Prices constraint food production in Sub-Saharan Africa: Assessing the economic yield gap

A data-science approach

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Bonilla-Cedrez, C., Chamberlin, J. and Hijmans, R.J., 2021. Fertilizer and grain prices constrain food production in sub-Saharan Africa. *Nature Food*, pp.1-7.

Multidisciplinary approach

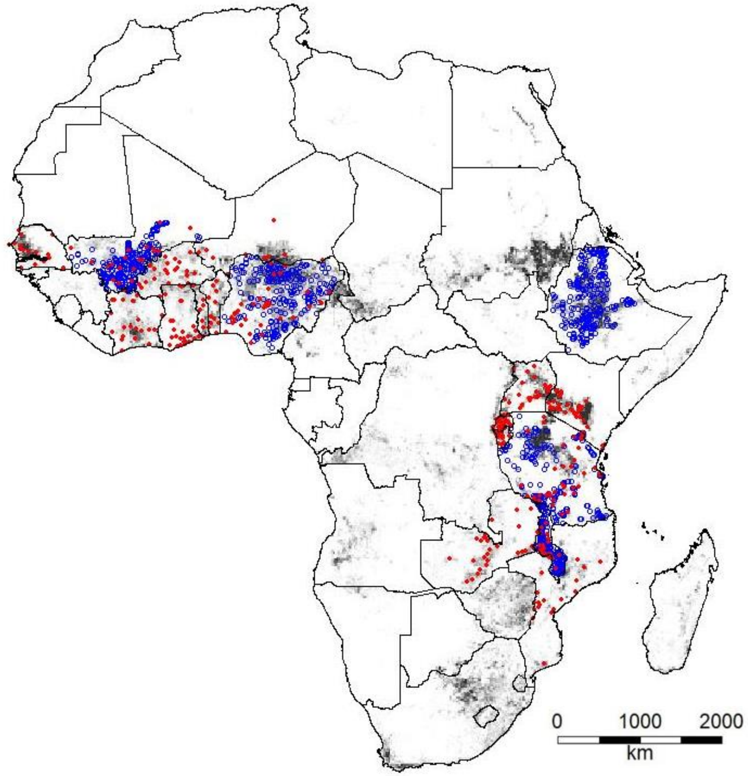
Fertilizer prices

Maize prices

Crop response

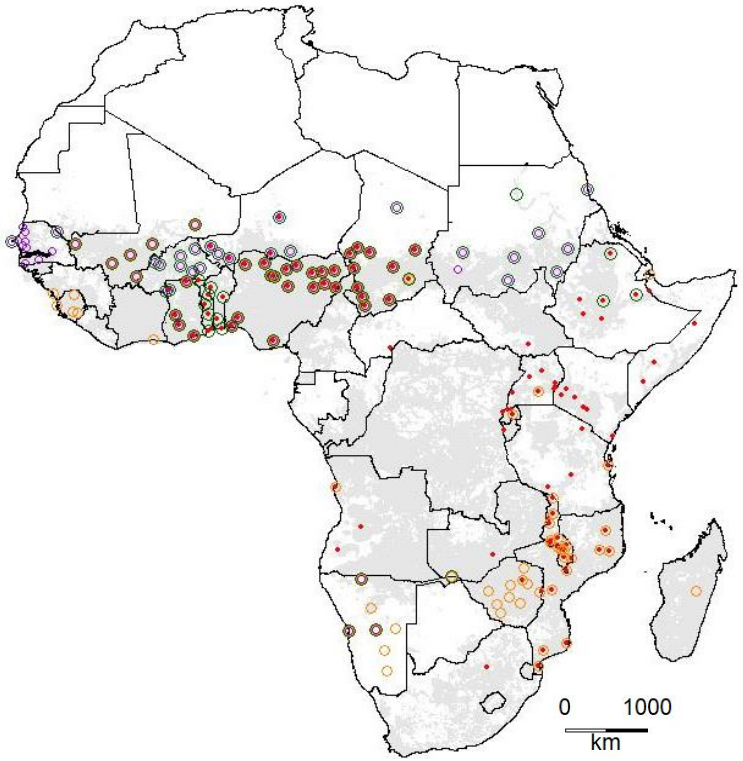
Profitability

Data-science approach



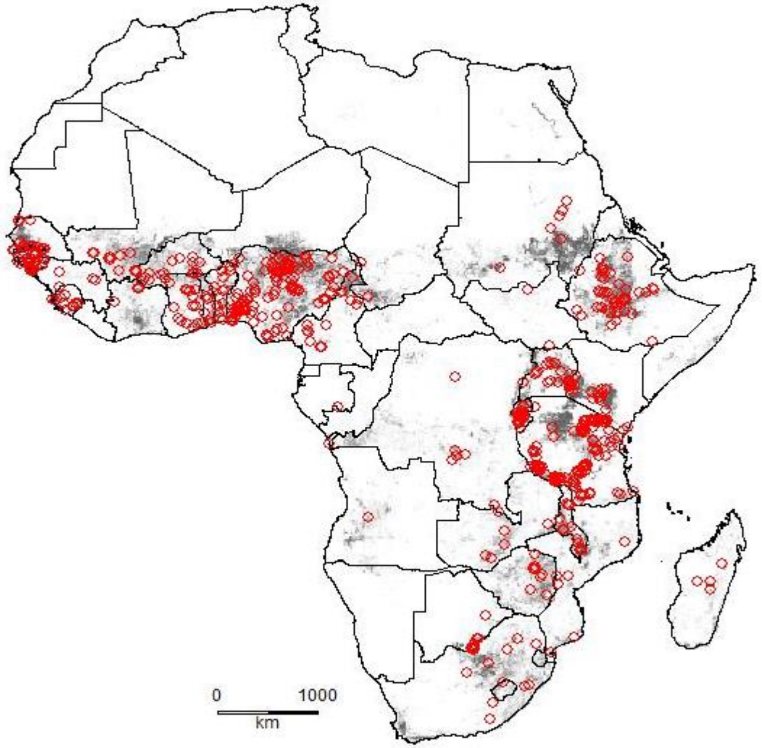
Fertilizer prices

Obs: >10,000
