Yield gap decomposition to identify limiting factors to production in farmers' fields

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Introduction

1. Growing interest in identifying causes behind yield gaps in the context of global food security and resource-use efficiency
2. Increasing availability of spatially explicit farmer field data (yield and management) and environmental data
3. Prioritization of research and development efforts based on the most limiting practices to crop production

Objective: Review the state-of-the-art methods and approaches for yield gap decomposition and delineate minimum data requirements for their implementation with on-farm data.

Yield gap analysis

- A means to unpack the relative contribution of growth-defining, -limiting, and -reducing factors to actual farm yields (van Ittersum & Rabbinge, 1997).
- Important to delineate how much food can be produced on the planet…
- …and to identify which interventions are need to raise actual yields closer to (water-limited) potential yields.
- At the core of the paradigm of sustainable intensification, together with improvements in resource use efficiency.
- Often biophysical, but increasingly considering management and socio-economic factors as means to derive policy recommendations.

1. Yield ceiling indicating the maximu
2. Field-specific farm yields and mana
3. A means to disentangle the yield g

farm yields in relation to M x E inte

Points #1 and #2 largely addressed by

Point #3 is the focus of this review

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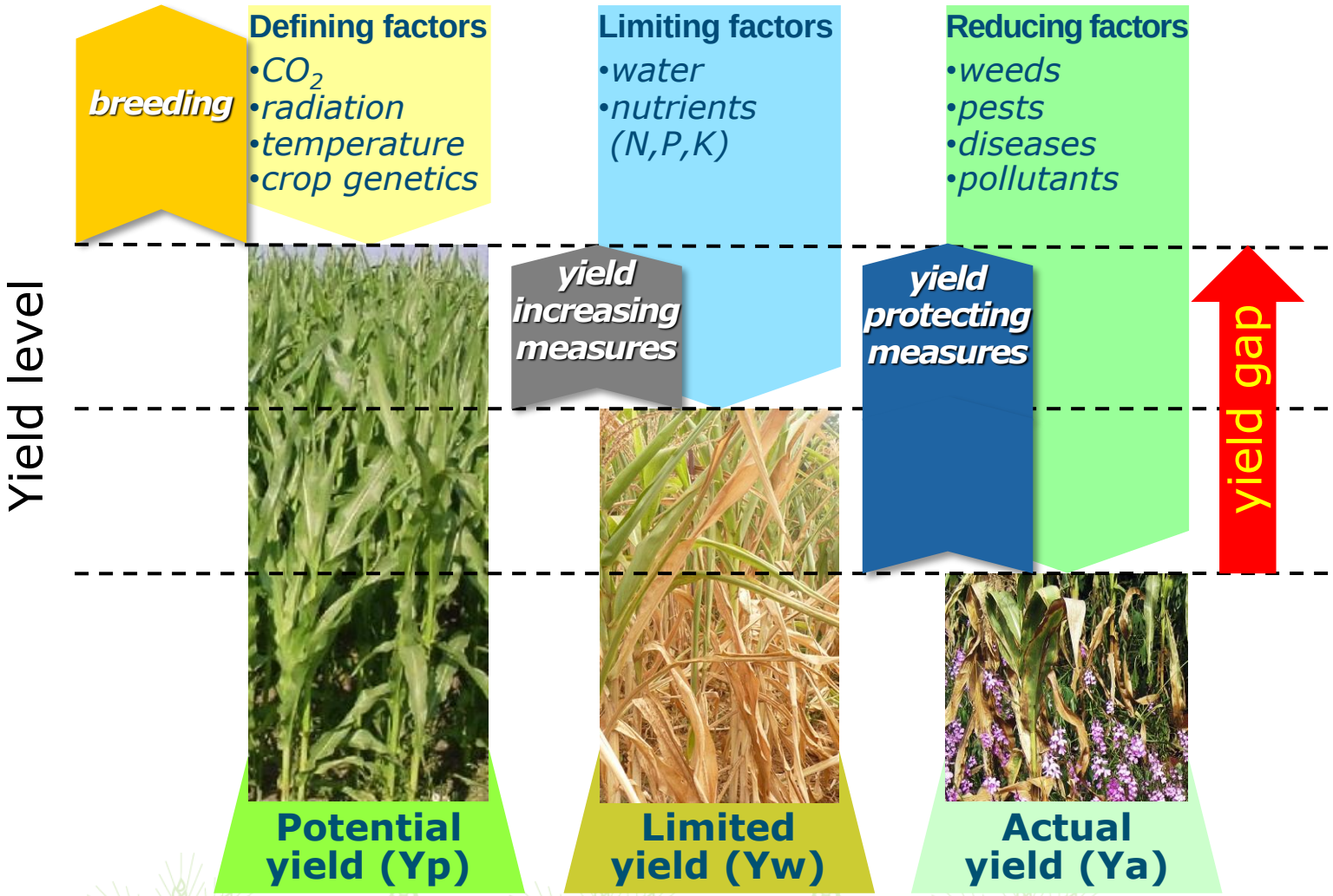
Concepts of production ecology



