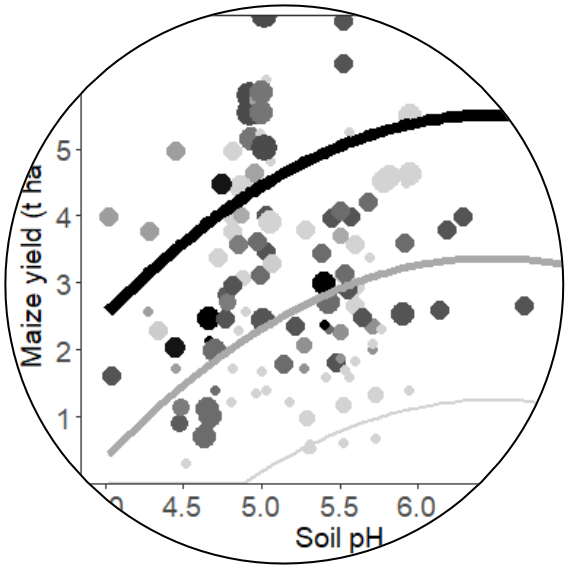
Liming agricultural soils in Africa

Can long-term economic and environmental benefits pay off short-term investments?

Martin van Ittersum and Renske Hijbeek

Hijbeek, R., van Loon, M. P., Ouaret, W., Boekelo, B., & van Ittersum, M.K., 2021. Liming agricultural soils in Western Kenya: Can long-term economic and environmental benefits pay off short term investments? Agricultural Systems, 190. doi:10.1016/j.agsy.2021.103095



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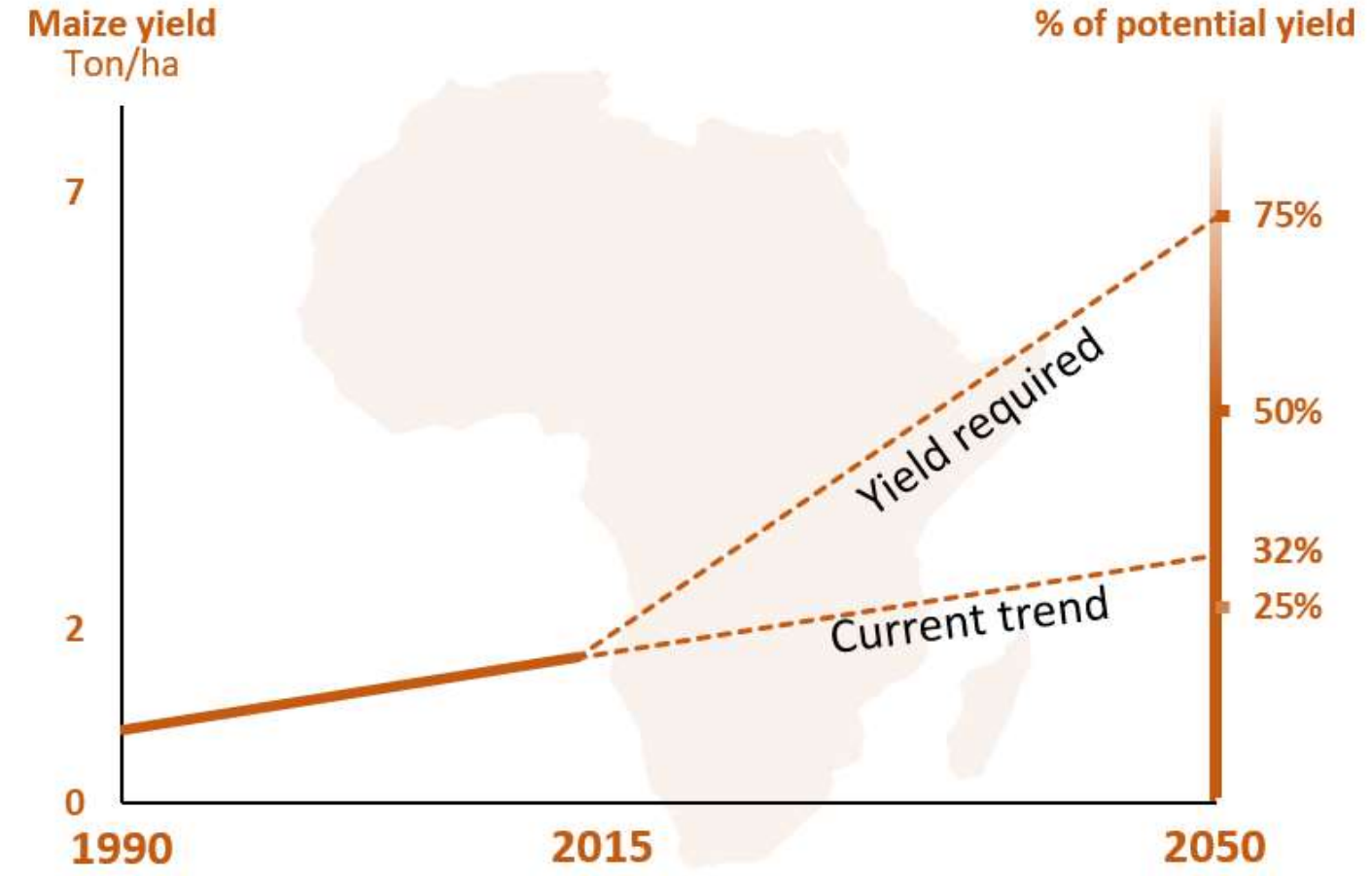
CPCN seminar, Wednesday 10 November 2021

