

The neglected nutrient? Exploring K limitation to crop yields in the humid tropics

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POTASSIUM LIMITATIONS: WHERE?

- **High-yield crops with large K removal**
  - Oil crops (*e.g.*, soybean: 17 kg K Mg^{-1} grain)
  - Forage crops (*e.g.*, alfalfa: 21 kg K Mg^{-1} DM)
  - Silage crops (*e.g.*, silage maize: 17 kg K Mg^{-1} DM)
  - Cereal systems with straw removal (rice: 3 and 17 kg K per ton of grain and straw, respectively)

- **Soils with low K-supply capacity**
  - Sandy soils
  - Tropical soils
  - K-fixing clays
  - Long history of agriculture

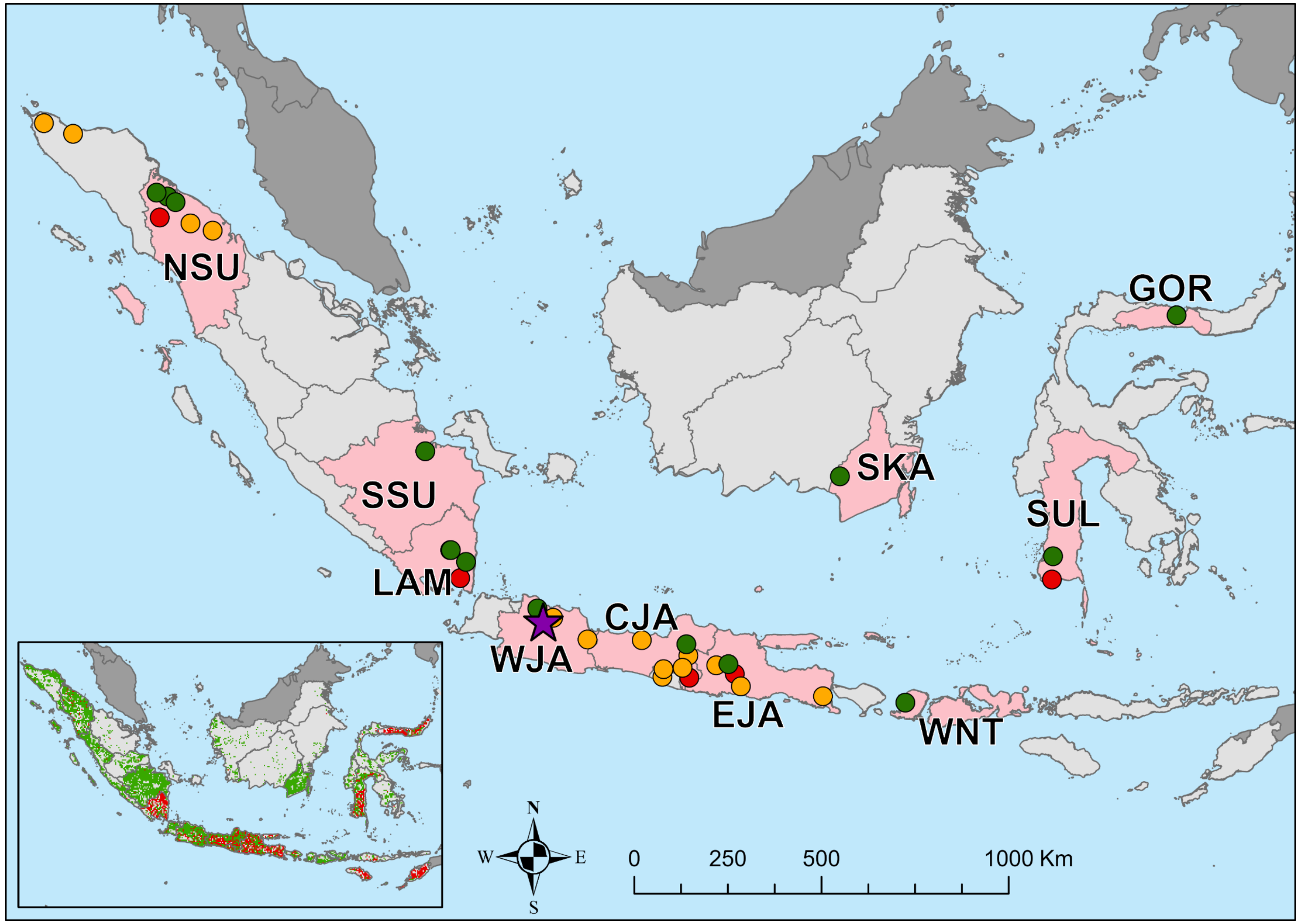
- **Small external K inputs (fertilizer, irrigation water and sediments)**

TODAY’S PRESENTATION

- Showcase K limitation in cropping systems with two case studies from Indonesia:
    - Rice-maize based systems
    - Smallholder oil palm fields
- Introduce project on global assessment of K limitation

CASE STUDY: RICE & MAIZE IN INDONESIA

Our study area accounts for 70% and 50% of national rice and maize area



Databases:

- Farmer field survey data (n=1600) and leaf tissue analysis (n=480)
- Rice (n=172) — on-farm trials (IRRI, IPNI)
- Maize (n=39) — on-farm trials (IRRI, IPNI)
- Long-term rice experiment