van Ittersum and Rabbinge (1997, FCR)

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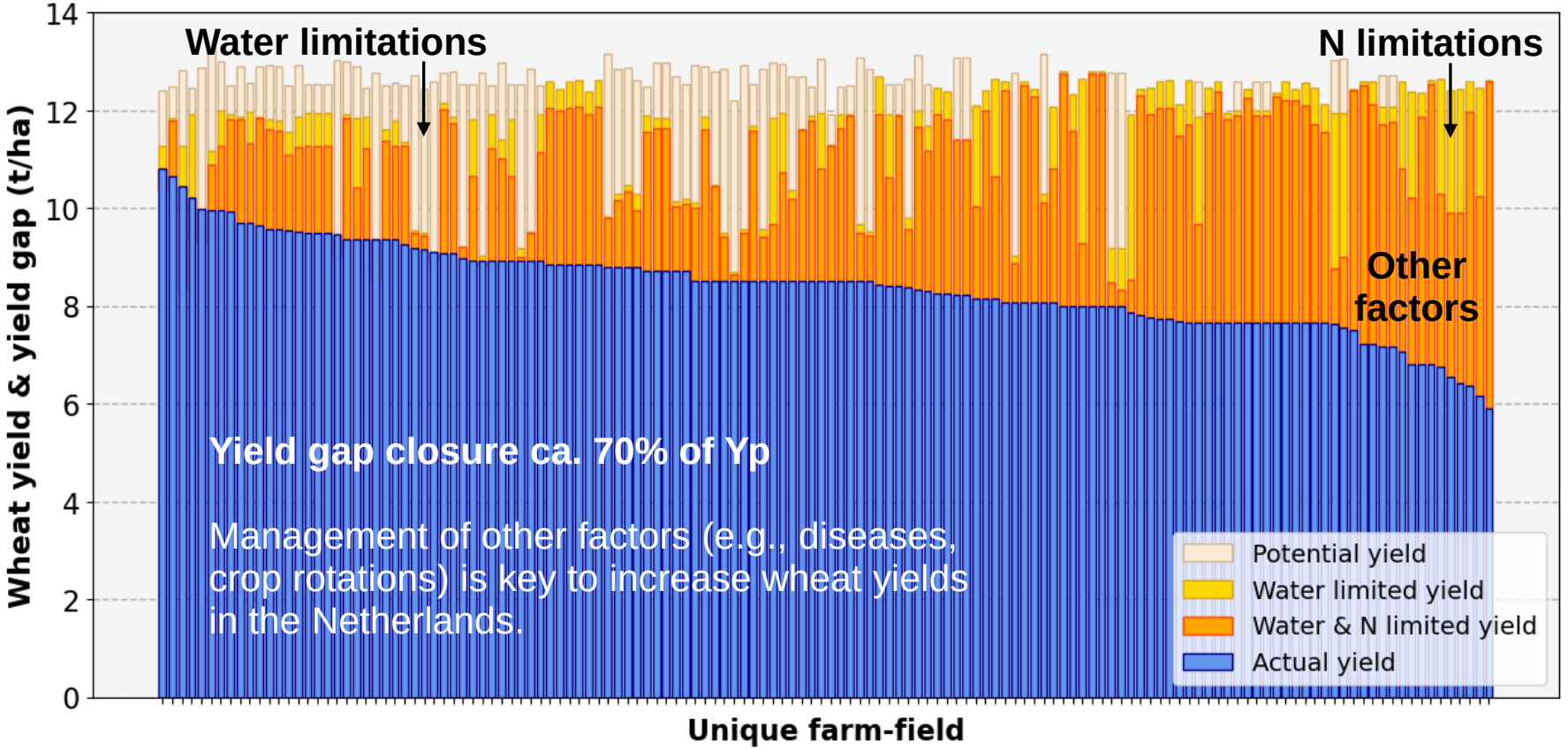
Process-based crop models