Farmbiz Africa & CIAT

Necessary trendbreak: yield increase and intensification



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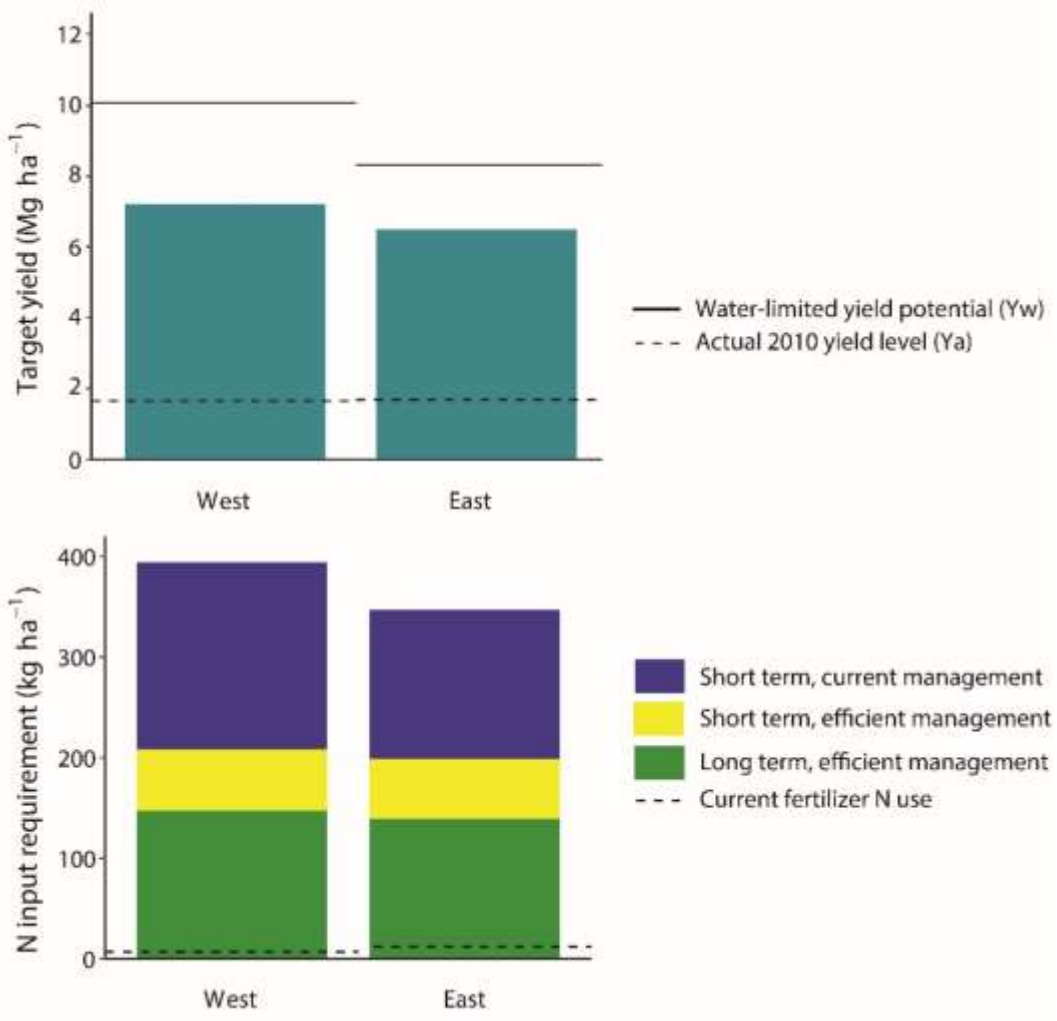
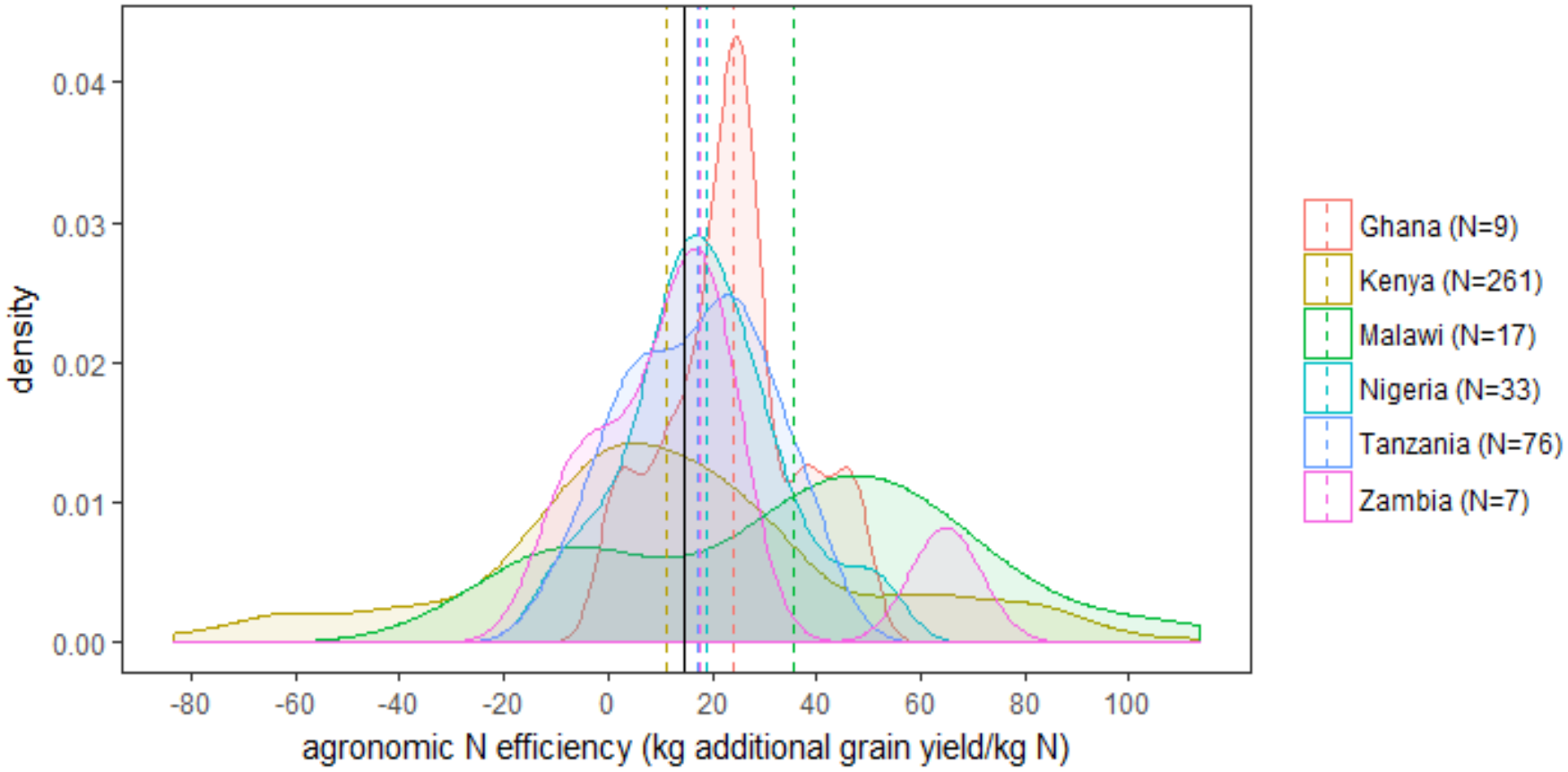
Van Ittersum et al., 2016 (PNAS)

