPLICATED.**

SOIL PROPERTY MAP: SOC



ISRIC - Soil property maps of Africa at 1 km

OUR APPROACH for **SIMULATING YIELDS** in **FARMERS' FIELDS** with (MODELED) **SOIL FERTILITY**

1. Use the soil property maps to set initial conditions
2. Model soil quality degradation under low-input monoculture scenario.
3. Simulate yield responses over time, on the initial and degraded soil properties.

- Interpolated, static surface using observations.
- Great resource for **initializing models** and understanding the **representative soil characteristics**.
- Does <u>not</u> necessarily represent the soil health status in <u>farmers' fields</u> (dynamic process, depending on the current/historic management practices, as much as the chemical properties).

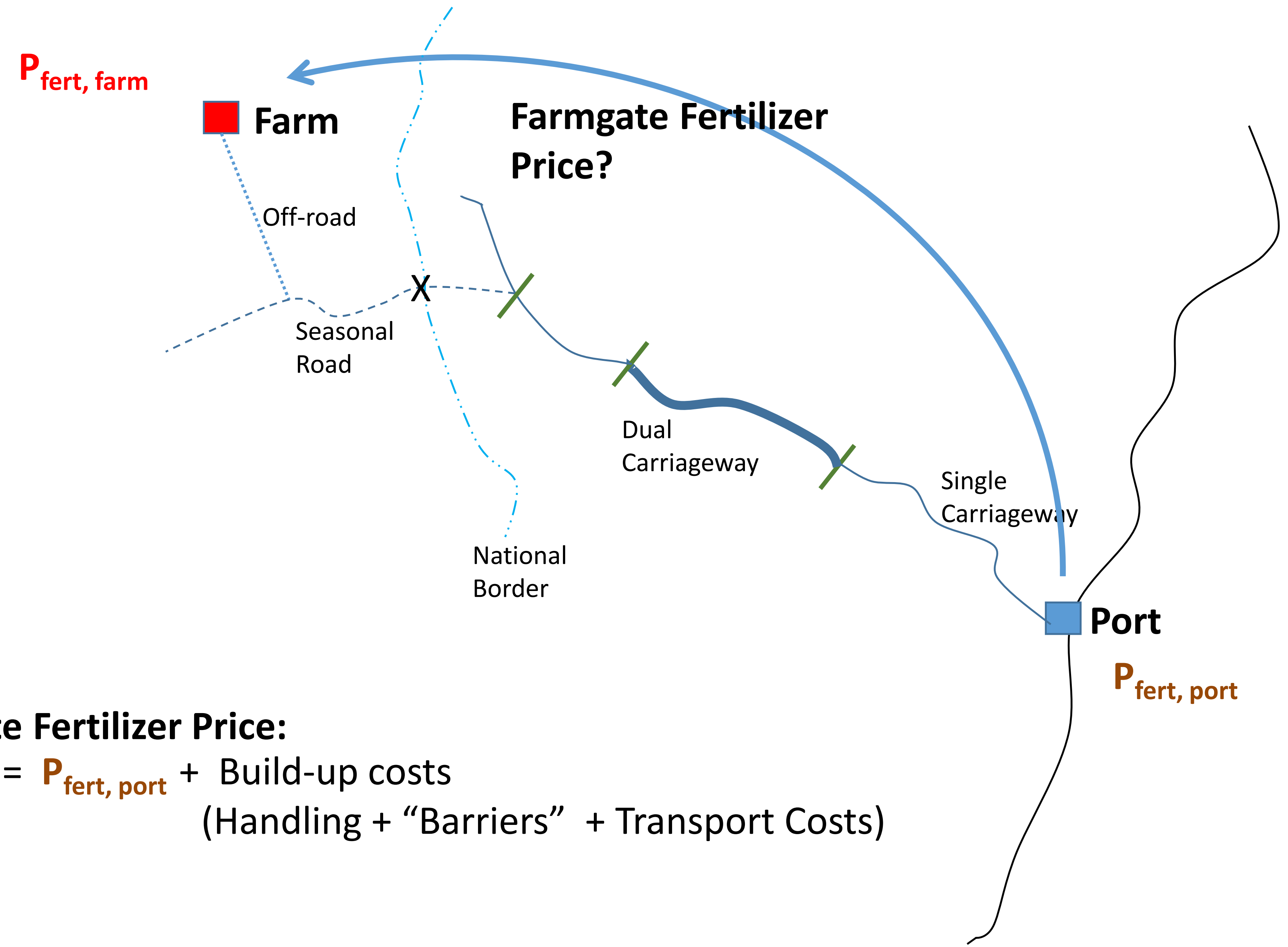
FERTILIZER POLICY OPTIONS in EAST AFRICA and THEIR IMPACTS on **FERTILIZER PROFITABILITY**

AGRA requested IFPRI an impact assessment study of:

1. Reducing the landed cost of fertilizer through collective bulk purchasing.
2. Reducing transport costs through improved road and related transportation infrastructure.
3. Reduced transactions costs through improved harmonization and streamlining of border crossing/customs procedures.

plus, SOIL FERTILITY IMPLICATIONS?