Unique loc: 1729



Maize prices

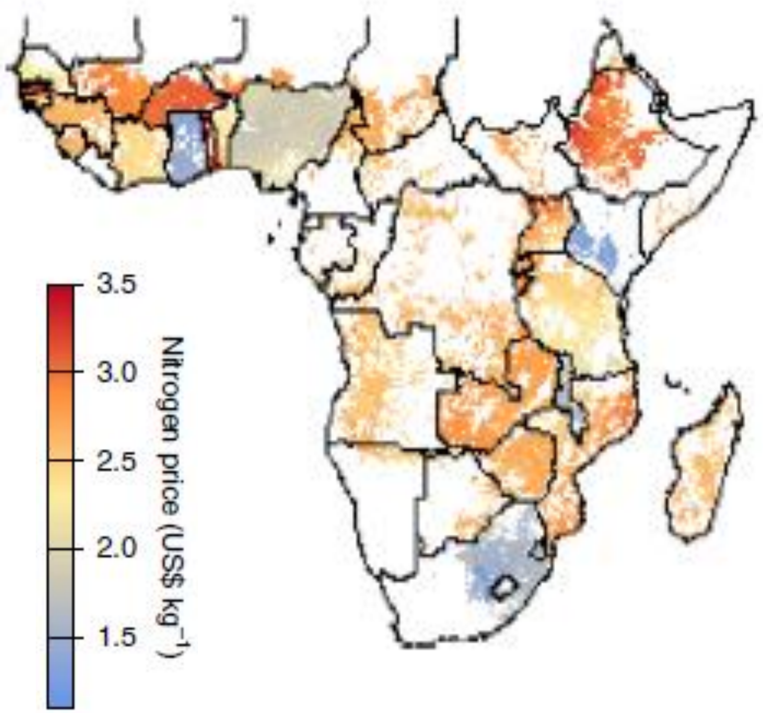
Obs: 43,399
Unique loc: 168



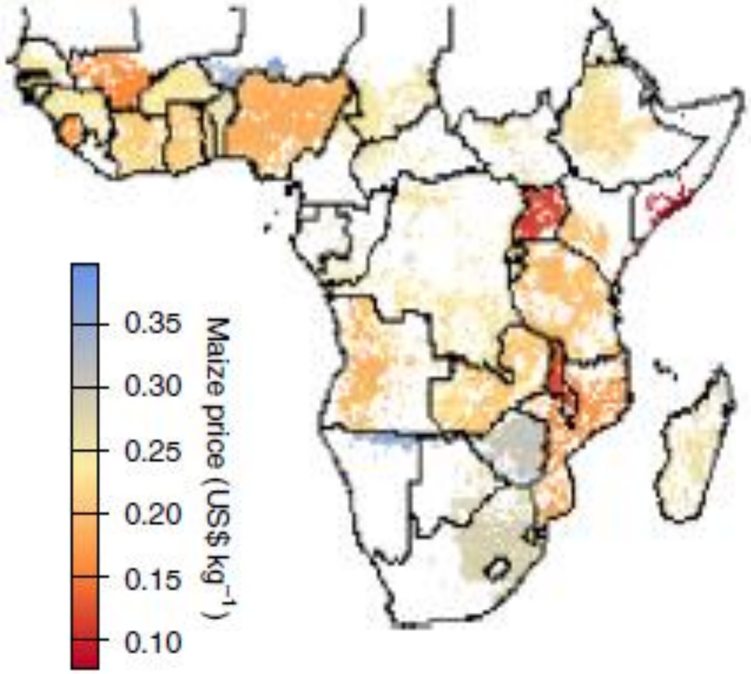
Crop yield

Obs: 12,081
Unique loc: 1141

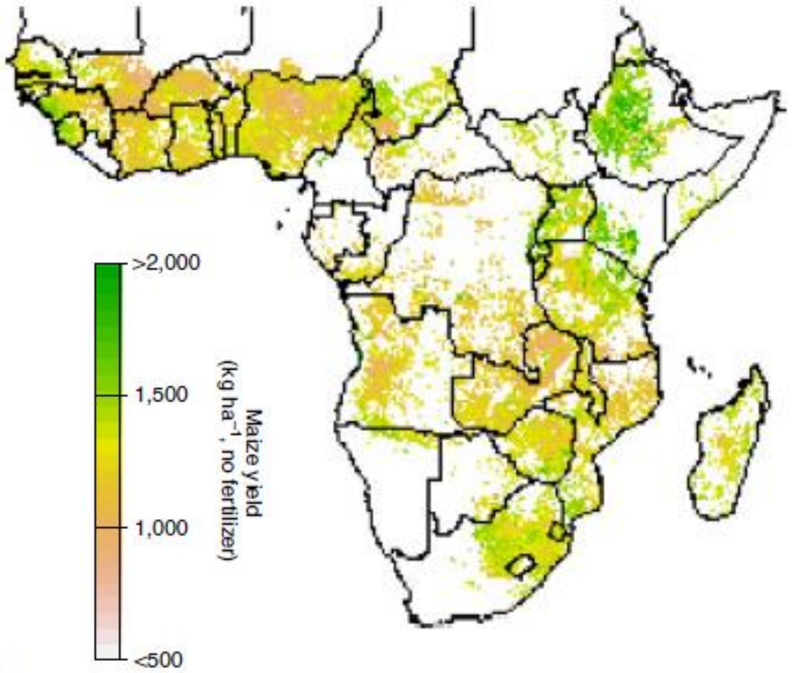
Data-science approach



Fertilizer prices



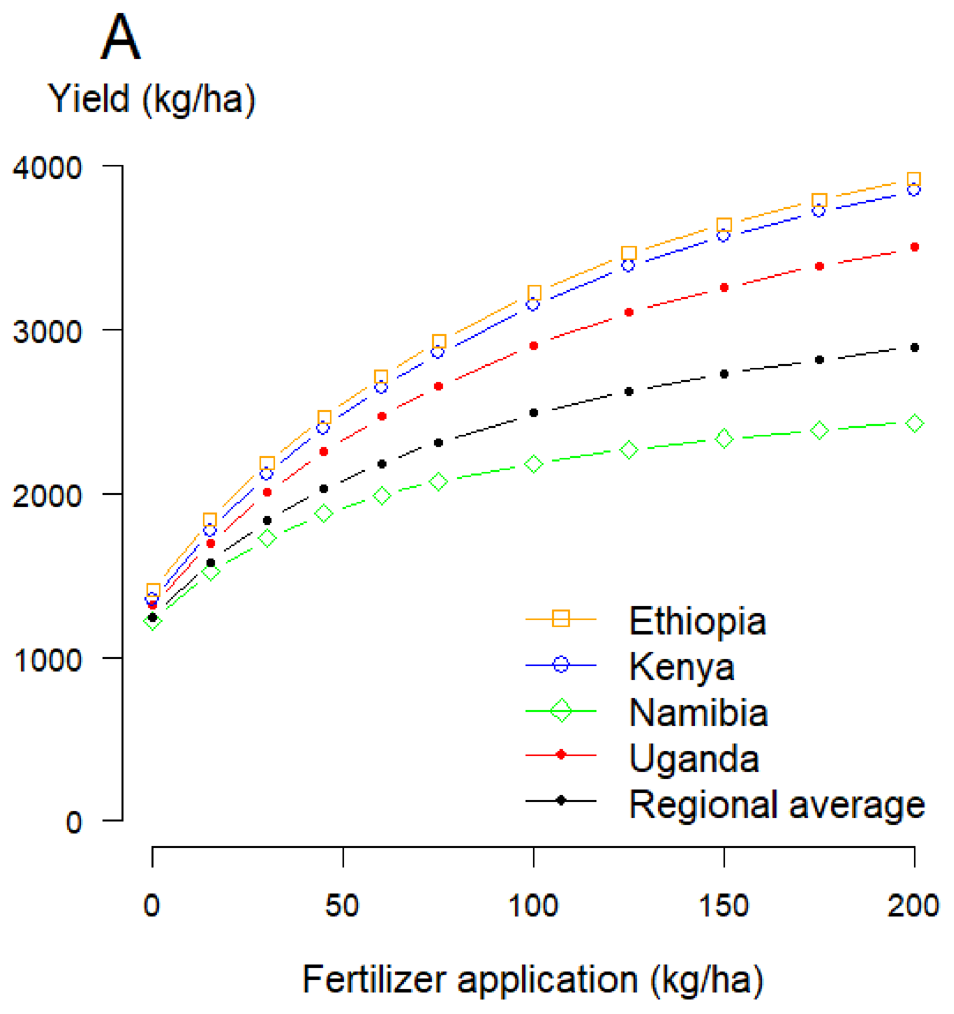
Maize prices



Crop yield

Bonilla-Cedrez et al., 2020. Spatial variation in fertilizer prices in Sub-Saharan Africa. *PloS one*, *15*(1), p.e0227764.
Bonilla-Cedrez et al., 2020. Seasonal, annual, and spatial variation in cereal prices in Sub-Saharan Africa. *Global Food Security*, *26*, p.100438.