Nitrogen requirements for maize self-sufficiency



Ten Berge et al., 2019 (Global Food Security)

Empirical agronomic N efficiencies far below theoretical



OFRA database, 2017

Ten Berge et al., 2019 (Global Food Security)

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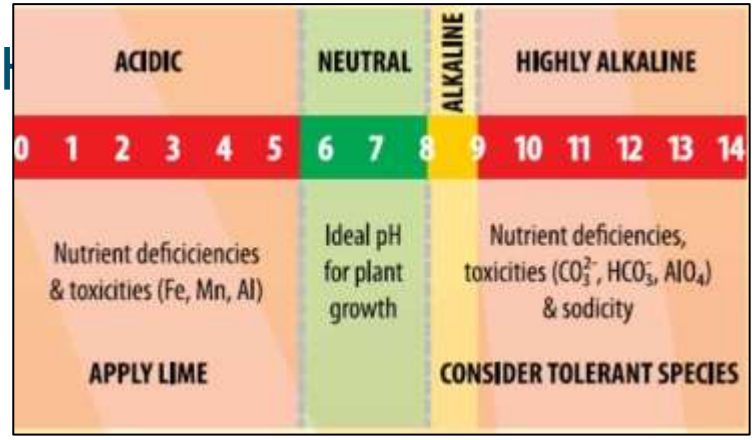
Liming an option but Profit and GHG effects