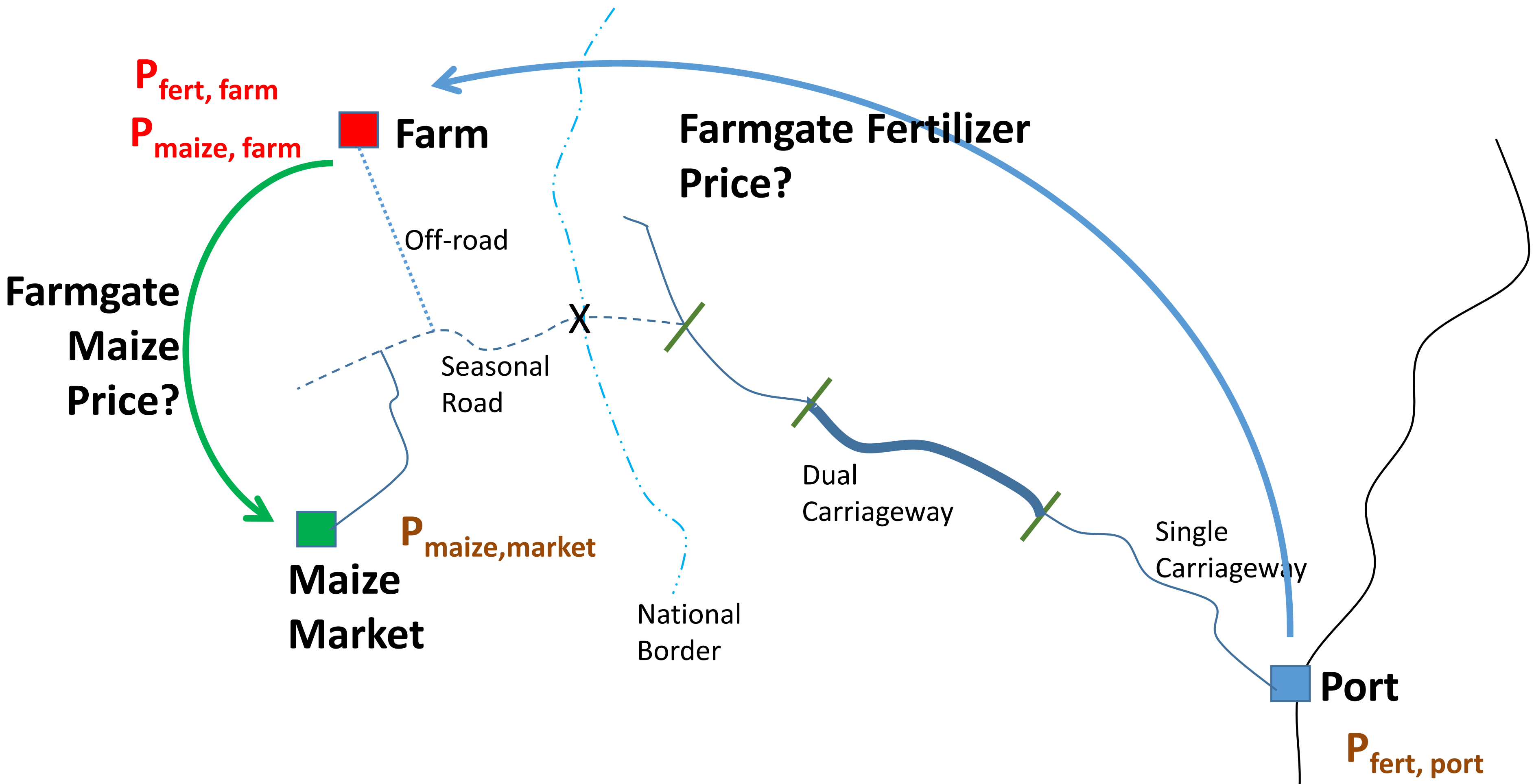
Assessing Farmgate Prices: 1. Imported Inputs



Farmgate Fertilizer Price:

$P_{fert,\ farm}$ = $P_{fert,\ port}$ + Build-up costs
(Handling + "Barriers" + Transport Costs)

Assessing Farmgate Prices: 2. Output Surplus to Local Markets



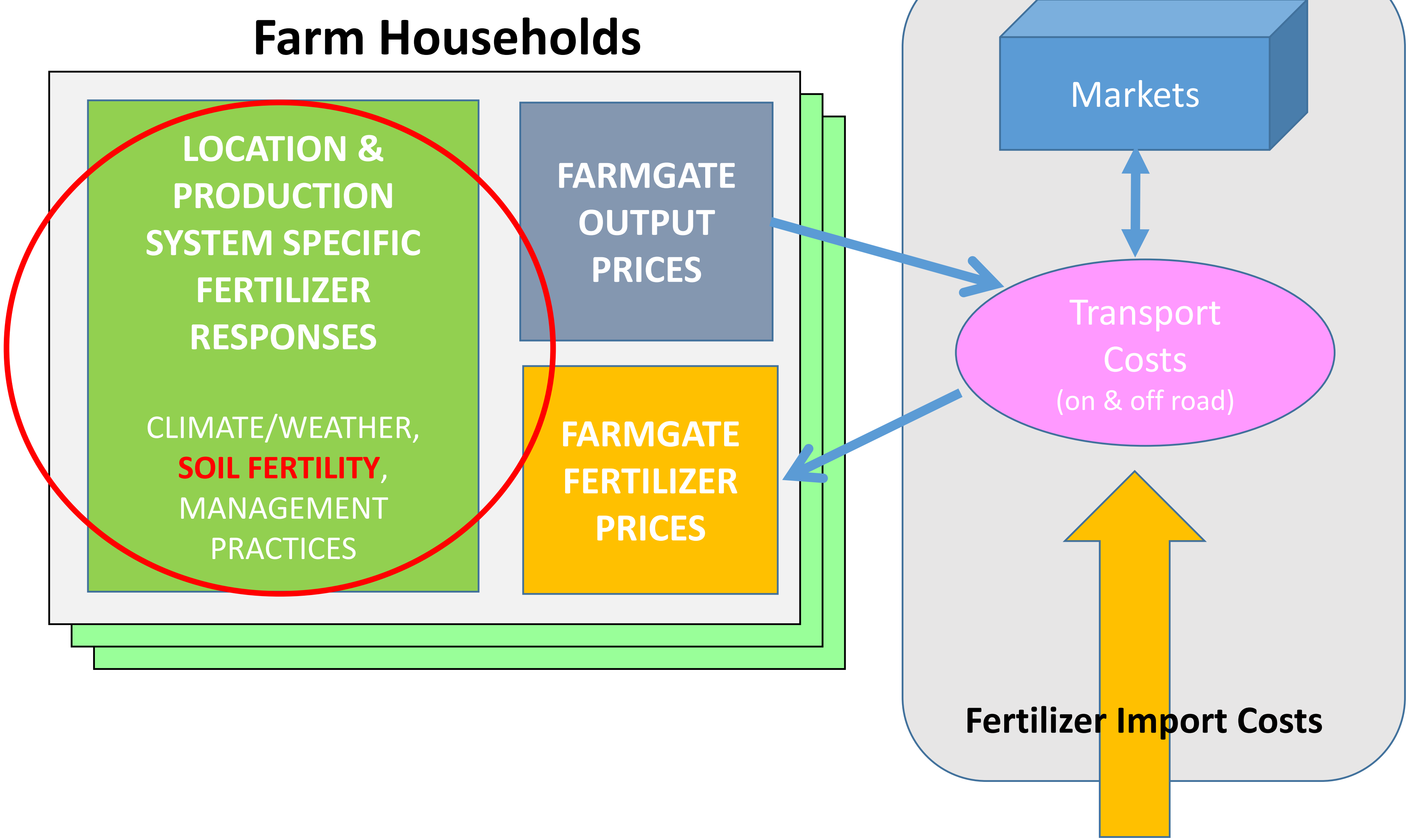
Farmgate Fertilizer Price:

$P_{\text{fert, farm}} = P_{\text{fert, port}}$ + Build-up costs (Handling + "Barriers" + Transport Costs)

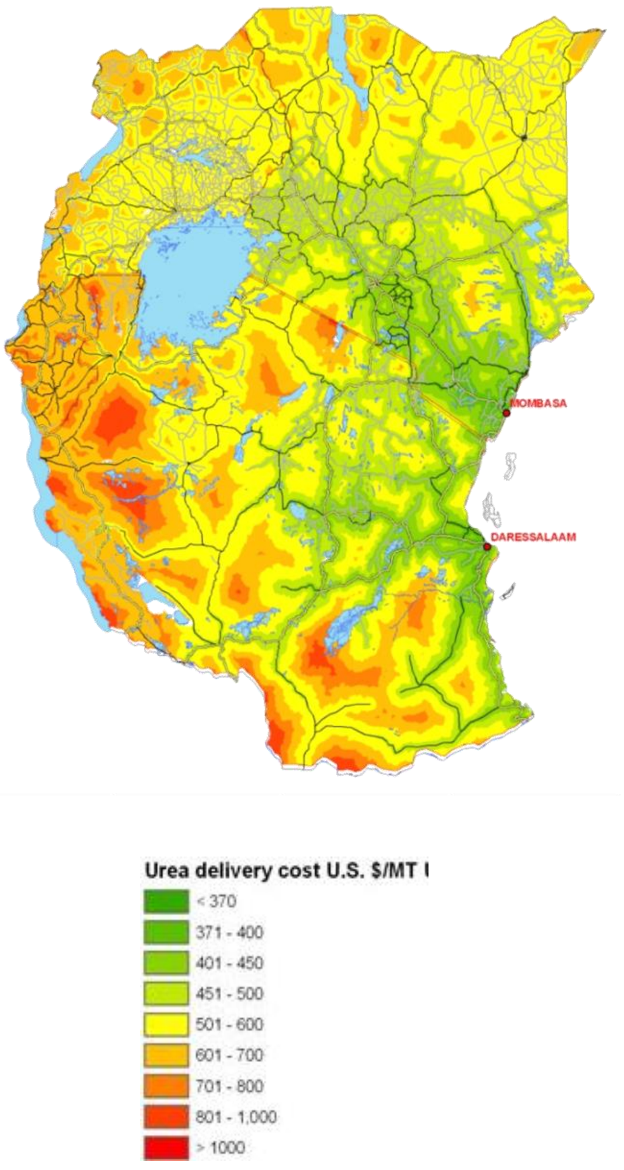
Farmgate Maize Price

$P_{\text{maize, farm}} = P_{\text{maize,market}}$ - *Transport Costs*

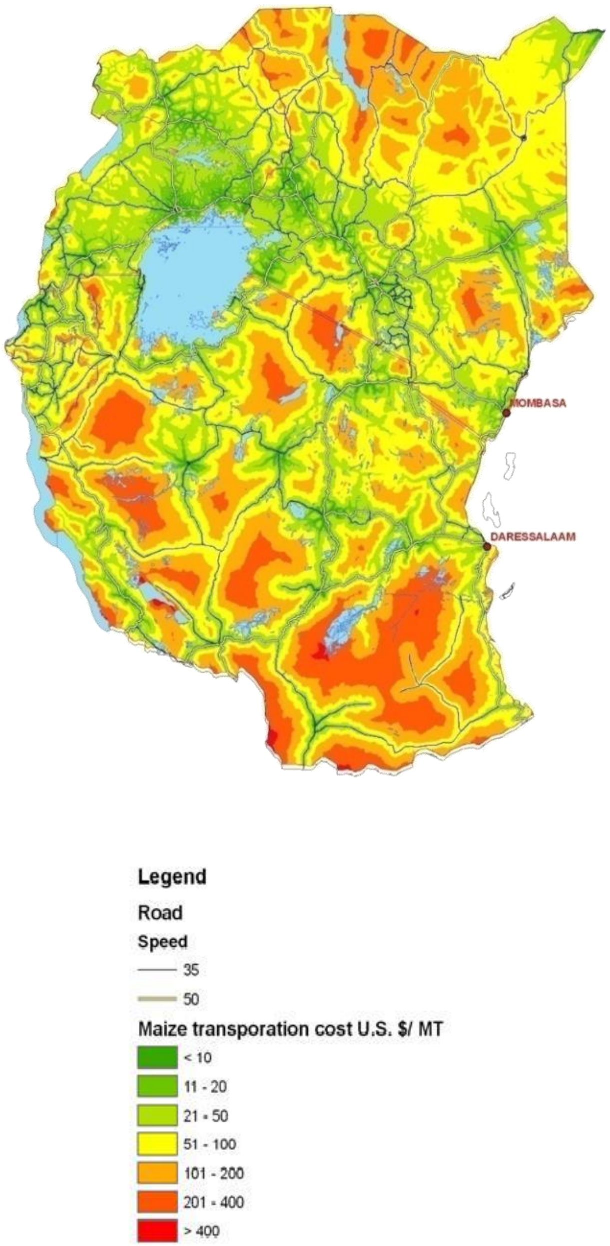
ON-SITE FERTILIZER **RESPONSES**



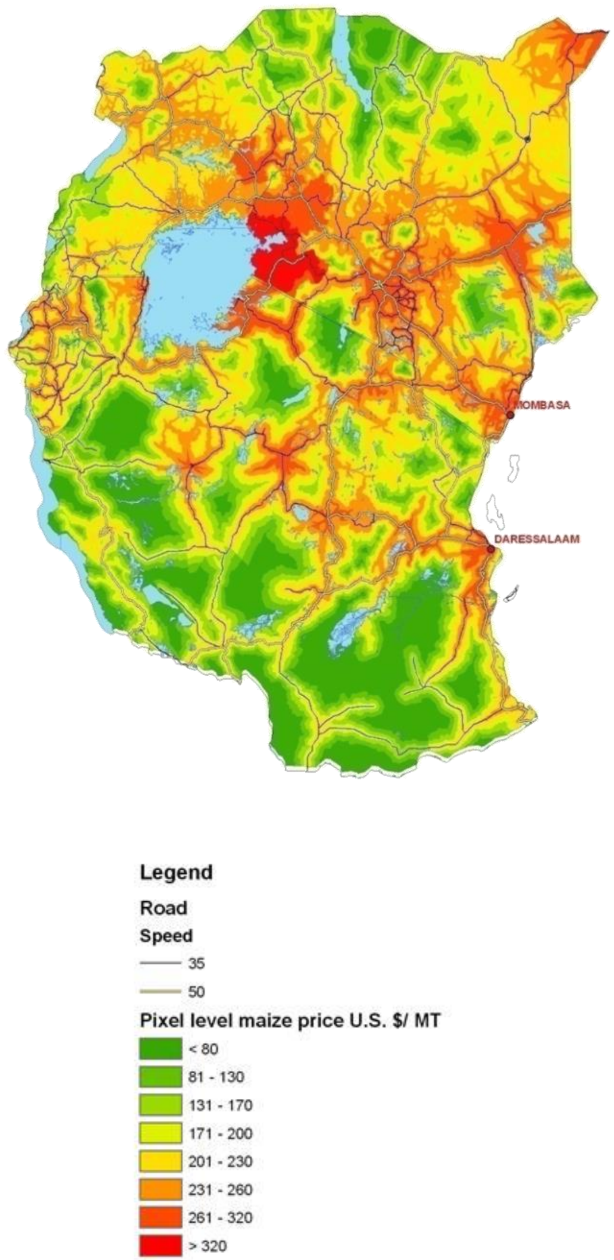
Fertilizer Delivery Cost



Maize Transport Cost



Maize Farm-gate Price



