Closing the yield gap under uncertain weather

A risk analysis of cropping system intensification in family agriculture of the tropics.

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Cerrados: savannah biome of Brazil
200 Mha
Annual Rainfall 1200 – 2000 mm

A Case Study in Central Brazil
• Agrarian revolution from subsistence to dairy farms within a decade
• Net income per worker / minimum legal salary:
  – 1992 subsistence farms: 0.2 - 0.5
  – 1999, dairy farms: 2.0 – 4.0

Possible causes of blue trajectories:
• Risk aversion of farmers?
• Distance to market?
• Access to bank credit?
• Constraining biophysical environment?
A high yield variability

Yield simulated using STICS (Ton.ha⁻¹)

Plots of preliminary validation

1:1 line

plots of the survey in farmers fields

Y₀

part of yield gap due to stand(RG), water or N

part of yield gap due to constraints other than stand(RG), water and N
Results of agronomic diagnosis

- Environmental constraints
  - drought periods combined with low AWC in soils and/or Al limited root growth
    - water stress (W)
  - stony topsoil on sloppy terrain
    - low stand density at emergence (D)
  - low organic N in soils after continuous low input, low restitution cropping >20 years
    - N stress (N)
  - full « seed bank » of weeds
    - weed competition (H)

- technical management constraints
  - poorly maintained collectively owned farm machinery (D, W, N, H)
  - poor availability of c.o. farm machinery (D, W, N, H)
  - farm level constraints on cash and labour limiting availability of mineral N, improved seeds, labor force at weeding (D, W, N, H)
• Stics modified into Stics-facb, accounting for:
  – [Al]/CEC limiting root growth
  – weeds competing with maize for Rg, Water, N

![Simulated vs. observed yield comparison using Stics_facb](image-url)
Assessment of environmental constraints to yield increase: a virtual experiment.

- simulation scenarios = management types x soil types x 21 years series of weather data
- all CS: soil tillage using tractors owned and managed by associations of 10 to 50 farmers, horse drawn weeding.
  - Ecs: horse drawn sowing, 3 pl.m-2, 15kg N.ha-1, low HI cultivar
  - IcsR: tractor drawn sowing, 5 pl.m-2, 70kg N.ha-1, soil limed to correct Al toxicity, top HI cultivar, optimal timing of management (plowing, sowing, weedicings)
  - IcsI: poorly mastered intensive management: = IcsR but random values (within intervals) for dates of plowing sowing and weeding, sowing depth and density) accounting for inadequate rules in management of collectively owned machinery.
Y0, Potential Yield
improved cultivar locally proposed by extension services, sown at optimal density and most practiced sowing date, as simulated by Stics when all stress functions de-activated i.e. determined by T and RG
Yw: Water limited Yield

As Y0 + water stress functions activated and accounting for soil water storage characteristics, daily rainfall distribution, root growth without pedologic limitation
YEcs: Yield under extensive cropping system
local cultivar with low HI, N fertilization, weed control, sowing t
density and date all according to local practice in Extensive CS.
Simulated using Stics-facb (water, Nitrogen, Al, weeds).
YlcsR: Yield under well mastered intensive cropping system
improved cultivar, sowing date and density as in Y0, N A1 and weed managements as best local practice of intensive CS. Simulated using Stics-facb (water, Nitrogen, Al, weeds).
Simulated Yield (Mg ha$^{-1}$)

- Potential (improved cultivar)
- Water limited (SWC in Root zone=180mm)
- Water+N+[Al]+Weeds limited, Ecs

YIcsl: Yield under poorly mastered intensive cropping system
Same as YIcsR, but with less optimal sowing date and density, and weed control accounting for inadequate management of farm machinery.
yield gain expected, well mastered « intensification »

yield gain expected, poorly mastered « intensification »
Cumulative probability distribution of yield gain between Ecs and Ics

Superficial Cambisol on sloping land with stony topsoil
AWC=105 mm

Deep Latossol on plateau
AWC=180 mm

P(yield increase <=0 when shifting from Ecs to Ics) = 0.2
Cumulative probability distribution of yield gain between Ecs and IcsR and between Ecs and IcsI
Conclusion

- Sound (quantified) local recommendation made possible (farm machinery management by farmers’ associations critical)
- Regional variations in environment may induce variations in risks related to closing the yield gap
- Policy implication:
  - insurance, subsidized inputs may help, policies should account for farm and environment diversity
- Research implication:
  - tools for a better mapping of these risks: crop / farm models; environment databases
  - conception / evaluation of possible risk coping strategies at field / farm levels