Bonilla-Cedrez et al., 2021 Fertilizer and grain prices constrain food production in sub-Saharan Africa. *Nature Food*, pp.1-7.

Framework to compute maximum profitability



NUE: 5 - 35 kg (grain) kg $(N)^{-1}$ | Fertilizer price: \$ 1.30 – 3.10 kg $(N)^{-1}$ | Maize price: \$ 0.11 – 0.36 kg $(grain)^{-1}$

Input and Output prices

Price = *f* (Market access + Demand + Environment)

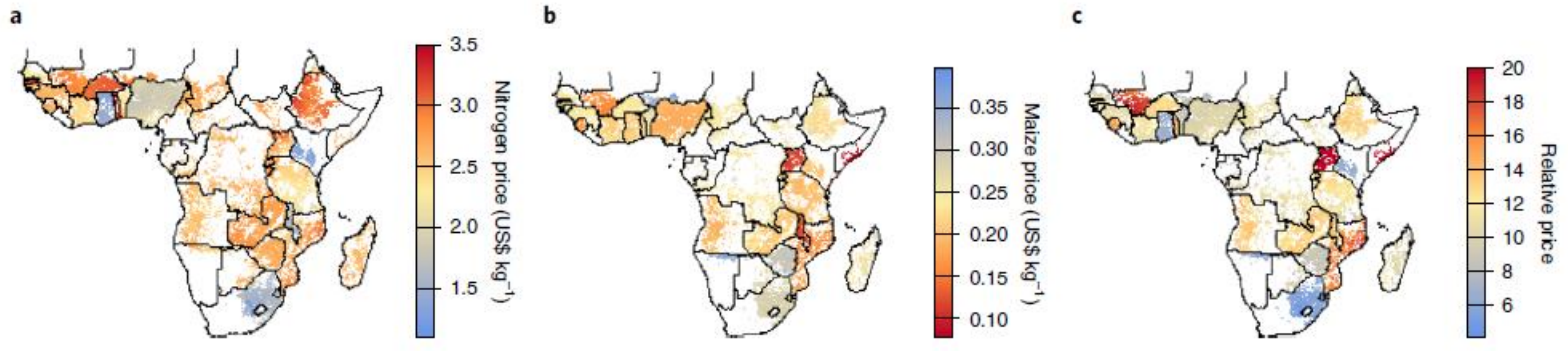


Fig. 2 | Spatial variation in prices in SSA. a, Nitrogen price (US$ kg^{-1}) in urea fertilizer. **b**, Maize price (US$ kg^{-1}). **c**, Relative price (nitrogen price/maize price).