ESTIMATING VALUE COST RATIOS (VCRS)


NOTES

Africa's Growing Soil Fertility Crisis: What Role For Fertilizer?

ARD

World Bank ARD Note
Issue 21 (2007)

"Fertilizer markets have failed in Africa"

- Scattered and small size of local market
- Weak demand for use with food staple crops
- High transportation cost – poor road and rail infrastructure, particularly in landlocked countries
- Low profitability

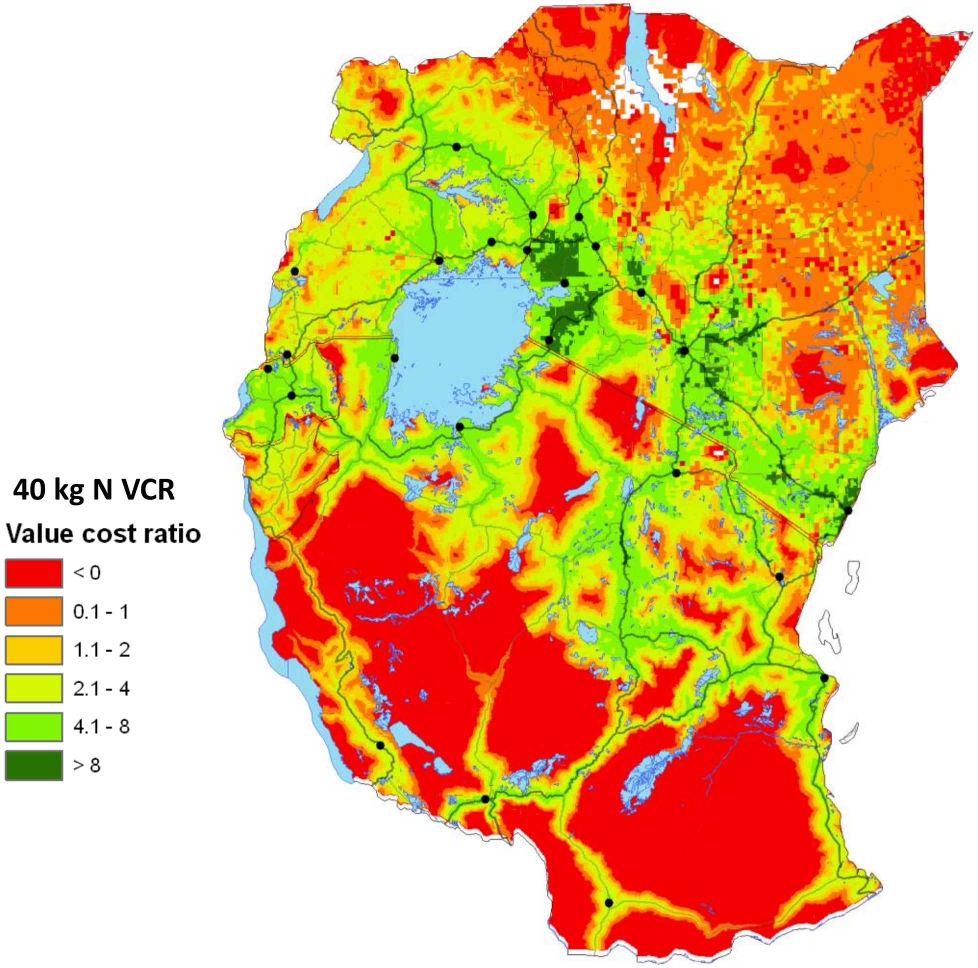
Value-Cost Ratio (VCR)