- Low pH of soils may be one of the factors limiting response to fertilisers and liming can be considered
- Smallholders limited in cash and liming to increase soil pH is an investment with delayed payback time (application in year 1; effects in years to follow)
- Liming leads to GHG emissions (production, transport, application)

Improving nutrient response

- Continued and renewed interest in liming acid soils in sub-Saharan Africa
- Common threshold of soil pH for maize is 5.6
- Unknowns:
  - Effects on yields?
  - Profitability?
  - Environmental impacts (GH



soilquality.org.au

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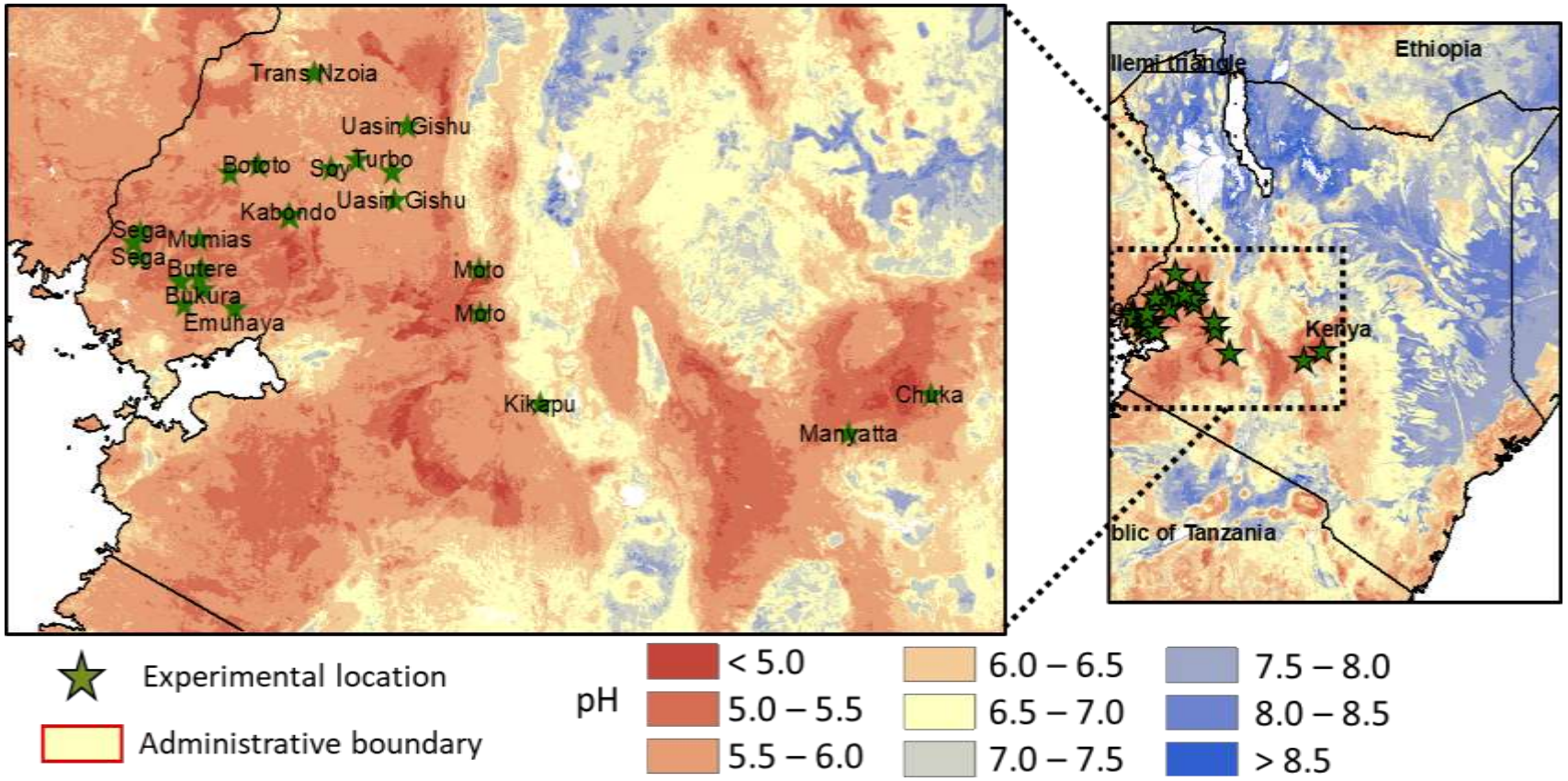
Research questions

1. What is the impact of liming on soil pH and maize yields?
2. Is liming an economically viable option for smallholder farmers?
3. What are the synergies or trade-offs between maize yields, return on investments and GHG emissions?