1. Simulation of different yield levels
2. Simulation of different management practices

Simulation of yield levels

- **Winter wheat crops in the Netherlands**:
  - High-yielding crop, due to high input use and intensive management
  - Important in the rotation to ensure high-yields of tuber/root crops

Simulation of yield levels



Berghuijs, Silva et al. (in preparation)

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Simulation of management practices

Myanmar
Ayeyarwady Delta

Indonesia
Java

Thailand
Chao Phraya

Vietnam
Mekong Delta

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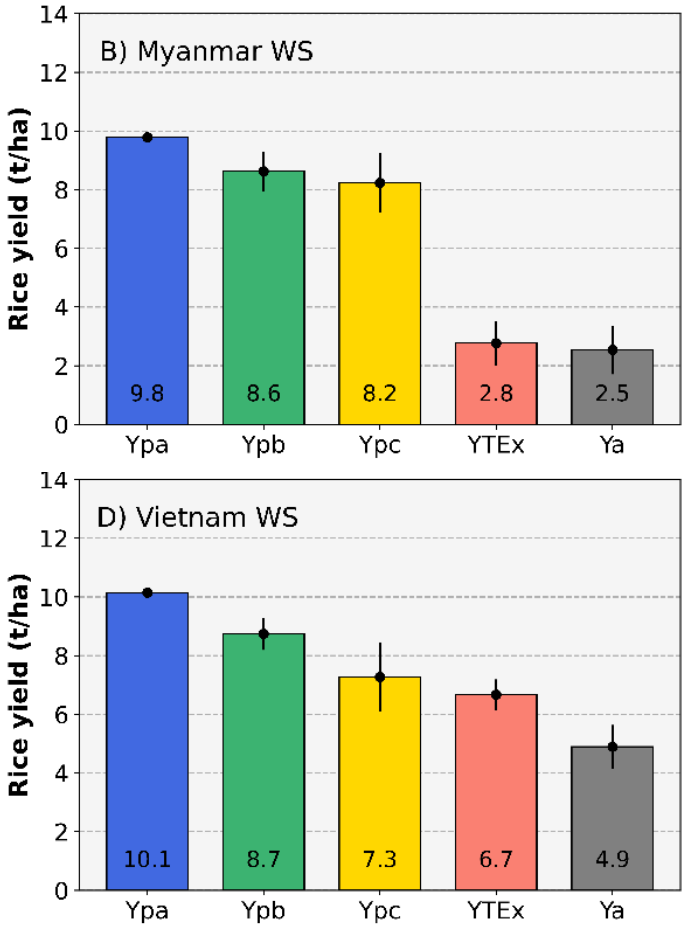
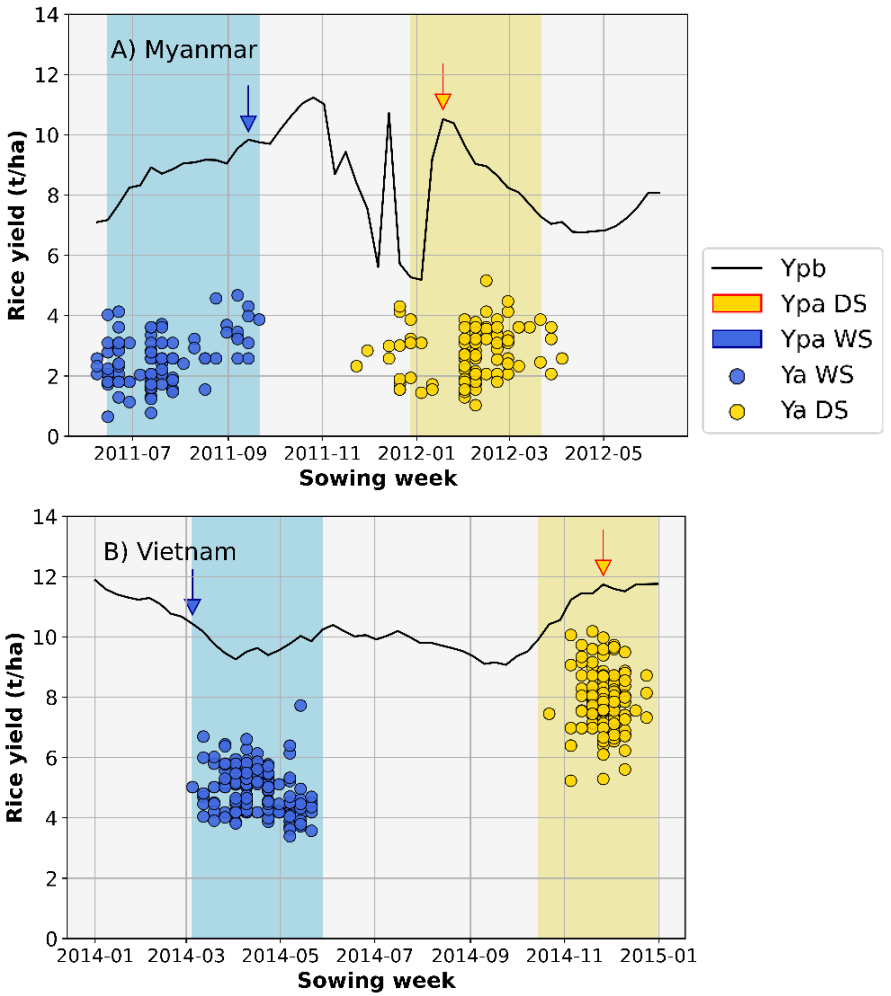
Simulation of management practices





Silva et al. (2022, AgSys)