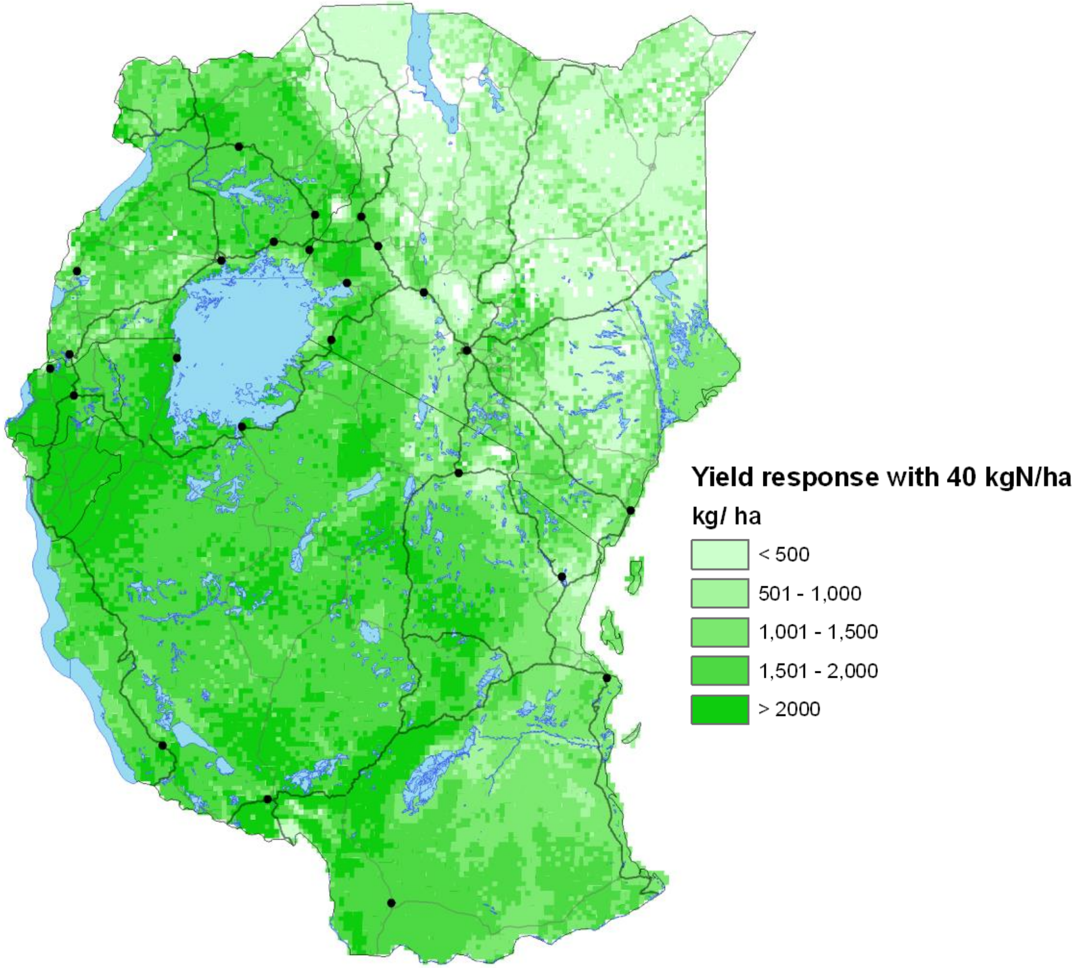
$$VCR_{x,y} = \frac{\Delta y(N)_{x,y} \times Price^{maize}_{x,y}}{N \times Price^{fertilizer}_{x,y}}$$

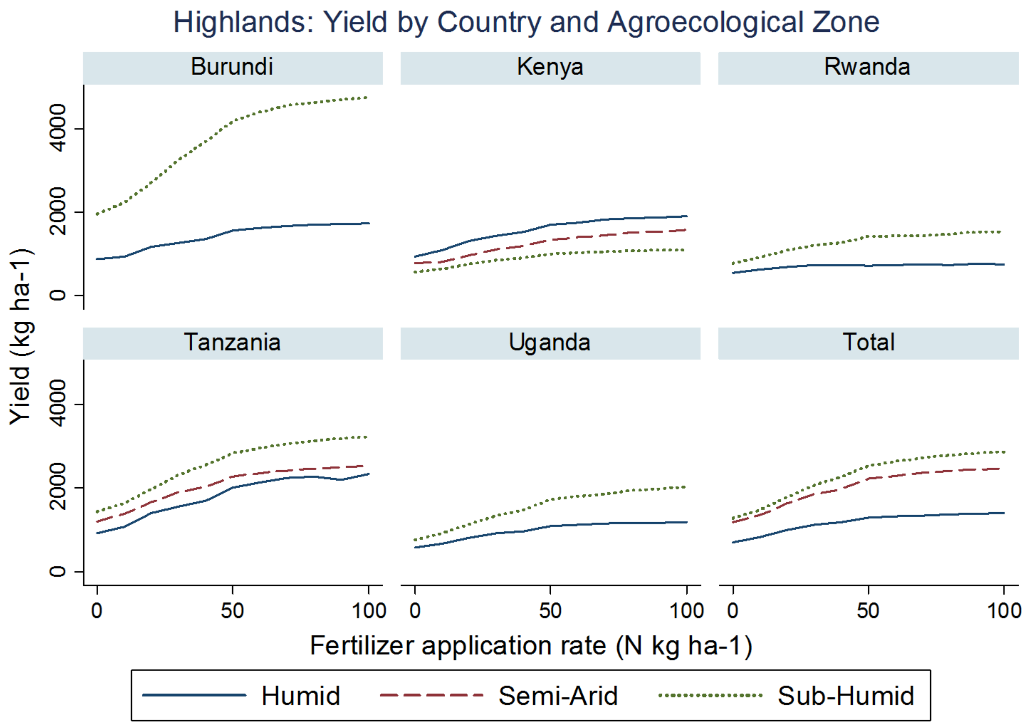
- N = fertilizer application rate (kg/ha)
- y(N) = maize yield with fertilizer at N rate (t/ha)
- Δy(N) = y(N) – y(0) (t/ha)