Bonilla Cedrez et al., 2020. Spatial variation in fertilizer prices in Sub-Saharan Africa. *PloS one*, *15*(1), p.e0227764.
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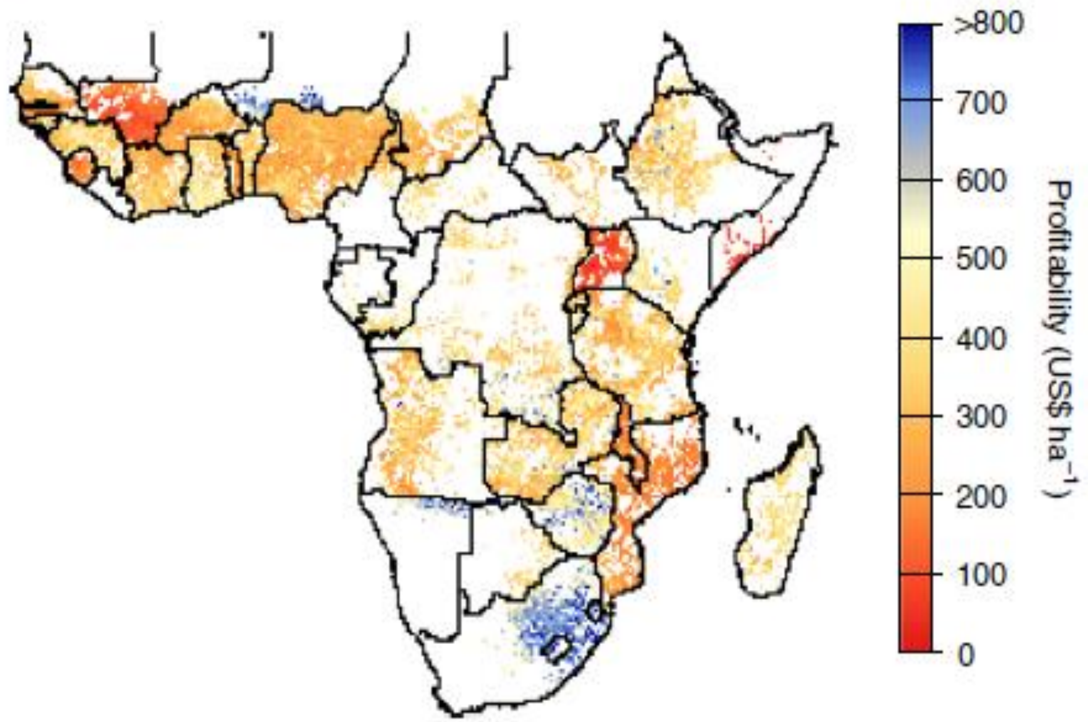
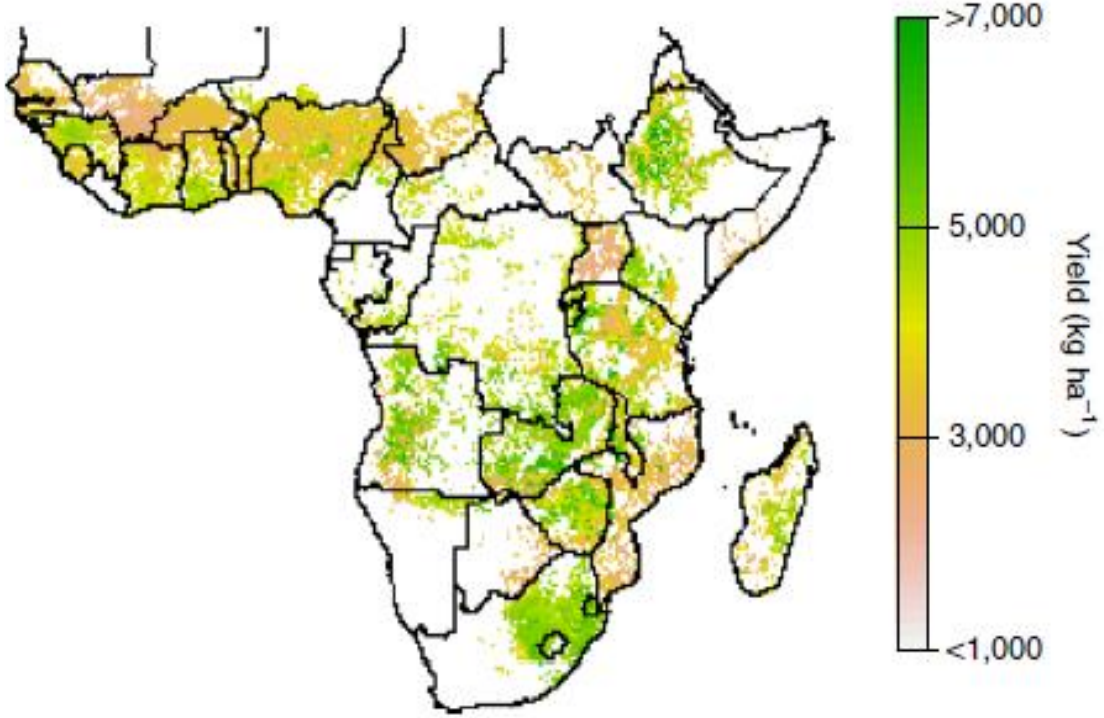
Maximum profitability