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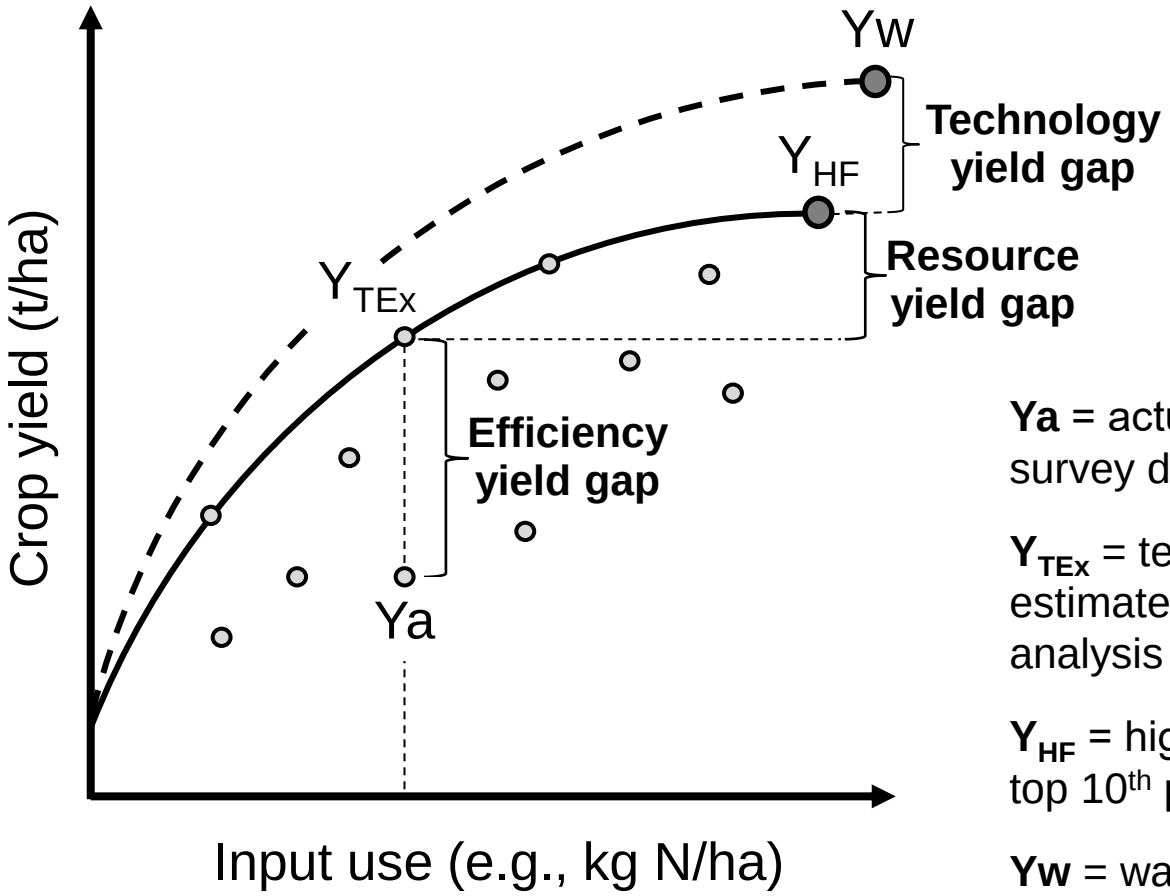
Data-driven approaches

1. Stochastic frontier analysis
2. Boundary line analysis
3. Machine learning

Stochastic frontier analysis



Ya = actual farmers' yields from farm survey data

Y_{TEx} = technical efficient yields estimated with stochastic frontier analysis

Y_{HF} = highest farmers' yields based on top 10th percentile of Ya

Yw = water-limited potential yield from crop models

Silva et al. (2017, EJA)