Data and methods

- West Kenya
- Empirical data (meta-analysis of 26 field experiments)
- Modelling dynamics (based on regression relations between liming, soil pH and maize yields)
    - Timeframe: 1-5 years after lime application
- Assessment of effects on returns on investments, profits and GHG emissions
    - Trade-off analysis

West Kenya - Locations of experiments



- 24% of agricultural land in West Kenya soil pH < 5.5

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Experiment details

Table 1. Overview of field experiments used in the analysis (data points used after outlier removal; i.e., a data point is a unique combination of site, year, season, liming rate, and fertiliser rate)

Publication	Sites	Year(s)	Seasons (#)	Liming rates (#)	N rates (#)	P rates (#)	FYM* rates (#)	Experiment Type**	Data points available		
									Soil pH in the first year (#)	Soil pH in years 2 to 5 (#)	Maize yield (#)
Ademba (2009)	Bototo, Kabondo	2007	2	2	2	1	0	F	0	0	10
Ademba et al. (2014)	Boboto	2007	2	2	2	1	0	F	0	0	5
Kihanda et al. (2013)	Manyatta	2 years	1	2	2	2	1	F	0	0	8
Kiplagat et al. (2014)	Ugenya, North Kakamega	2010	2	4	1	1	0	F	8	6	8
Kisinyo et al. (2014)	Sega	2005-2008	2	4	1	3	0	F	10	24	16
Kisinyo et al. (2015)	Busia	2008	2	3	2	2	0	F	3	0	0
Kisinyo (2016)	Uasin Gishu	2005-2008	1	2	3	2	0	F	5	6	2
Lelei et al. (2014)	Molo	2009-2010	1	2	1	2	2	R	0	0	8
Mochoge et al. (2010)	Molo	1 year	1	2	2	1	0	R	0	0	4
Mucheru-Muna et al. (2007)	Chuka	2000 - 2003	2	0	1	2	0	R	2	2	0
Mungai et al. (2009)	Kikapu	2006 - 2007	1	1	1	1	0	F	0	0	2
Ndung'u-Magiroi et al. (2010)	Trans Nzoia, Uasin Gishu	1 year	1	2	2	2	0	F	0	0	8
Njoroge et al. (2019)	Sidindi	2014-2018	2	0	2	2	0	F	4	4	0
Nekesa et al. (2011)	Kuinet	2005	1	4	4	4	0	F	0	0	16
Okalebo et al. (2009)	Mabanga, Sega	2005	1	2	1	2	0	F	14	10	10
Onyango (2013)	Shianda	2011	2	2	1	2	0	F	4	0	4
Opala et al. (2010)	Bukura	2006 - 2007	2	0	2	2	0	F	8	4	4
Opala et al. (2018)	Butere, Emuhaya, North Kakamega, Mumias	2015-2016	2	2	2	2	0	F	6	4	16
Tabu et al. (2007)	Shitirira	1 year	1	2	1	1	0	F	0	0	2
Total data points									**64**	**60**	**123**

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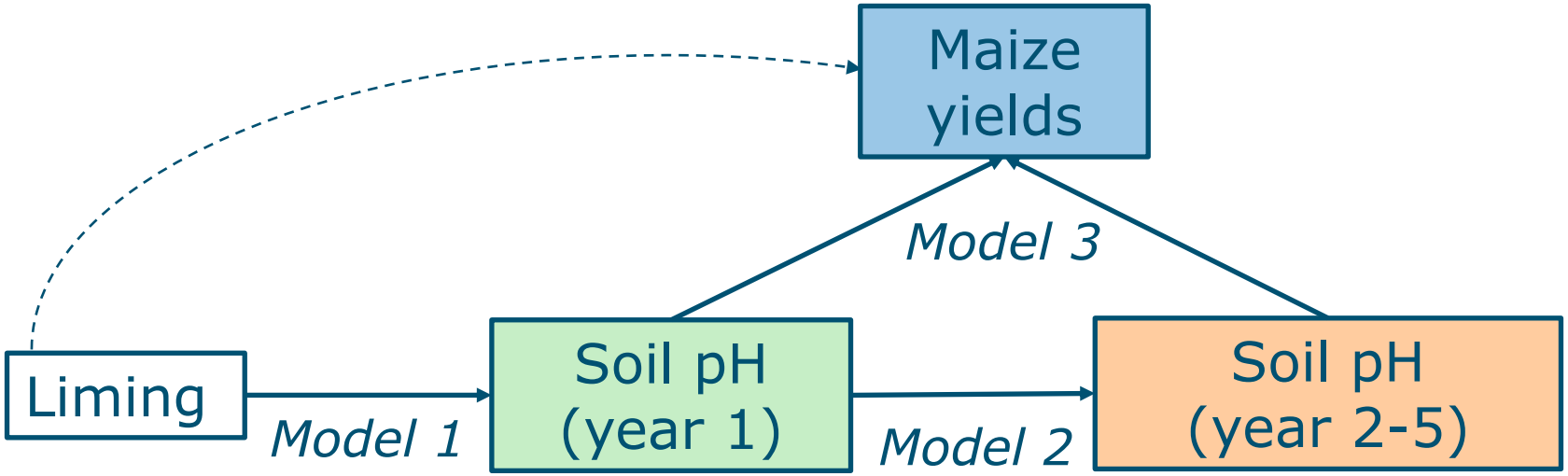
Modelling soil pH and maize yields (meta-analysis)