BRIN
BADAN RISET
DAN INOVASI NASIONAL

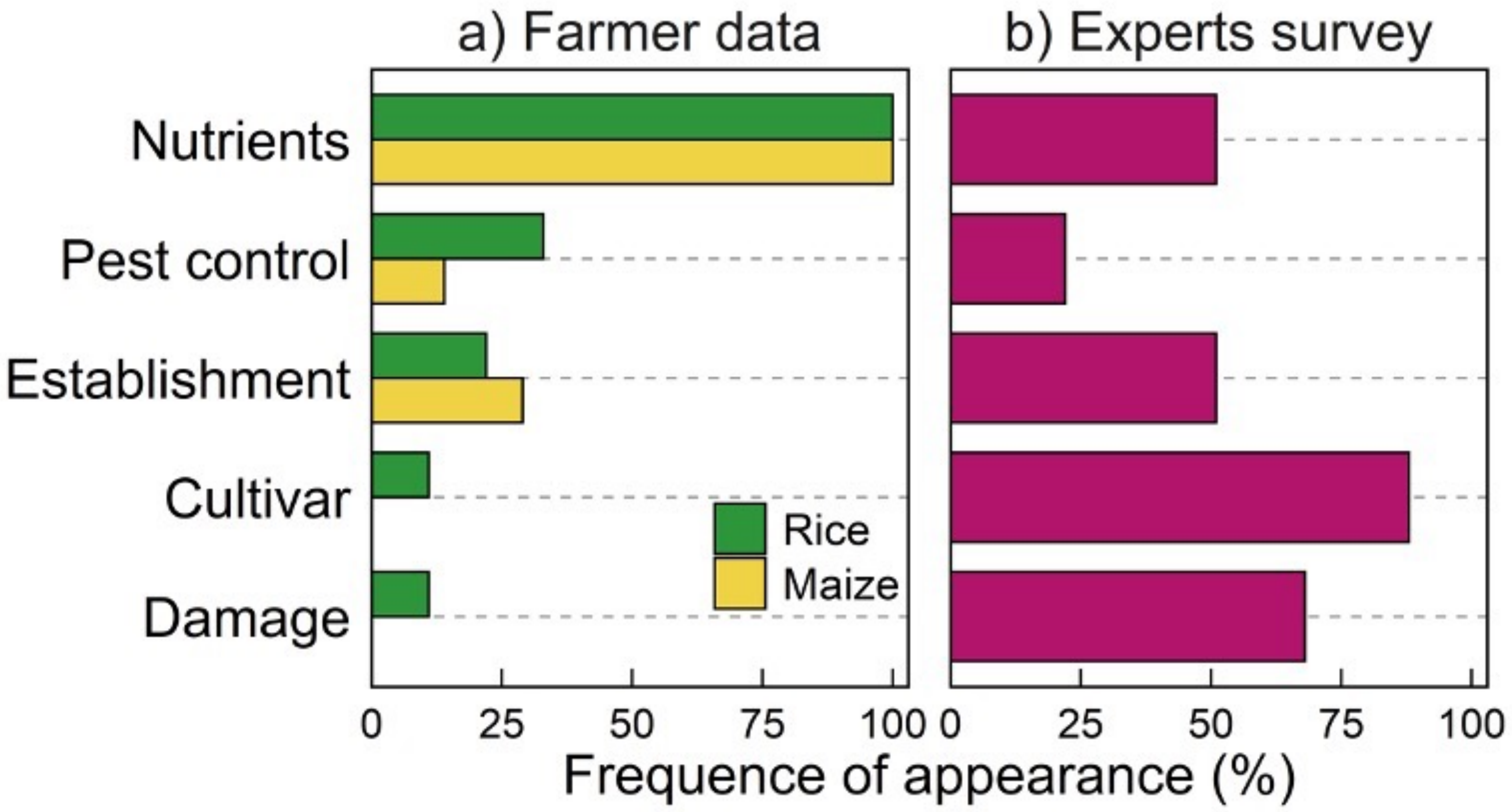
North Sumatra (NSU), South Sumatra (SSU), Lampung (LAM), West Java (WJA), Central Java (CJA), East Java (EJA), West Nusa Tenggara (WNT), South Kalimantan (SKA), South Sulawesi (SUL), Gorontalo (GOR)

Rice-maize systems in Indonesia can include up to three crops per year (average yield: 5-6 t/ha)
Harvest is manual and straw is usually burned or removed from the field after threshing

Photos: P Grassini (C. Java, W. Java, Sulawesi, & Nusa Tenggara)

YIELD CONSTRAINTS: REALITY VERSUS PERCEPTIONS

Comparison of causes of yield gaps as determined *via* analysis of farmer data (left) *versus* those reported as important by local researchers and extensionists (right)



Adapted from Rizzo *et al.* (Field Crops Research, 2023)

FOUR APPROACHES TO ASSESS K LIMITATION

Approach 1 — Calculation of nutrient balances based on farmer survey data

Approach 2 — In-situ nutrient status diagnosis based on leaf tissue analysis

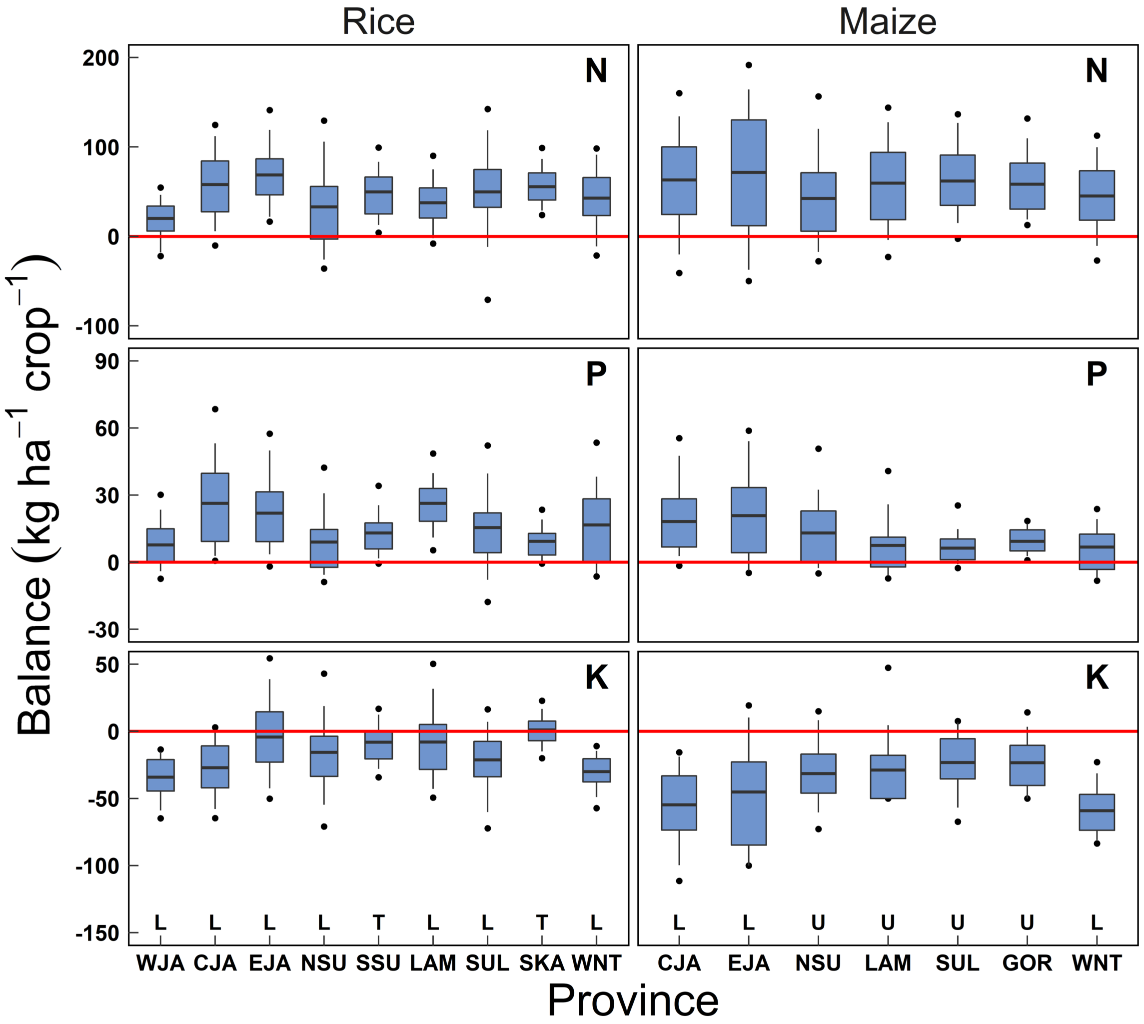
Approach 3 — Analysis of data from long-term fertility experiments.