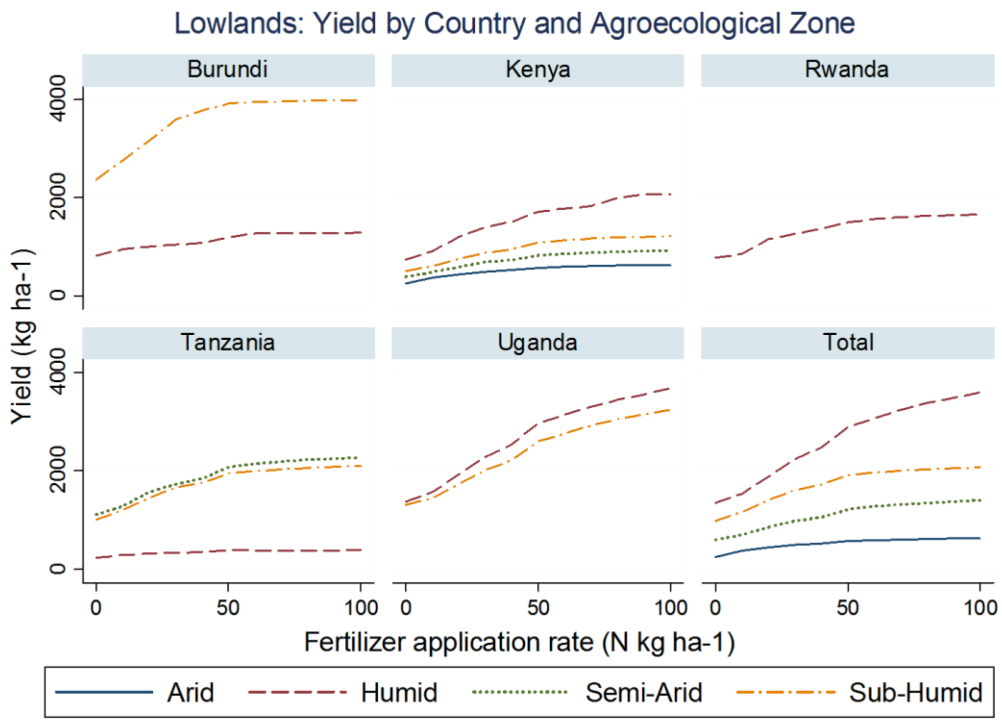
"…IFDC suggests **VCR>2** to accommodate price and climatic risks and still provide an incentive to farmers"