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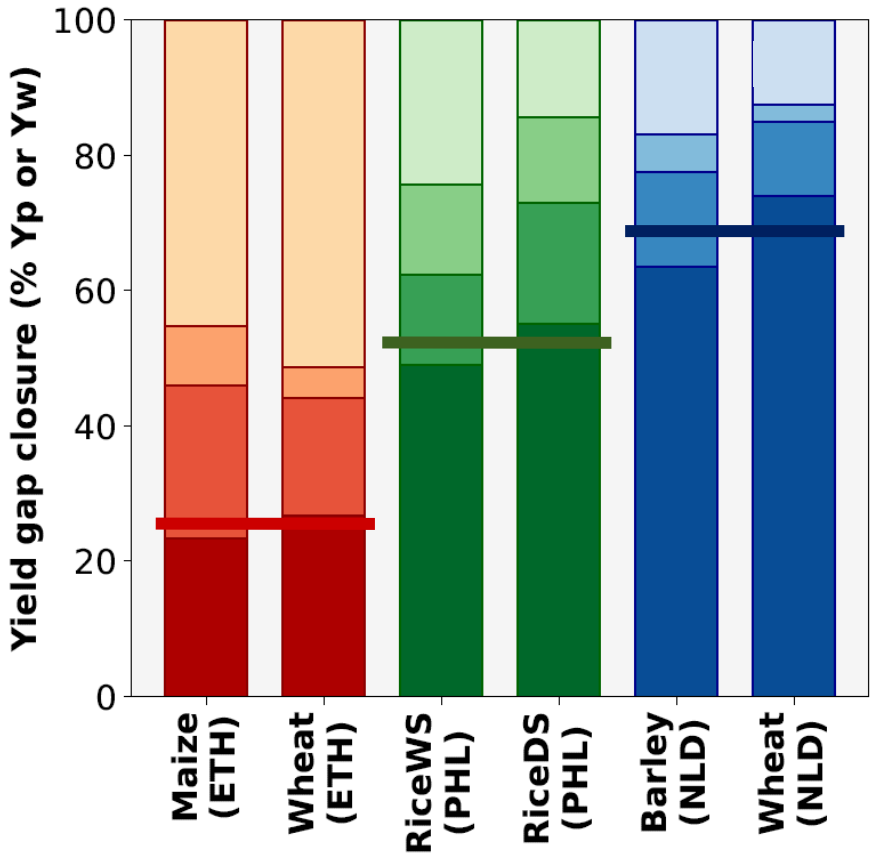
Stochastic frontier analysis



Southern Ethiopia

Large yield gap attributed to technology yield gaps.

Silva et al. (AgSys, 2019)

Central Luzon, Philippines

Medium yield gap due to efficiency, resource and technology yield gaps.

Silva et al. (2017a, EJA)

The Netherlands

Small yield gap attributed to efficiency yield gaps.

Silva et al. (2017b, AgSys)

Silva et al. (2021, GFS)