Approach 4 — Analysis of on-farm fertilizer trials.

Approach 1

ON-FARM CROP NUTRIENT BALANCES

Average N and P balances were positive, but negative for K.

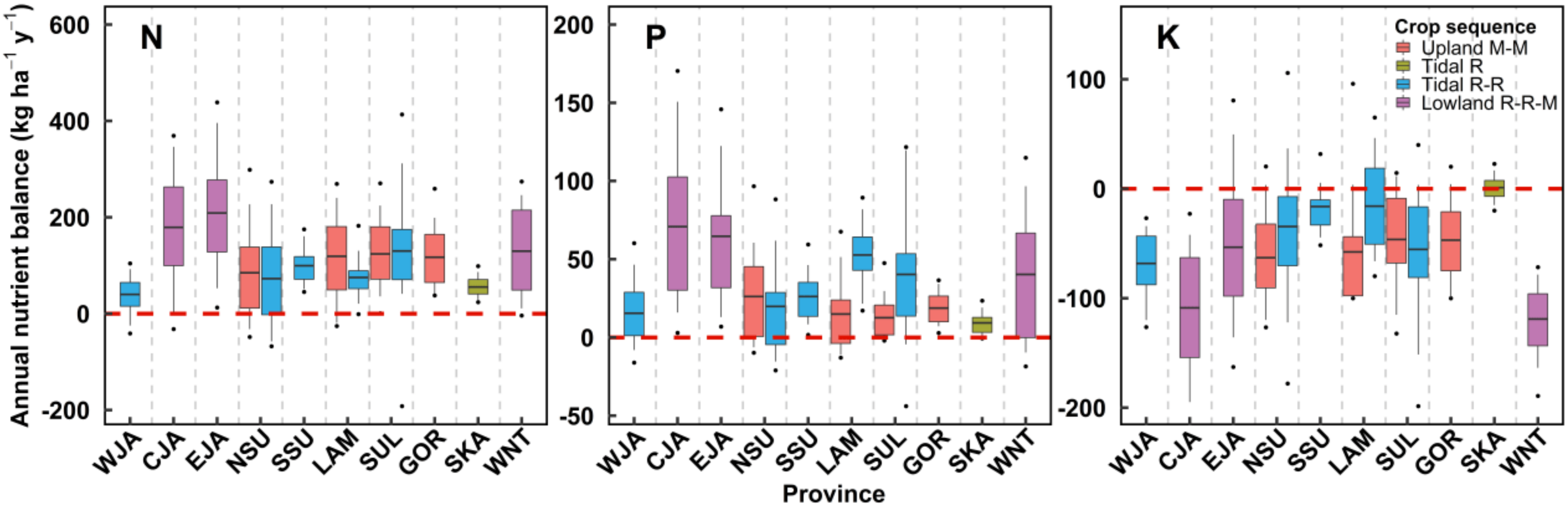


*Nutrient balance estimated as the difference between crop nutrient removal and nutrient inputs (including fertilizer, manure and N fixation in rice) based on survey data collected from 1,600 fields in North Sumatra (NSU), South Sumatra (SSU), Lampung (LAM), West Java (WJA), Central Java (CJA), East Java (EJA), West Nusa Tenggara (WNT), South Kalimantan (SKA), South Sulawesi (SUL), Gorontalo (GOR).

Approach 1

ON-FARM SYSTEM NUTRIENT BALANCES

Large negative annual K balance across all provinces (except low-yield systems)