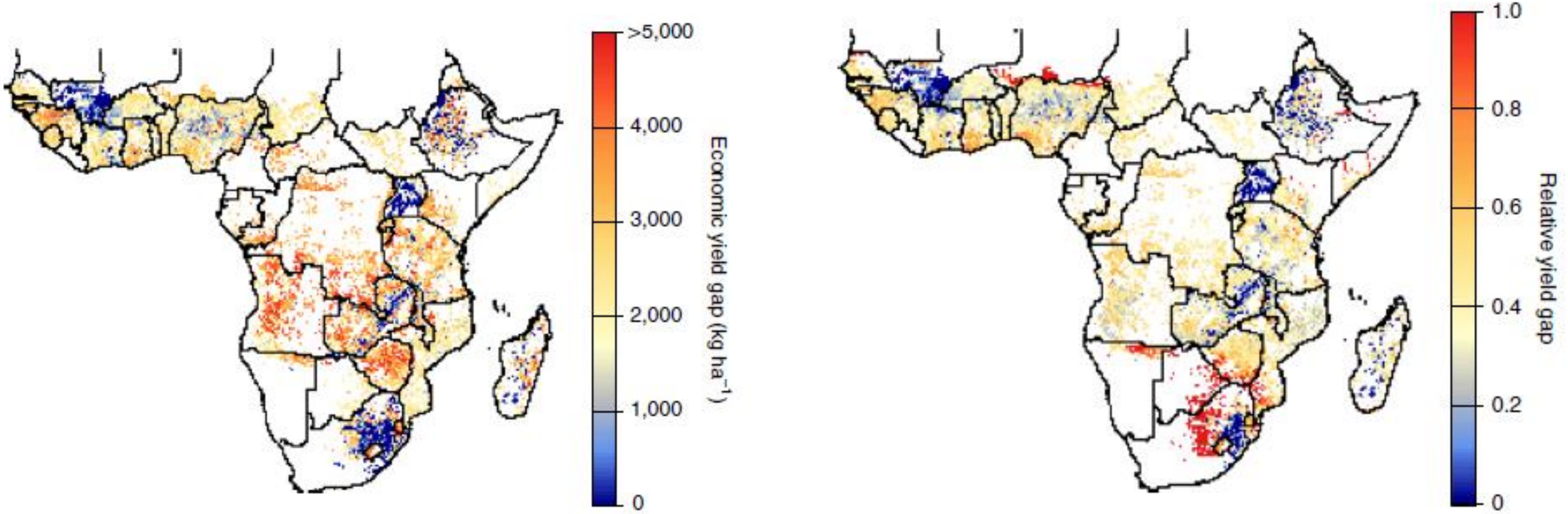
Maximum profitability*



Maximum profitable yield*

*Empirical model

Economic yield gap = (Max prof yield – Actual yield)