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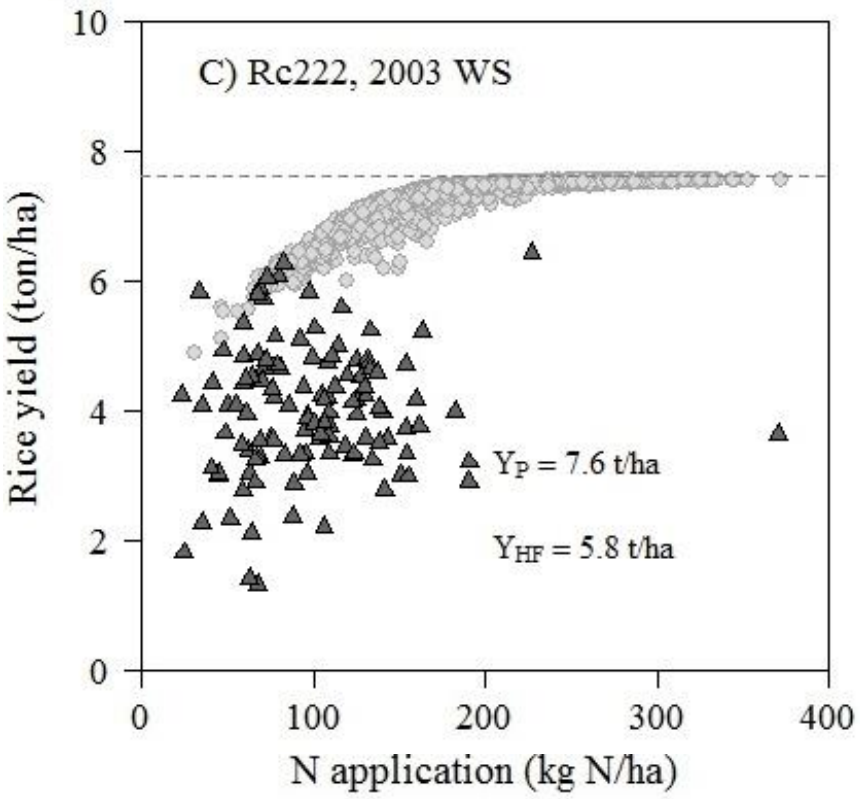
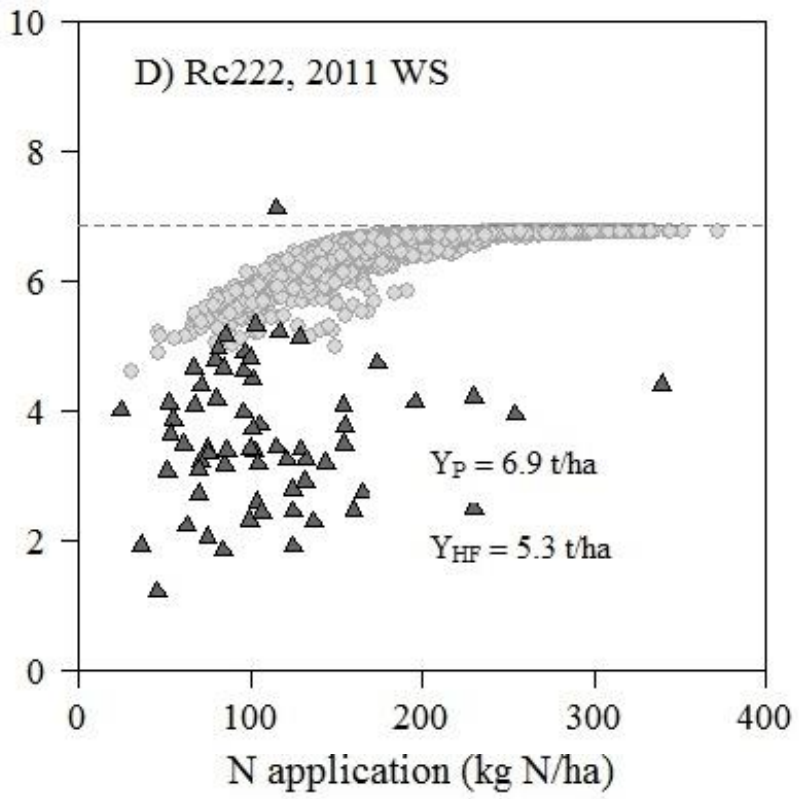
Stochastic frontier analysis





Silva et al. (2017, EJA)

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Boundary line analysis

Machine learning

Tree-based methods: CART and random forest – interface between complexity and interpretability

Most to explain yield variability so far but can also be used for YGD if used to predict stepwise yield increments from most important variables. Not tried to date though, so good test case is needed.

Just an example but there are many others:

Contents lists available at ScienceDirect

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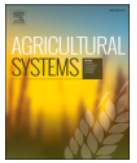

Coupling landscape-scale diagnostics surveys, on-farm experiments, and simulation to identify entry points for sustainably closing rice yield gaps in Nepal

Krishna Prasad Devkota [a,*], Mina Devkota [b], Gokul Prasad Paudel [c], Andrew James McDonald [d]

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[b] International Center for Agricultural Research in the Dry Areas (ICARDA), Rabat, Morocco
[c] International Maize and Wheat Improvement Center (CIMMYT), Botany Division- NARC, Khumaltar, Kathmandu, Nepal
[d] Soil and Crop Sciences, School of Integrative Plant Science, Cornell University, Ithaca, NY, USA

Future applications

- Standard database of farm practices for M x E across global South
- More investments in delineation of environmental units
- Minimum data requirements for different methods
- Move from data analysis to practice
- Cheaper, faster and standardized methods
- Web-based one stop resources for YGD
- Do we need new methods, better data, or both?
- Link with crop physiology (zooming in) and farm(ing) systems (zooming out)
- Other ideas?