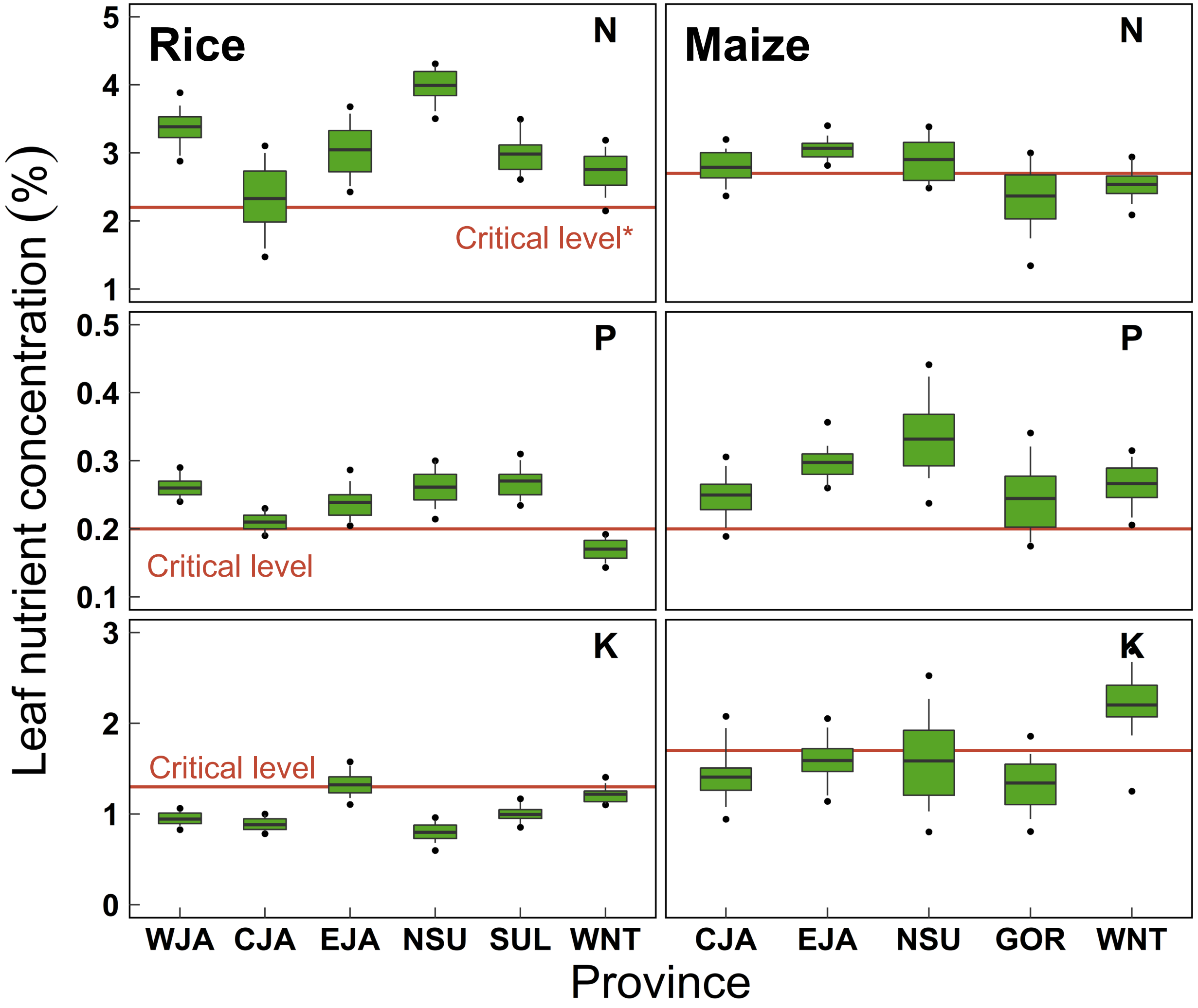


North Sumatra (NSU), South Sumatra (SSU), Lampung (LAM), West Java (WJA), Central Java (CJA), East Java (EJA), West Nusa Tenggara (WNT), South Kalimantan (SKA), South Sulawesi (SUL), Gorontalo (GOR).

Approach 2

ON-FARM CROP NUTRIENT STATUS

Fields were generally sufficient in N&P and deficient in K

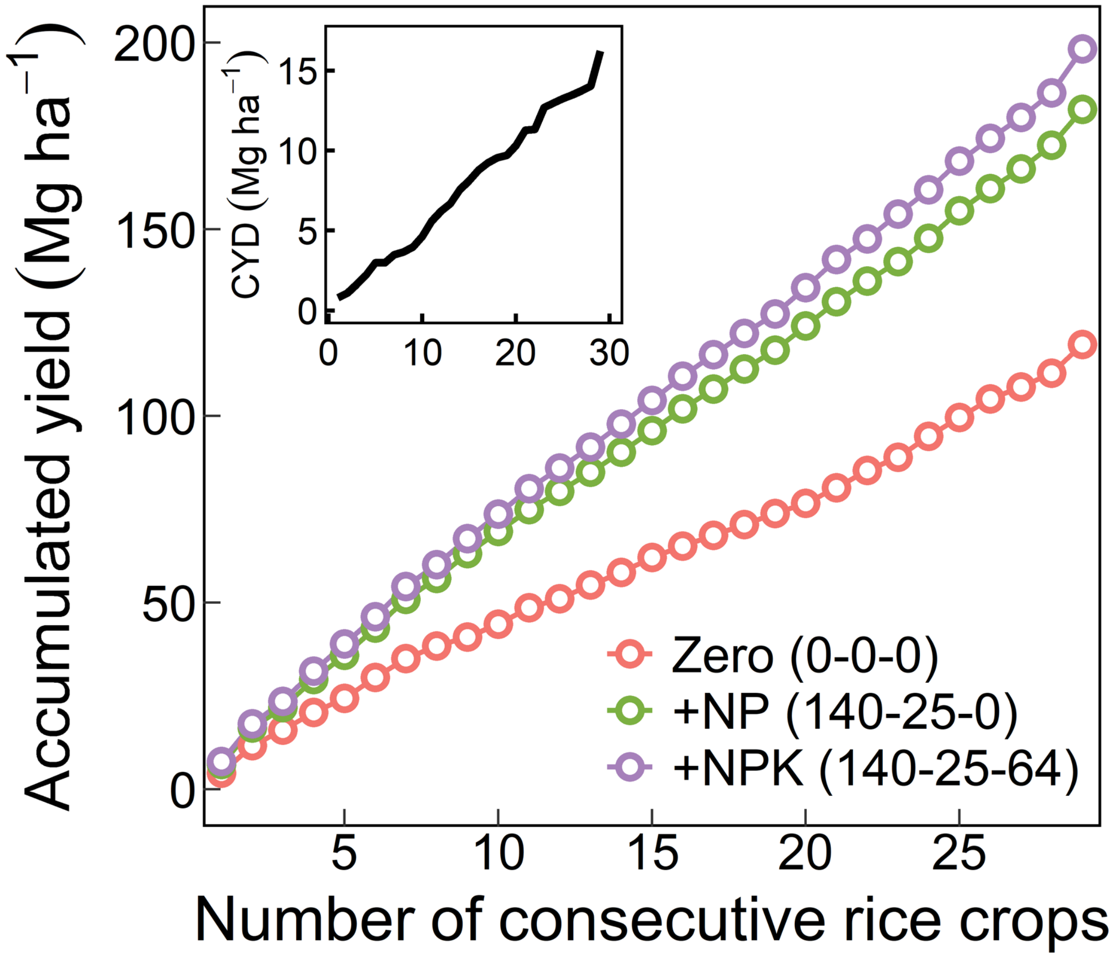


* Based on leaf tissue samples (flag leaf in rice & ear leaf in maize) collected at the beginning of flowering in 480 fields in Indonesia. Critical level established based on our review of 86 articles reporting critical nutrient concentrations for rice and maize

Approach 3

LONG-TERM EXPERIMENTS

Over 29 crop cycles, accumulated yield loss in the K-omission treatment was 16 t/ha (0.55 t crop^{-1})