+ Relative yield increase in 1st year due to liming

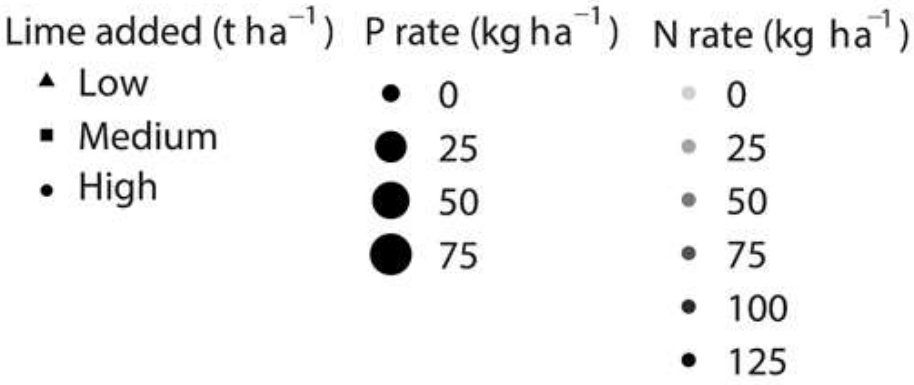
Explorations: Assessing different combinations of initial soil pH and fertiliser schemes

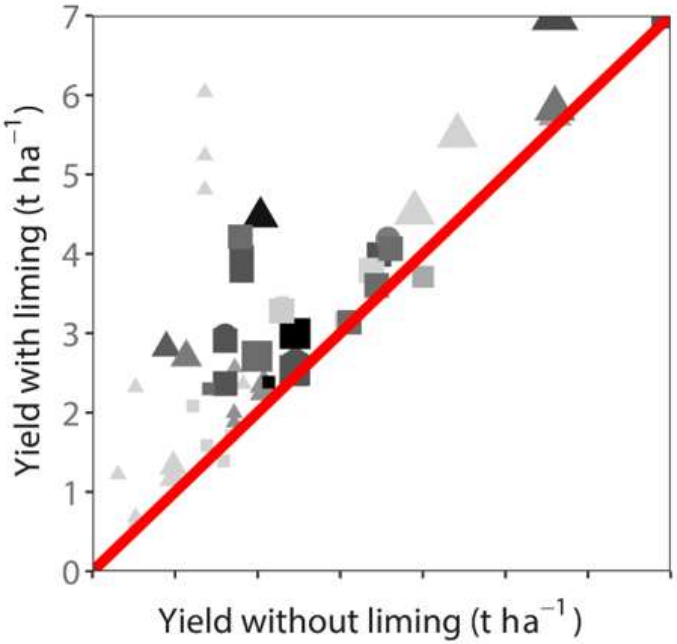
- Yield, economic benefits and GHG emissions were modelled for:
  - 3 levels of initial soil pH
    - 4.5
    - 5.0
    - 5.5
  - 3 levels of fertiliser application
    - 0 kg N and 0 kg P per ha
    - 50 kg N and 25 kg P per ha
    - 100 kg N and 50 kg P per ha

➔combined with different liming rates (incl. the economic optimum one of ca. 2 t/ha)

Results meta-analysis: relative yield increase in the 1st year after liming

- 1 data point = comparison between yields of two treatments, all equal, besides lime (N = 54)
- Average lime application (2 t/ha) leads to a yield increase from 2.3 to 3.6 t/ha (57%)