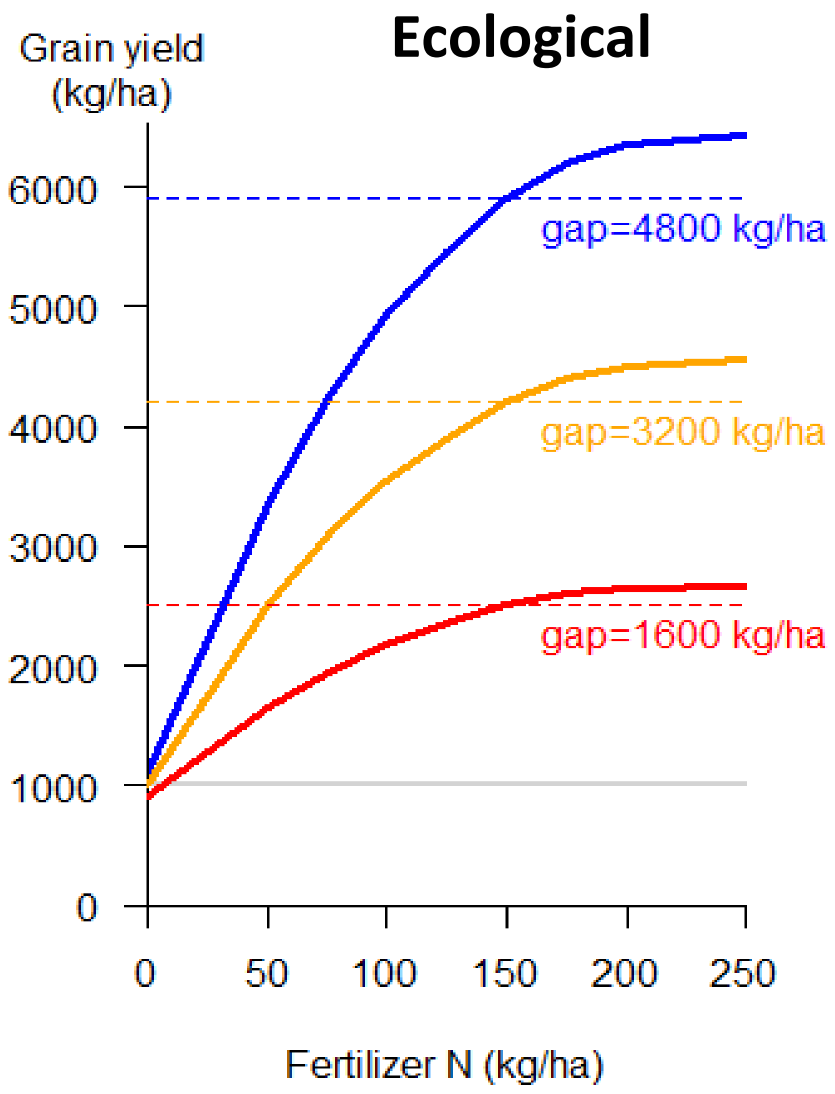
Economic yield gap*

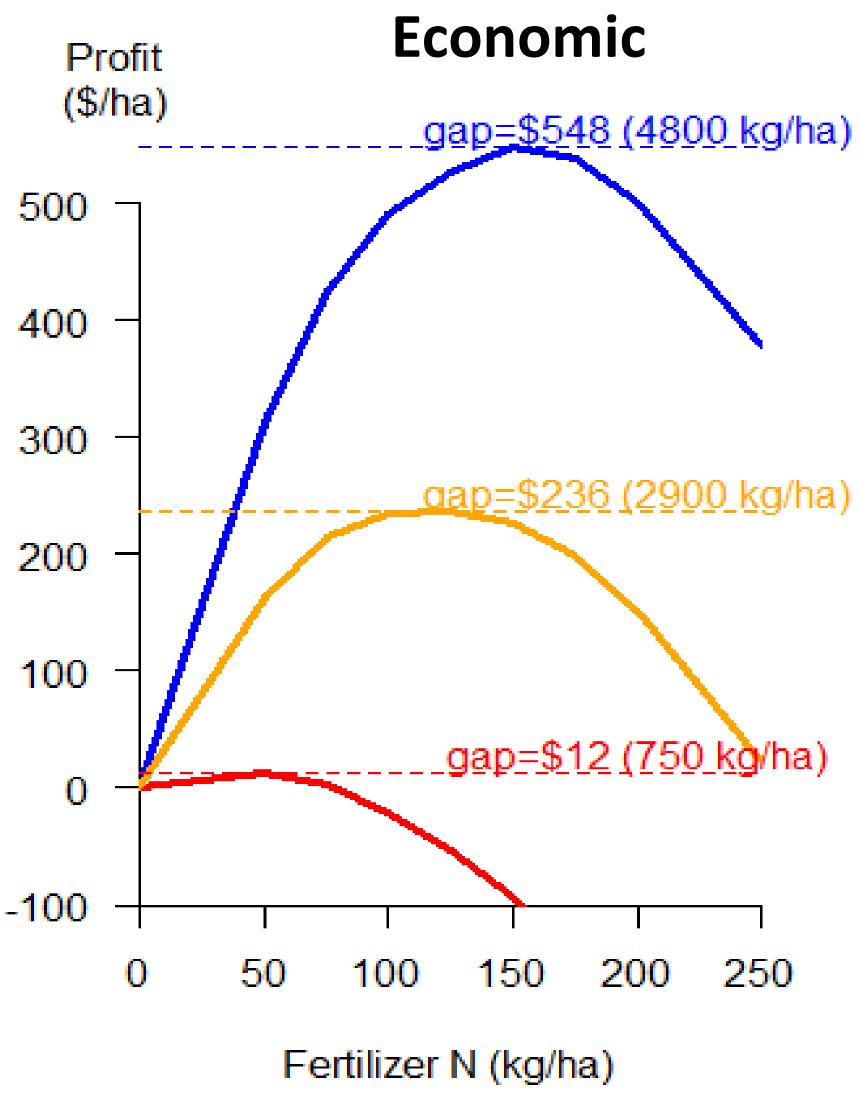
Relative ecological yield gap*

Avg fertilizer: 72-93 kg ha^{-1} | Avg Economic yield gap 27% of the Ecological yield gap

*Empirical model

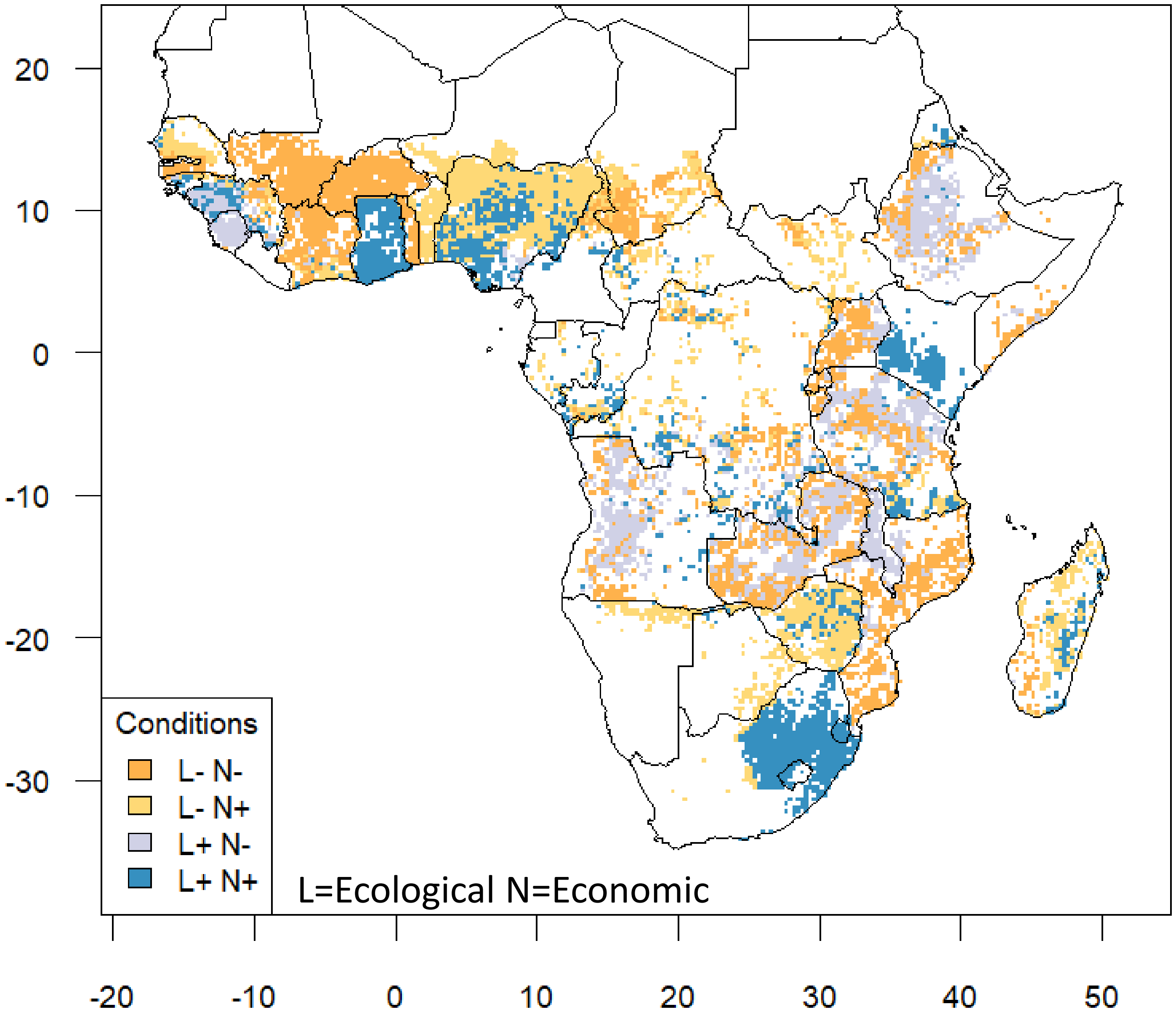
Hypothetical scenarios





Maize price: $0.20 kg | N price: $2.50 kg

Zonification for fertilizer use



Discussion

- **Differences between models**
  - Accurate fertilizer response models
  - Biology-guided empirical learning models
  - Open data sources

- **Price**
  - National average
  - ‘Last-mile’
  - Other constraints
  - Risk

Discussion

- **Spatially targeted fertilizer recommendations**
  - NUE vary between 5 and 53 kg grain per kg N applied.
  - Varied geospatial response of maize to fertilizer, is further nuanced by prices.
  - Farmers could double maize yields in many areas, but the economic incentives may be weak.