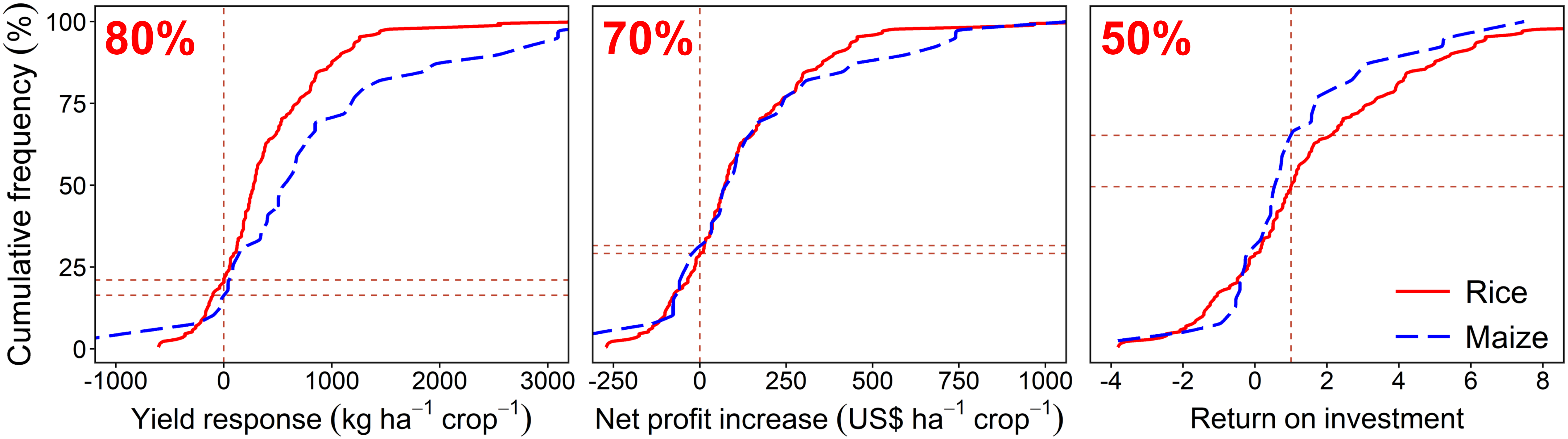


* CYD: cumulative yield difference between +NPK and +NP treatments.

Approach 4

ON-FARM TRIALS

Consistent yield response to K fertilizer, but uncertain return on investment*.



*Based on 172 and 39 on-farm trials in Indonesia. Return on investment (ROI) was calculated as the ratio between net profit increase and K fertilizer cost, using historical average rice and MOP prices. A ROI > 1 is usually desirable to ensure widespread adoption of a technology

ENTRY POINTS TO REMOVE K LIMITATION

- **Identify spatial domains/regions where response to K is more likely.**
  - Based on K in water and sediments, straw management, soil, yield, leaf diagnosis
- **Fertilization based on nutrient balances and yield goals.**
  - Reduce NP rates in fields with large NP surpluses and reinvest on K fertilizer.
  - Partial K maintenance plus episodic larger K applications when profit is high
- **Tuning current fertilizer subsidy programs.**
  - Current programs promote sources rich in NP (urea, ‘phonska’), but poor in K.
- **Changes in harvest and crop residue management**
  - Less likely to be adopted in the short term.

OIL PALM SMALLHOLDERS IN INDONESIA

- Oil palm: 40% global vegetal oil production (Indonesia is #1 producer & exporter)
- 6 millions ha managed by smallholders (2 ha each); large yield gaps (average yield: 40% of potential)
- Efforts to increase yield focus on adoption of better planting material; little interest on better agronomy

PUSAT PENELITIAN KELAPA SAWIT
Indonesian Oil Palm Research Institute

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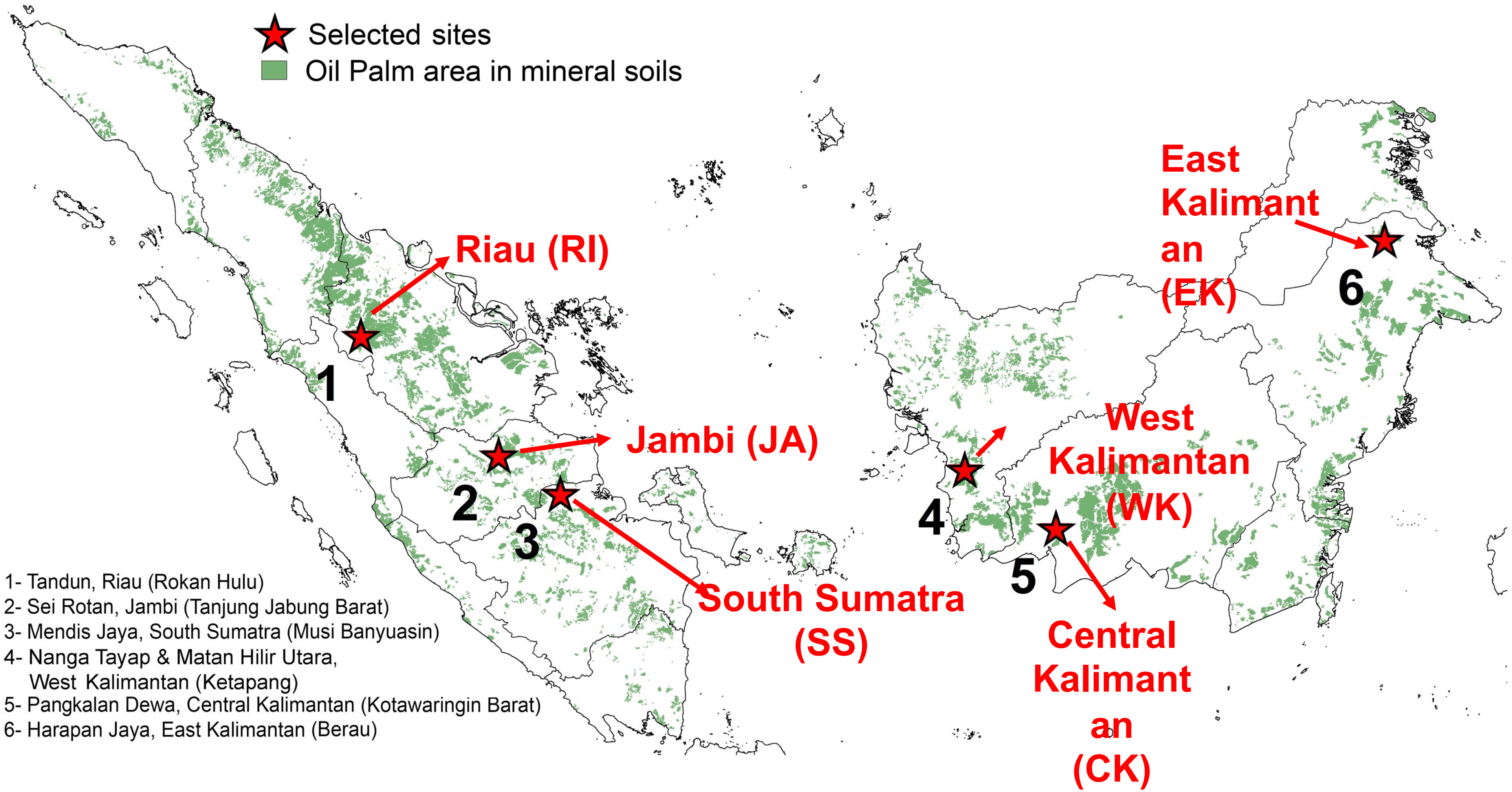
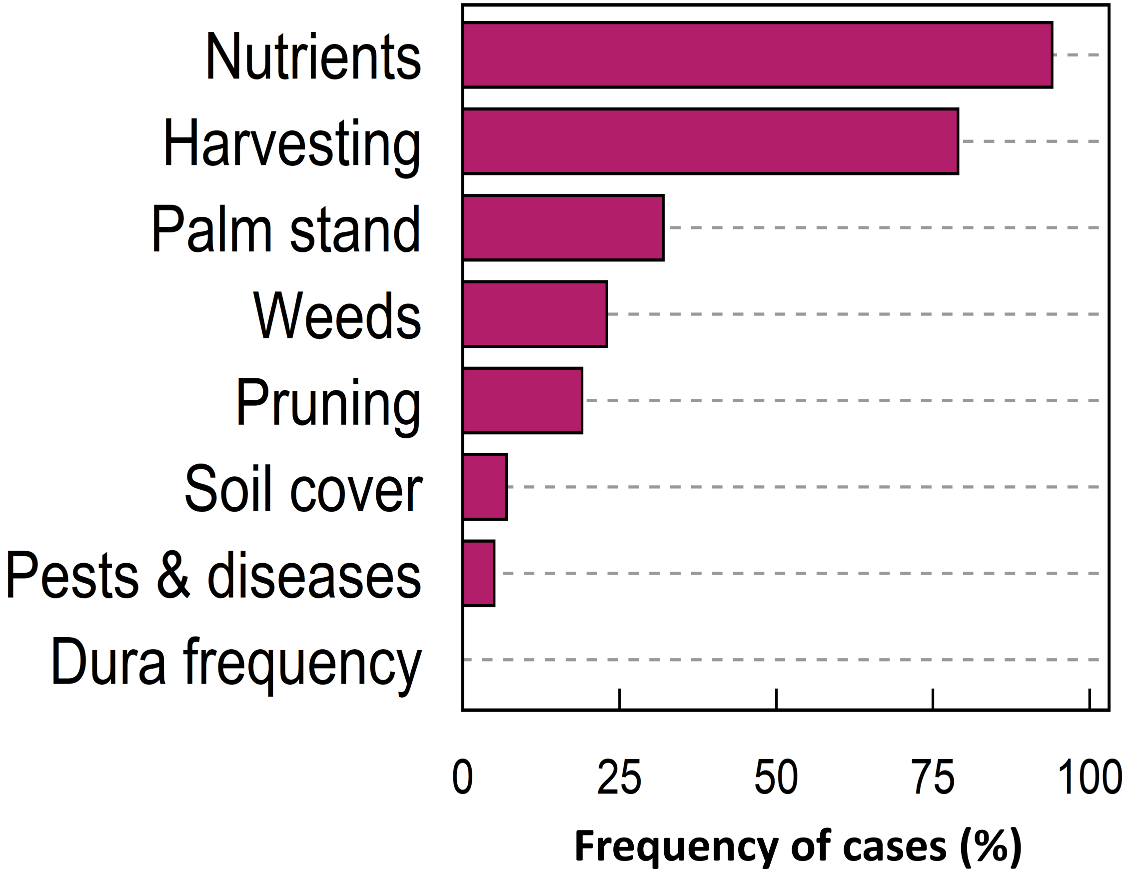
PROJECT ON OIL PALM INTENSIFICATION