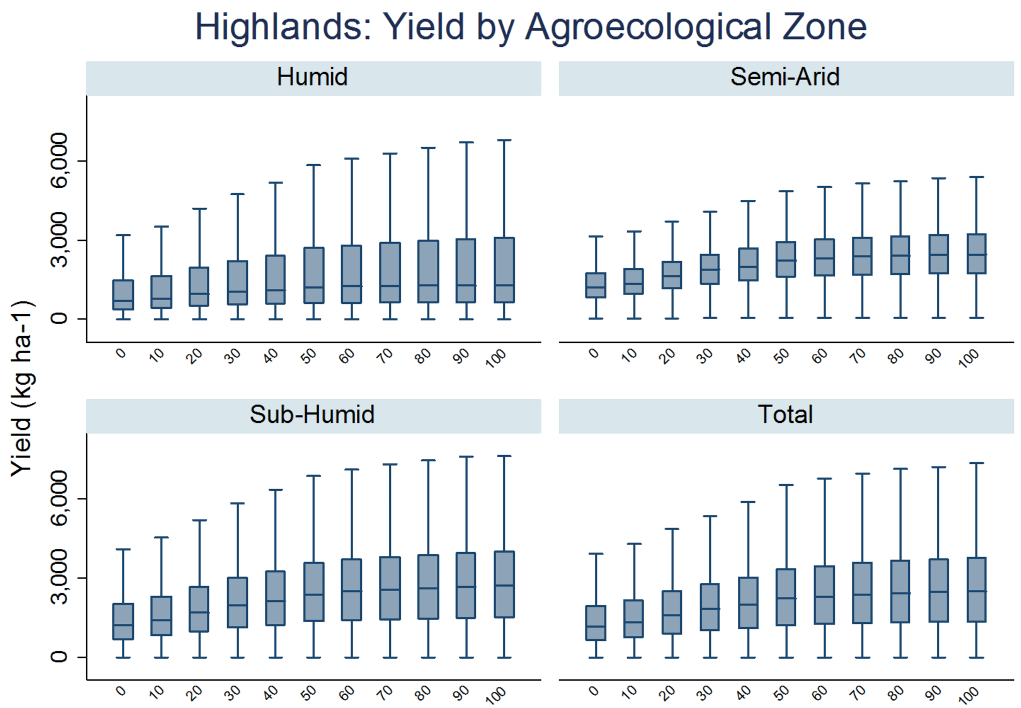
VALUE-COST RATIO

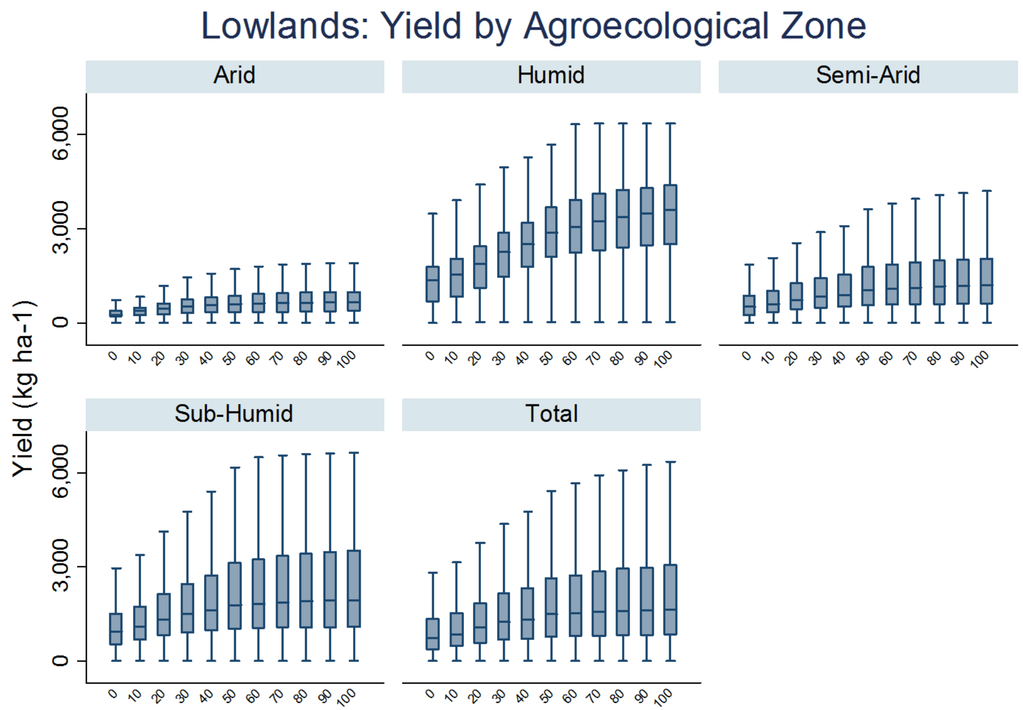


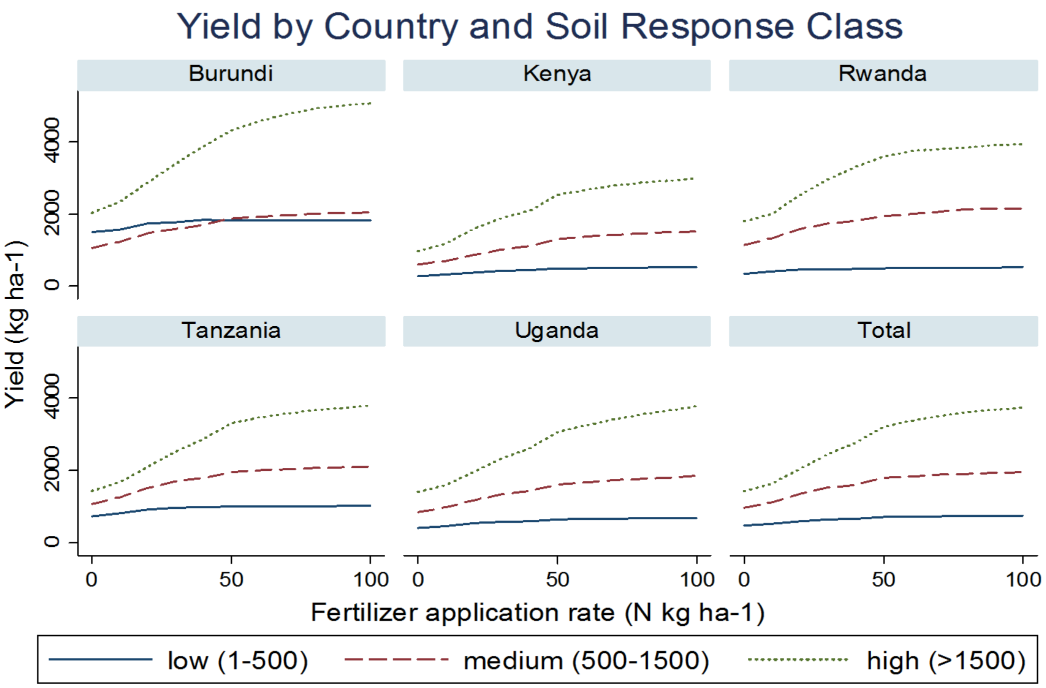


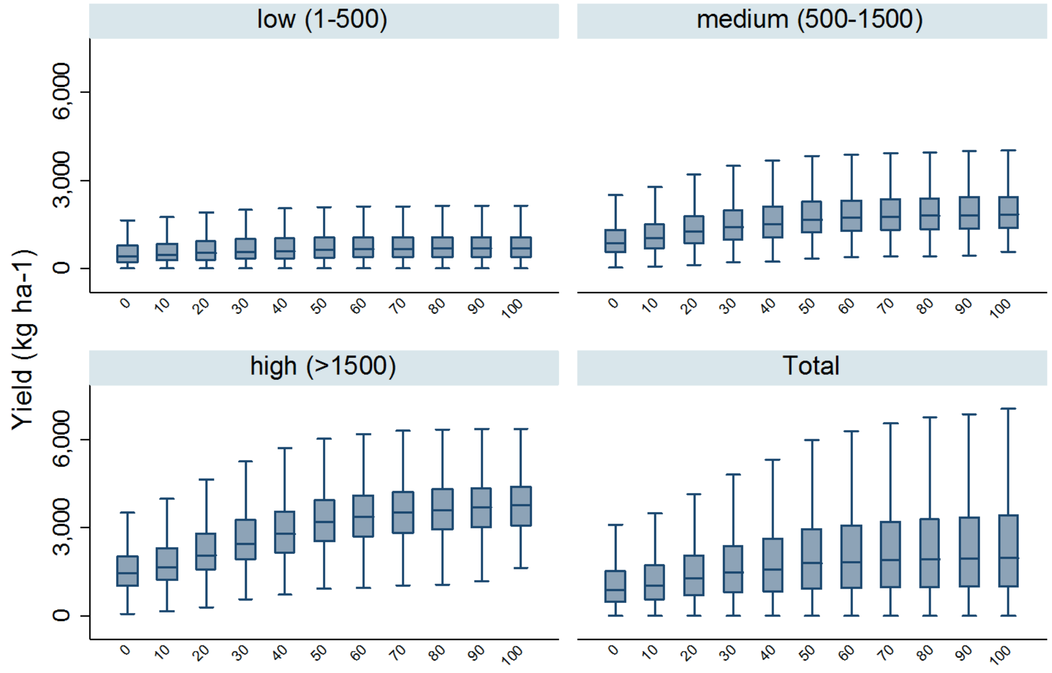

Highlands: Yield by Country and Agroecological Zone
Burundi
Kenya
Rwanda
Tanzania
Uganda
Total
Yield (kg ha-1)
Fertilizer application rate (N kg ha-1)
Humid
Semi-Arid
Sub-Humid