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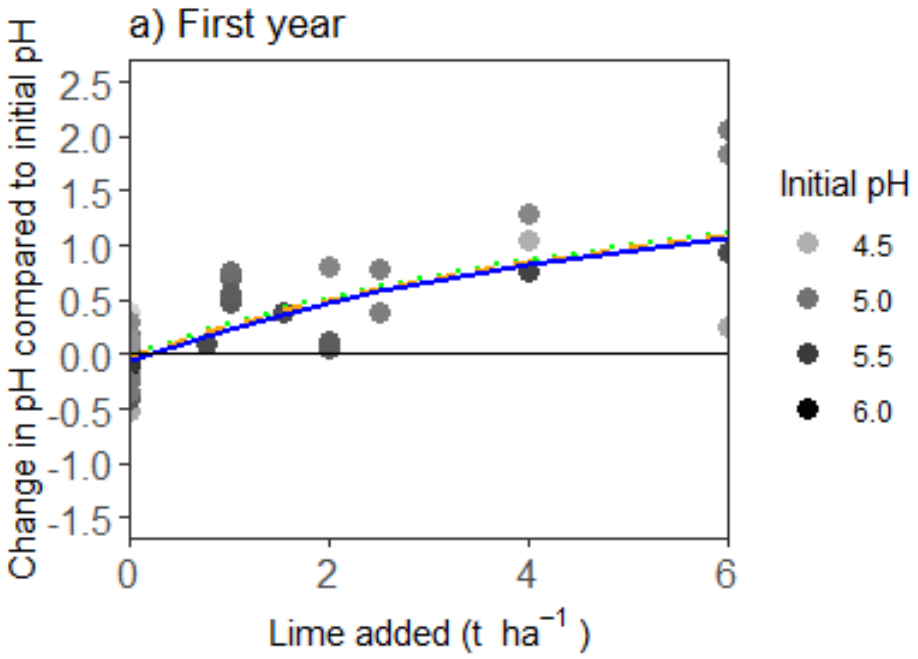
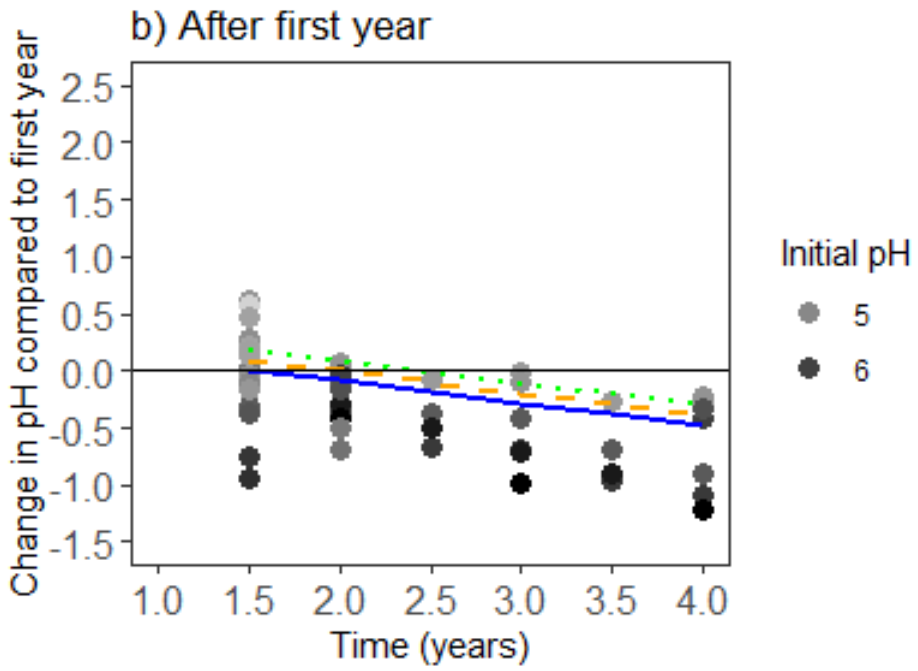
Results – model 1: lime & soil pH



Different colours of lines: no, low and medium fertiliser application

Variables added to model:
- Initial soil pH (-)
- Lime application (+)
- Fertiliser application

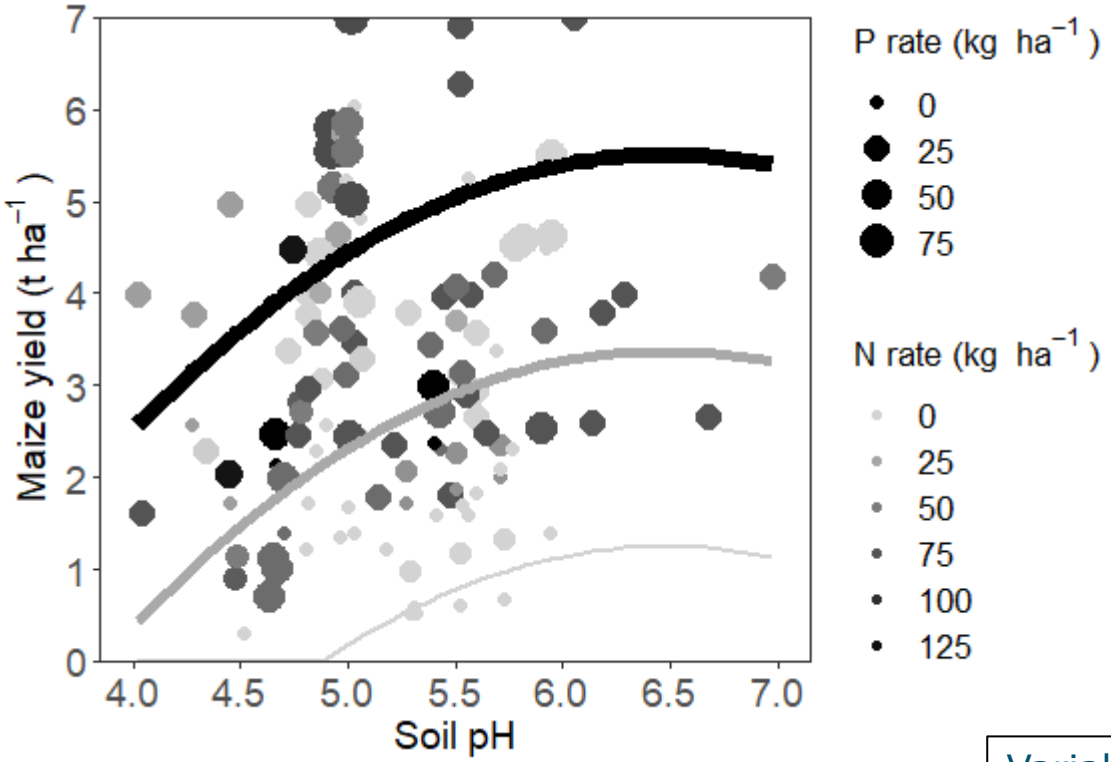
Results – model 2: change in soil pH years 2-5