1- Tandun, Riau (Rokan Hulu)
2- Sei Rotan, Jambi (Tanjung Jabung Barat)
3- Mendis Jaya, South Sumatra (Musi Banyuasin)
4- Nanga Tayap & Matan Hilir Utara, West Kalimantan (Ketapang)
5- Pangkalan Dewa, Central Kalimantan (Kotawaringin Barat)
6- Harapan Jaya, East Kalimantan (Berau)

OIL PALM SMALLHOLDERS: YIELD CONSTRAINTS

Analysis of farmer data collected from 1,200 smallholder fields identified nutrients, harvest, weeds, and pruning as key factors explaining low yields

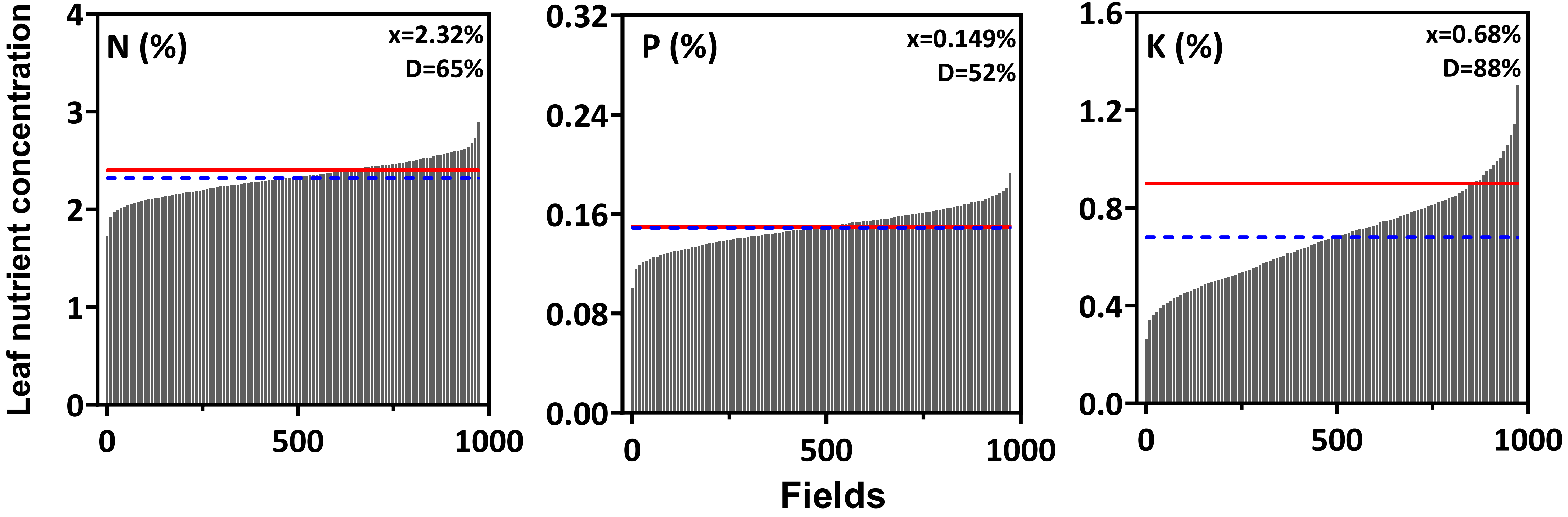


Monzon *et al.* (Agricultural Systems, accepted)

CURRENT NUTRIENT STATUS

Widespread nutrient deficiencies across independent smallholder fields.
About 90% of fields with K deficiency and 60% of fields showed N & P deficiencies.