- **Ecological + Economic yield gaps**
  - Yield gap analysis is practical to evaluate agronomic performance. But include economic implications.
  - Comprehensive evaluation of fertilizer use in terms of agronomic performance and economic implications.

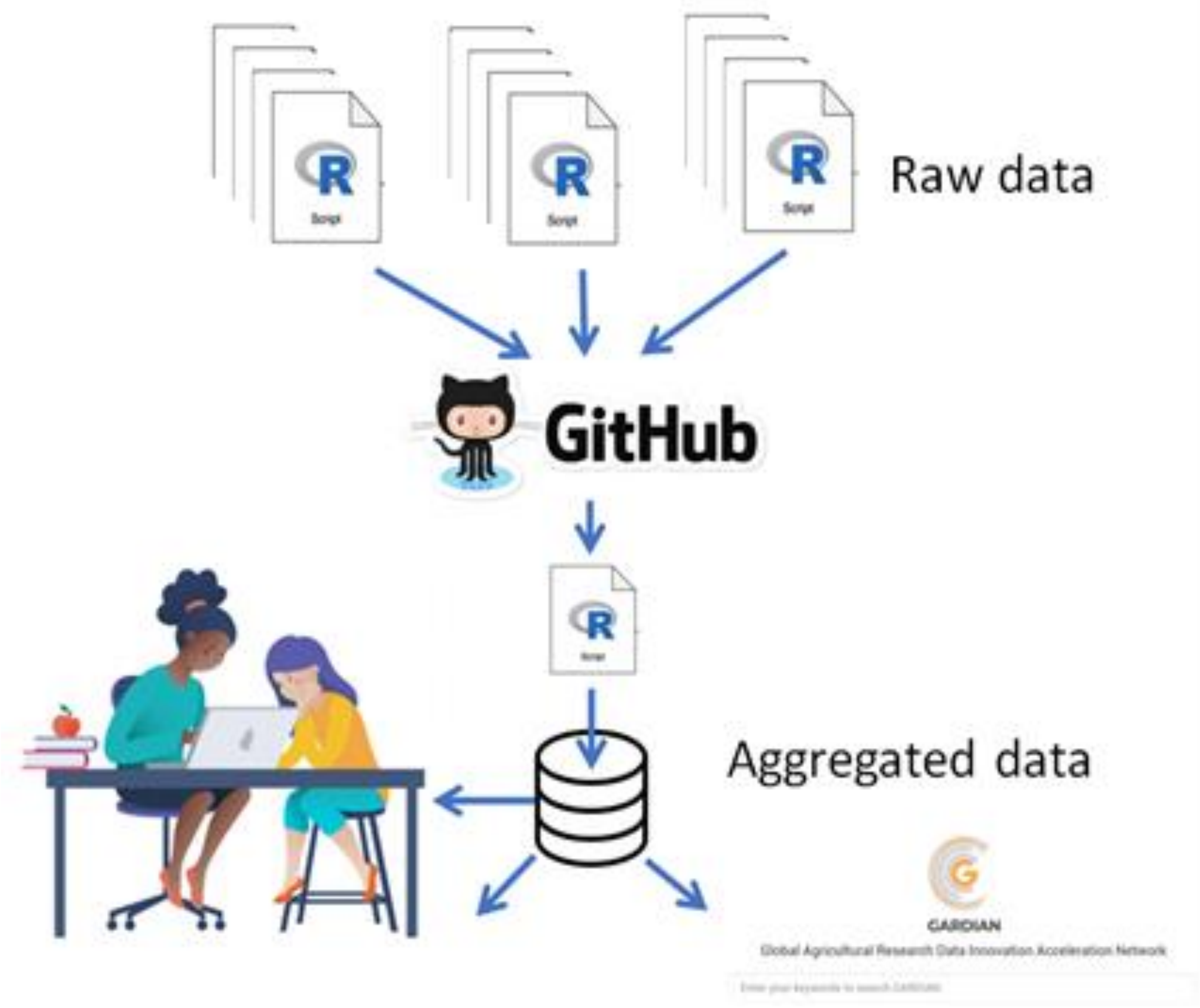
Discussion

- **Obvious point**
  - Best place for fertilizer: high fertilizer use efficiency + low fertilizer/grain price ratio.
  - To sell fertilizer: (i) identify promising places, (ii) deliver cheap appropriate products (quality assurance).
  - Large areas where NUE is low + fertilizer prices are not right → uphill battle, especially for a cheap food crop.
  - Spillover benefits → establish a good fertilizer market for cash crops, and food crop production in the same regions could benefit as well.