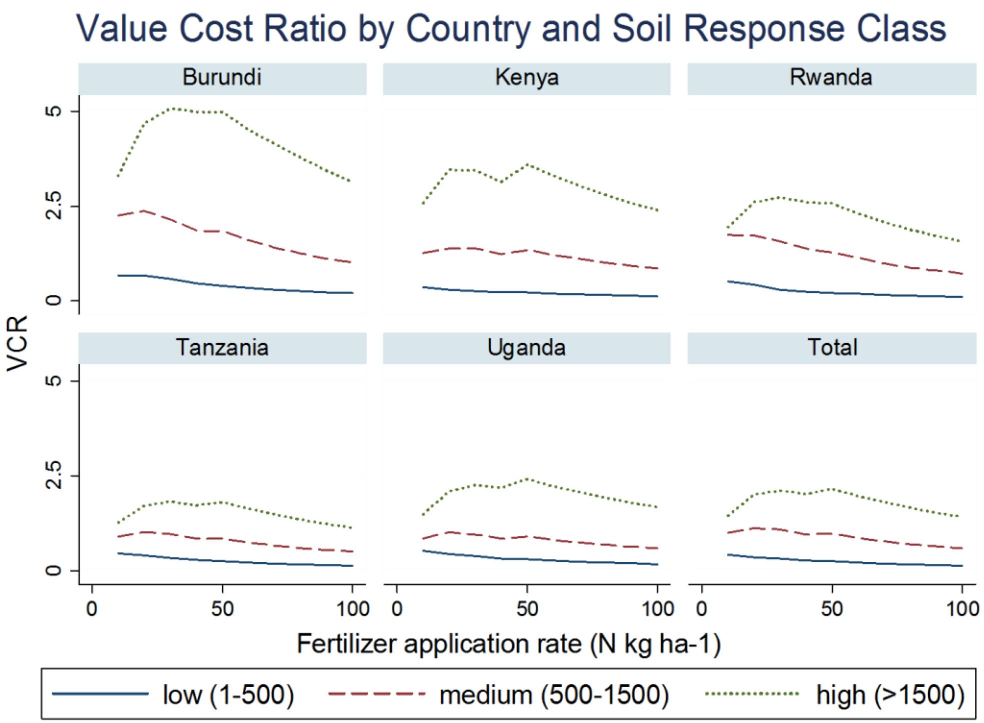

Lowlands: Yield by Country and Agroecological Zone
Burundi
Kenya
Rwanda
Tanzania
Uganda
Total
Yield (kg ha-1)
Fertilizer application rate (N kg ha-1)
Arid
Humid
Semi-Arid
Sub-Humid

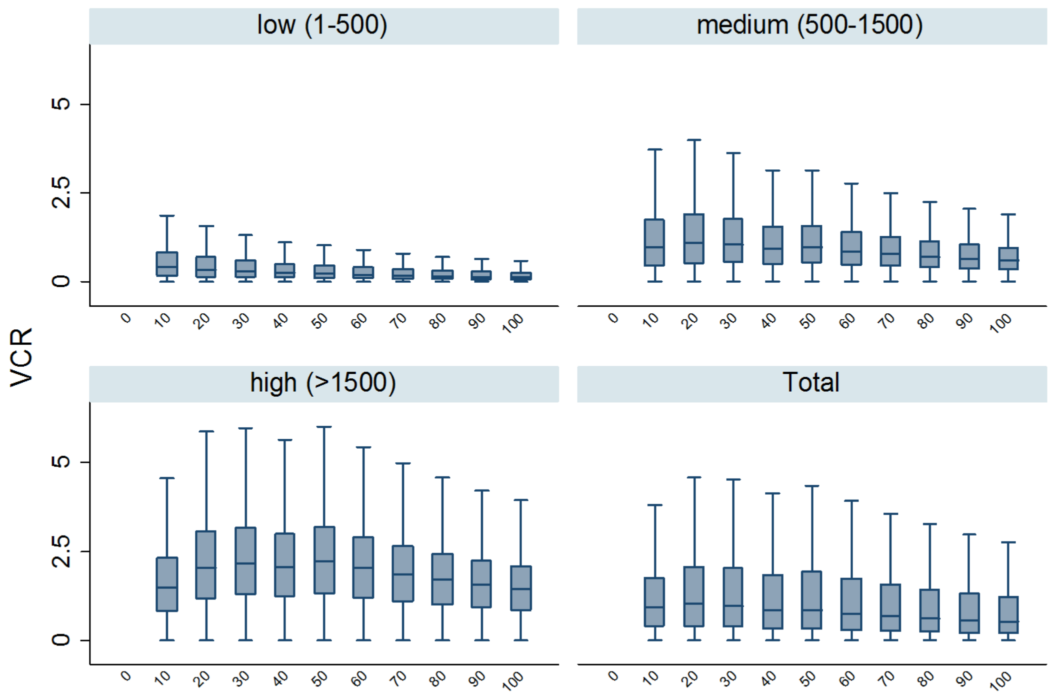

Highlands: Yield by Agroecological Zone
Humid
Semi-Arid
Sub-Humid
Total
Yield (kg ha-1)


Lowlands: Yield by Agroecological Zone
Arid
Humid
Semi-Arid
Sub-Humid
Total
Yield (kg ha-1)


Yield by Country and Soil Response Class
Burundi
Kenya
Rwanda
Tanzania
Uganda
Total
Yield (kg ha-1)
0
2000
4000
0
50
100
Fertilizer application rate (N kg ha-1)
low (1-500)
medium (500-1500)
high (>1500)


low (1-500)
medium (500-1500)
high (>1500)
Total
Yield (kg ha-1)
0
3,000
6,000
0
10
20
30
40
50
60
70
80
90
100


Value Cost Ratio by Country and Soil Response Class
Burundi
Kenya
Rwanda
Tanzania
Uganda
Total
VCR
0
2.5
5
0
50
100
Fertilizer application rate (N kg ha-1)
low (1-500)
medium (500-1500)
high (>1500)


low (1-500)
medium (500-1500)
high (>1500)
Total
VCR
0
2.5
5
0
10
20
30
40
50
60
70
80
90
100

CONCLUDING **REMARKS**

- Soil carbon is key indicator to understand the various aspects of crop productivity, especially under low-input systems.
- Good understanding of soil carbon content in the field can explain the yield level, yield variability, and yield responses to interventions.

CONCLUDING **REMARKS**

- However, use of static soil carbon data may potentially be misleading. Soil carbon content is highly dependent on farmers' management practices and dynamic in nature; static soil property maps may not adequately inform the actual soil quality status.
- Process-based modeling framework, whose initial conditions to be set with soil property databases, can dynamically simulate the dynamics of soil carbon changes and its effects on crop growth and yields.

CONCLUDING **REMARKS**

- As shown in the profitability study example, single assumption of soil fertility in a given location can potentially mislead the impact of intervention.
- To take into account the heterogeneity of soil fertility in farmers’ fields, model-estimated crop yield responses under various scenarios may need to be disaggregated based on soil fertility classes.