Each bar corresponds to an individual field (n= 973). Frequency of deficient fields (D) for each nutrient is shown. Means (x) are shown with blue line. Red lines indicates the nutrient sufficiency level (Rankine and Fairhurst, 1999)



* Nutrient status determined based on ten sampled palms per field (average field size: 2 ha)

Sugianto *et al.*, in review

Widespread potassium (K) deficiencies and imbalances with nitrogen (N)

Photos: P Grassini & H Sugianto

INSUFICIENT AND IMBALANCED NUTRIENT SUPPLY

Half of farmers **do not apply fertilizer** and the rest rely on **subsidized fertilizer containing no/little potassium** (urea, phonska) which is not suitable for a balanced palm nutrition

Nutrient	Nutrient requirement for attainable yield*	Current nutrient input**	
	kg nutrient ha^{-1} y^{-1}	kg nutrient ha^{-1} y^{-1}	As % of nutrient requirement
Nitrogen (N)	139	20	14%
Phosphorous (P)	16	5	31%
Potassium (K)	193	15	8%

* Nutrient requirement (as kg of elemental nutrient) to achieve attainable yield based on FFB nutrient removal and expected trunk nutrient immobilization, following Ng et al. (1999). ** Average nutrient input (via fertilizer and organic sources) based on the data from independent smallholders collected over two years (2020-2021) across six provinces (total of 1,200 fields).

Lim *et al.* (in review)

EVALUATION OF BEST MANAGEMENT PRACTICES (BMPs)

Harvest criteria and frequency

Pruning and frond arrangement

Nutrient rate, source, timing, and placement

Management of weeds and beneficial vegetation

Side-by-side comparison between best management practices (BMPs) versus the reference (REF) farmer management across 31 sites

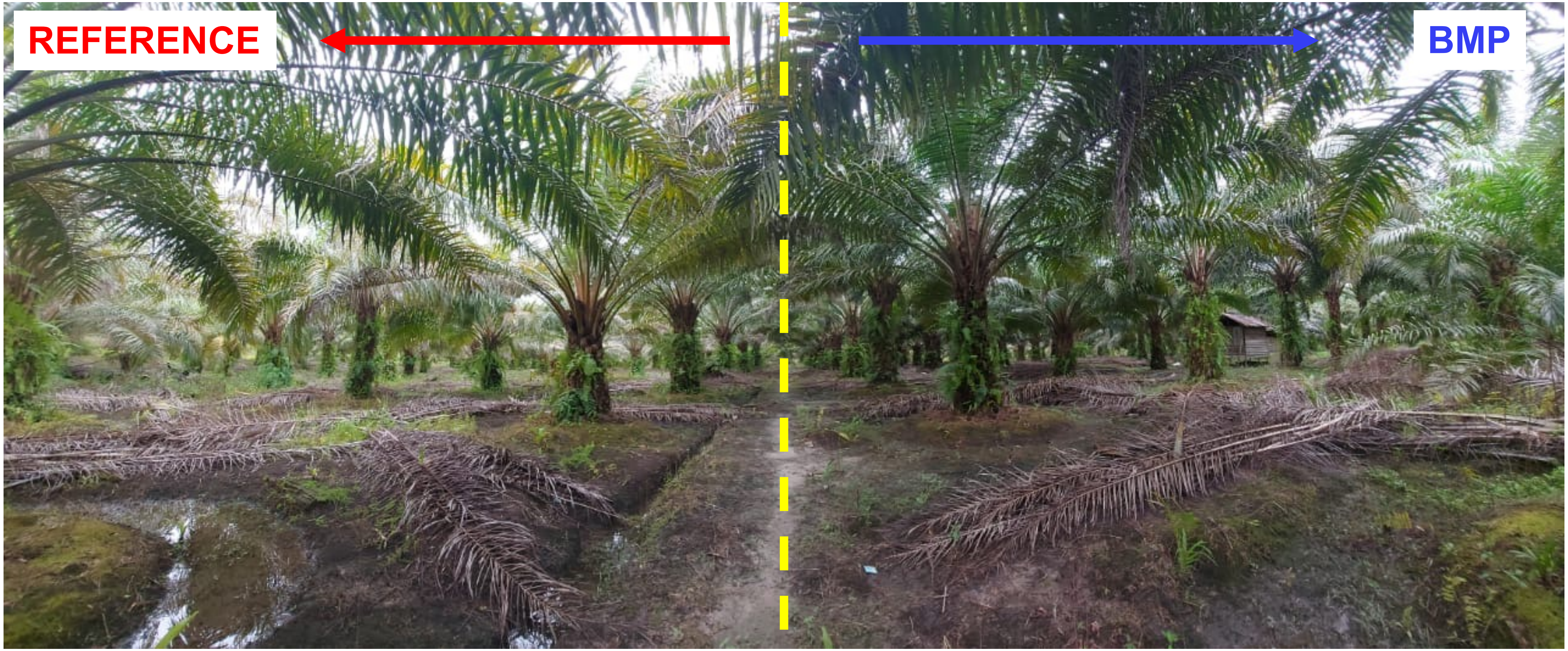
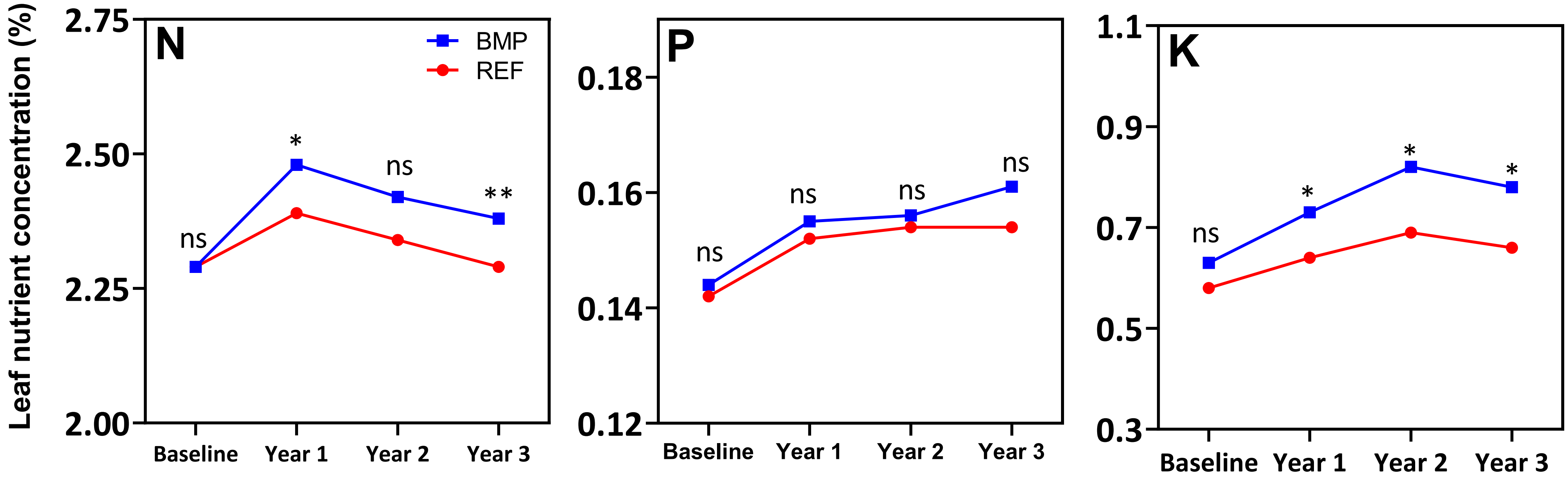