Discussion

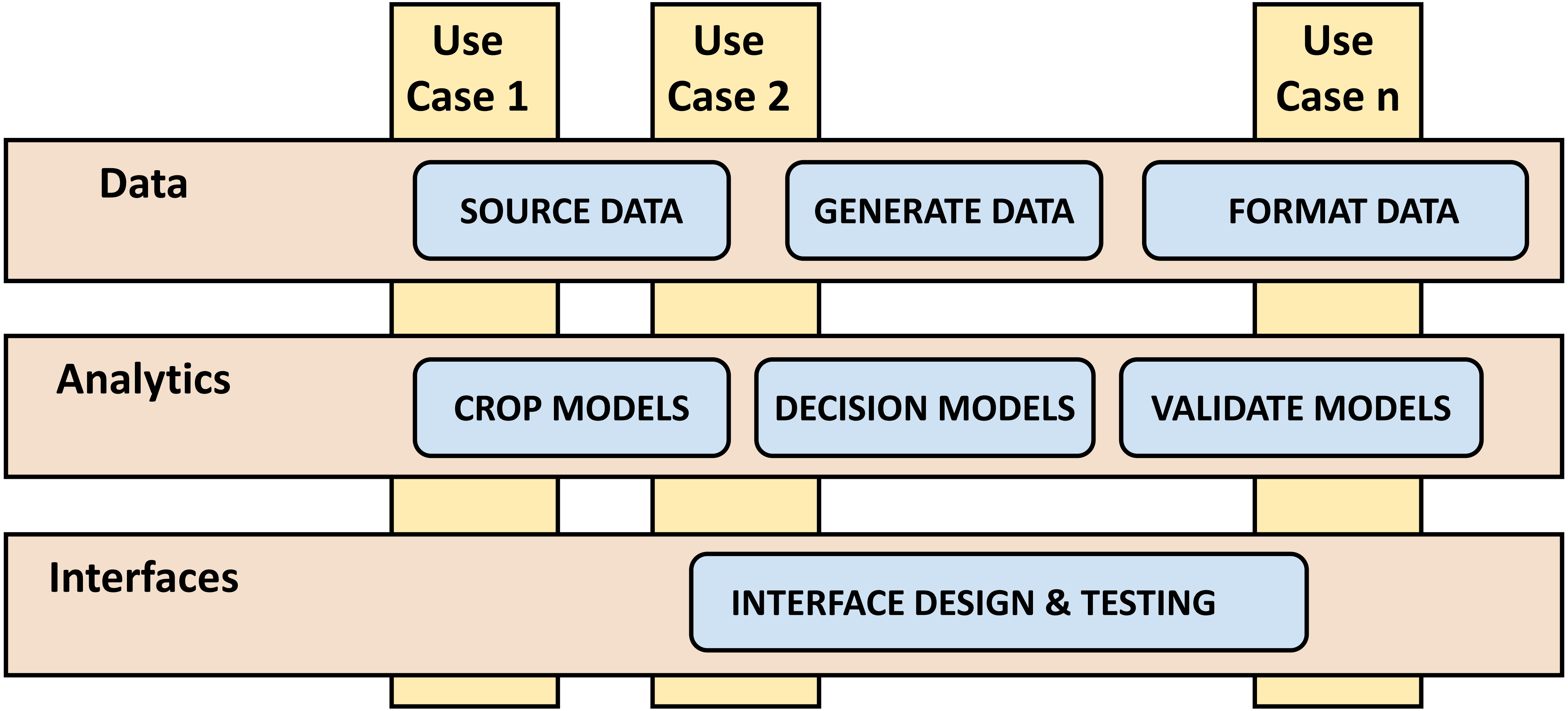
- **Moving forward-Agronomic approach**
  - Complementary agronomic approaches to improve soil fertility, lowering the fertilizer cost, and spatial targeting of fertilizer recommendations.
  - Integrated cereal-legume-livestock systems: fix N, tighten nutrient cycles, and minimize losses.
  - Circular approach:
    - Converting non-edible biomass into high-value animal products
    - Builds household capital and increases income → subsidize crop inputs.
    - Retain nutrients and biomass while generating more revenue.
  - Support services to improve farmers' decision making.

Open data - Carob workflow



https://github.com/reagro/carob

New use case model




Thank you for your attention

Cumulative proportion

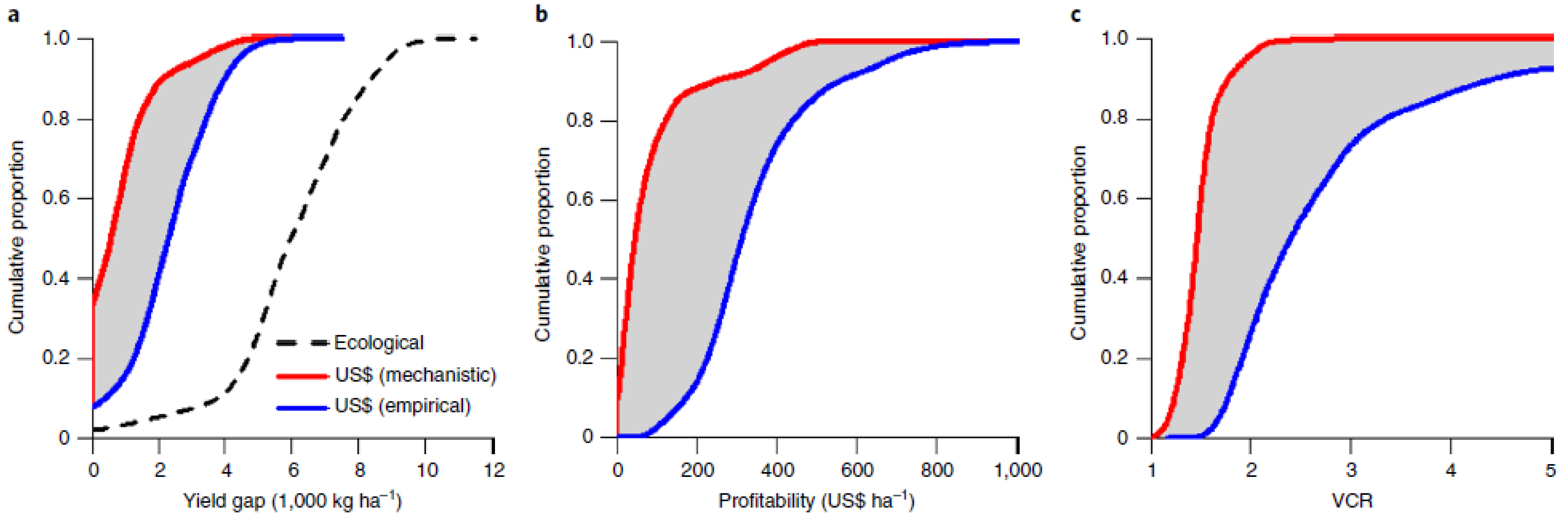


Fig. 5 | Cumulative proportion of the economic and ecological yield gaps, maximum profitability of fertilizer use and the VCR for the most profitable fertilizer use for maize production in SSA. a–c, Cumulative proportion of the economic yield gaps (blue and red lines, representing mechanistic and empirical models, respectively) and the ecological yield gap (black dashed line) (**a**), maximum profitability of fertilizer use (**b**) and the VCR for the most profitable fertilizer use (**c**) for maize production in SSA. The grey shading indicates the area of uncertainty between the empirical and mechanistic models. The VCR was set to 1 if it is not profitable to use any fertilizer.