- Prioritization of research and development efforts
- Prioritization of investments
- Informing national policies (e.g., Ethiopia's MoA)
- Measurement/evaluation of agronomic gains (KPIs)

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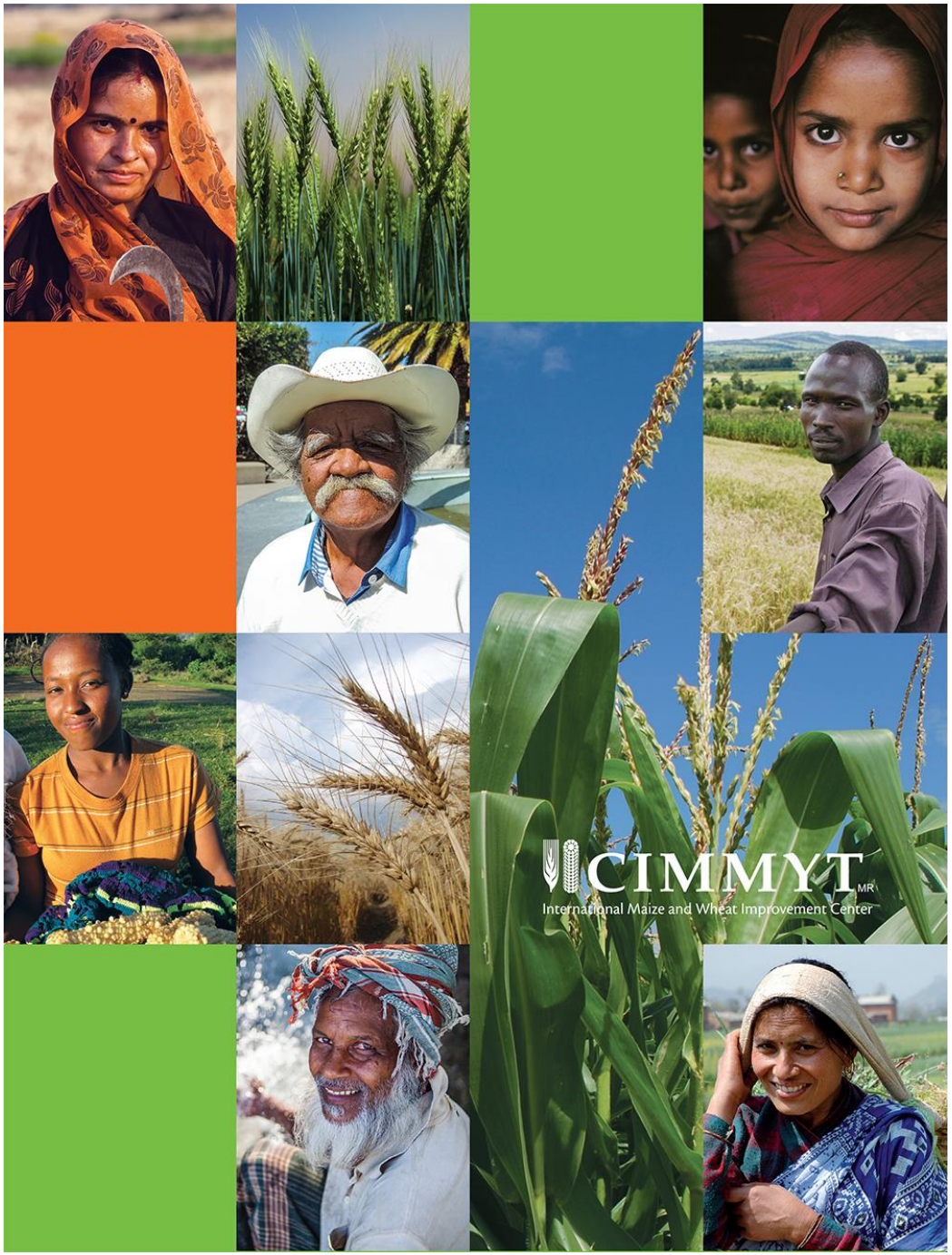

Thank you for your interest!