Photo taken by Hendra Sugianto

IMPROVED PLANT NUTRITION

Larger & balanced nutrient amounts in BMP fields improved plant nutrient status, especially N & K, compared with the reference (REF) fields following farmer practices

Total of 31 paired BMP-REF comparisons across five provinces. Shown here are the average values.



Sugianto *et al.*, in preparation

IMPACT OF BMPs ON YIELD

Implementation of BMPs lead to higher yields in Year 1 (+12%), Year 2 (+39%), and Year 3 (+35%).

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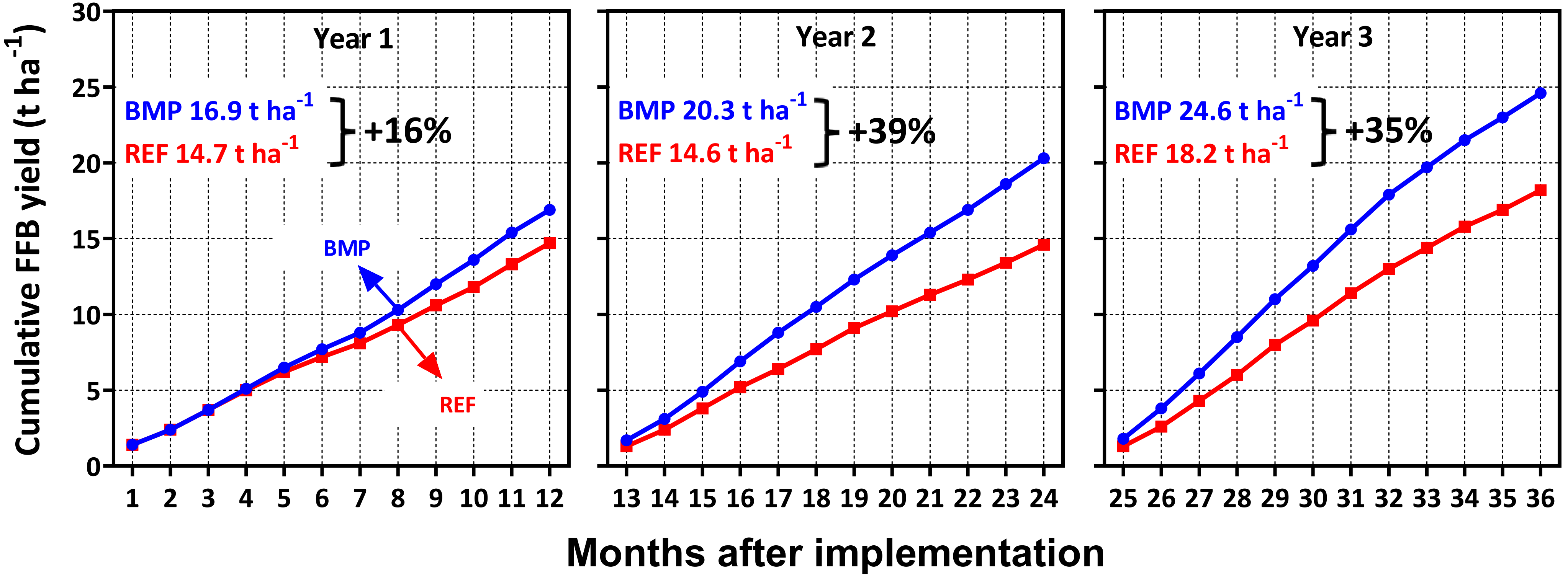

Sugianto *et al.*, in preparation

NEXT STEPS:

Global assessment of potassium limitation to crop production

PROJECT DESCRIPTION

- 2-year project starting July 1st , 2023
- Lead by University of Nebraska-Lincoln (UNL) & International Fertilizer Association (IFA)
  - PIs: Dr Patricio Grassini (UNL) & Achim Dobermann (IFA)
  - Post-doctoral Research Associate Dr Walter Carciochi
- Steering committee including the companies supporting the project:
  - Nutrien
  - Mosaic
  - K+S
  - ICL
  - AngloAmerican
  - BHP

SCOPE

- **Spatial**
  - **Crop systems where we know K is limiting but do not know if K fertilizer amounts are sufficient - e.g., Brazil**
  - **Crops systems where we suspect K is (becoming) limiting– e.g. South East Asia, South American Pampas**
  - **Crop systems where we have no idea whether K is limiting of not – e.g., NW China**
- **Temporal**
  - **Recent years (after 2000)**
  - **Combination of short- and long-term data**
- **Agronomic context**
  - **Focus on crop system rather than individual crops**
  - **Priority given to on-farm data**

APPROACH & DATA SOURCES

- **Estimation of partial K balances**
  - **Survey data, FAO-IFA crop nutrient budget database**
- **Determination of plant K deficiency *via* leaf tissue analysis**
  - **Published data, existing non-published data, new data**
- **Soil tests and data on K uptake from fertilizer omission plots and other expts**
  - **Published data, existing non-published data, soil labs**
- **Data from experiments & trials**
  - **Published and unpublished – literature search & ingestion**
  - **Priority to on-farm trials, but also OK to include data from research stations**
  - **Short- and long-term experiments**
- **All the information collected via this approach can be distilled through a ‘traffic light’ system indicating *where* K limitation is likely to occur**

TAKE-HOME MESSAGES

- A novel approach incl. nutrient balances, leaf tissue analysis, and on-farm fertilizer trials was used to diagnose K limitation
- Our case studies showed widespread K limitations in annual and perennial crops in the humid tropics of Indonesia.
- Potassium limitations are NOT limited to Indonesia
  - Well known for some crop systems (e.g., Brazilian Cerrado)
  - Scattered evidence for others (e.g., South American Pampas)
  - Not known at all for many
- Our new project will orient us on where K limitations are likely
  - Our success will depend upon compiling existing data from K experiments and/or on-farm trials – we need your help!



Thank you!

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