green, orange, and blue lines: no, low and medium fertiliser application

Variables added to model:
- Soil pH at year 1 (-)
- Time (-)
- Fertiliser application (-)

Results – model 3: soil pH & maize yields



Variables added to the model:
- Soil pH (+)
- N rate (+)
- P rate (+)

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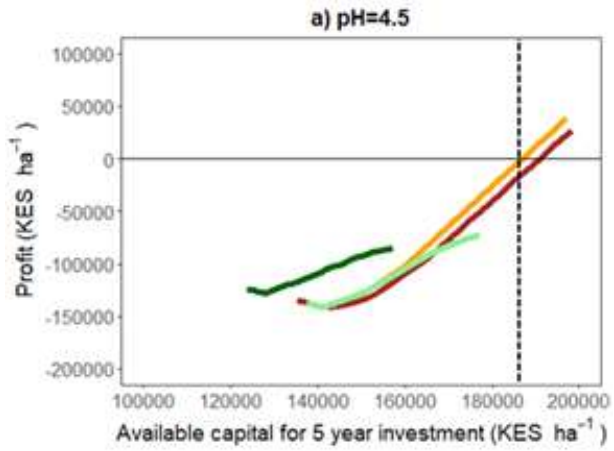
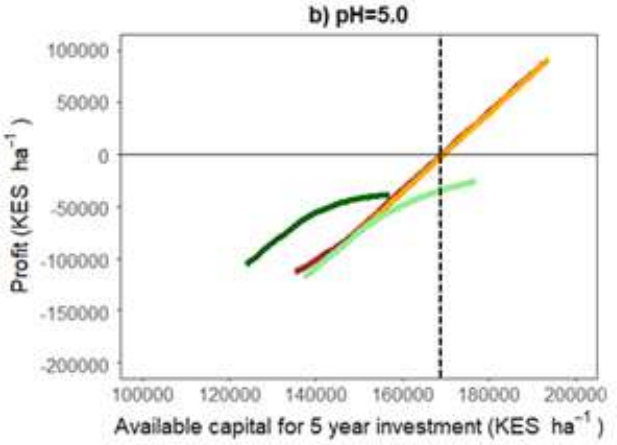
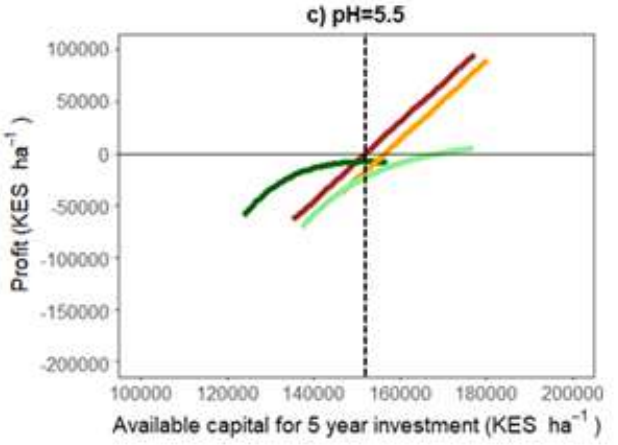
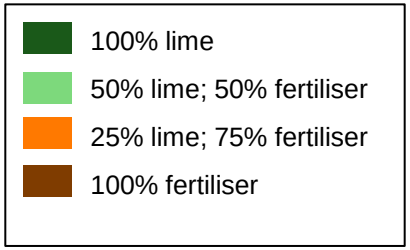
Exploration – profits

- Profit related to investments in lime and/or mineral fertiliser (N:P ratio 2:1)
  - Summed over 5 years
  - Including labour costs
  - Lime application in year 1
  - Fertiliser application annually









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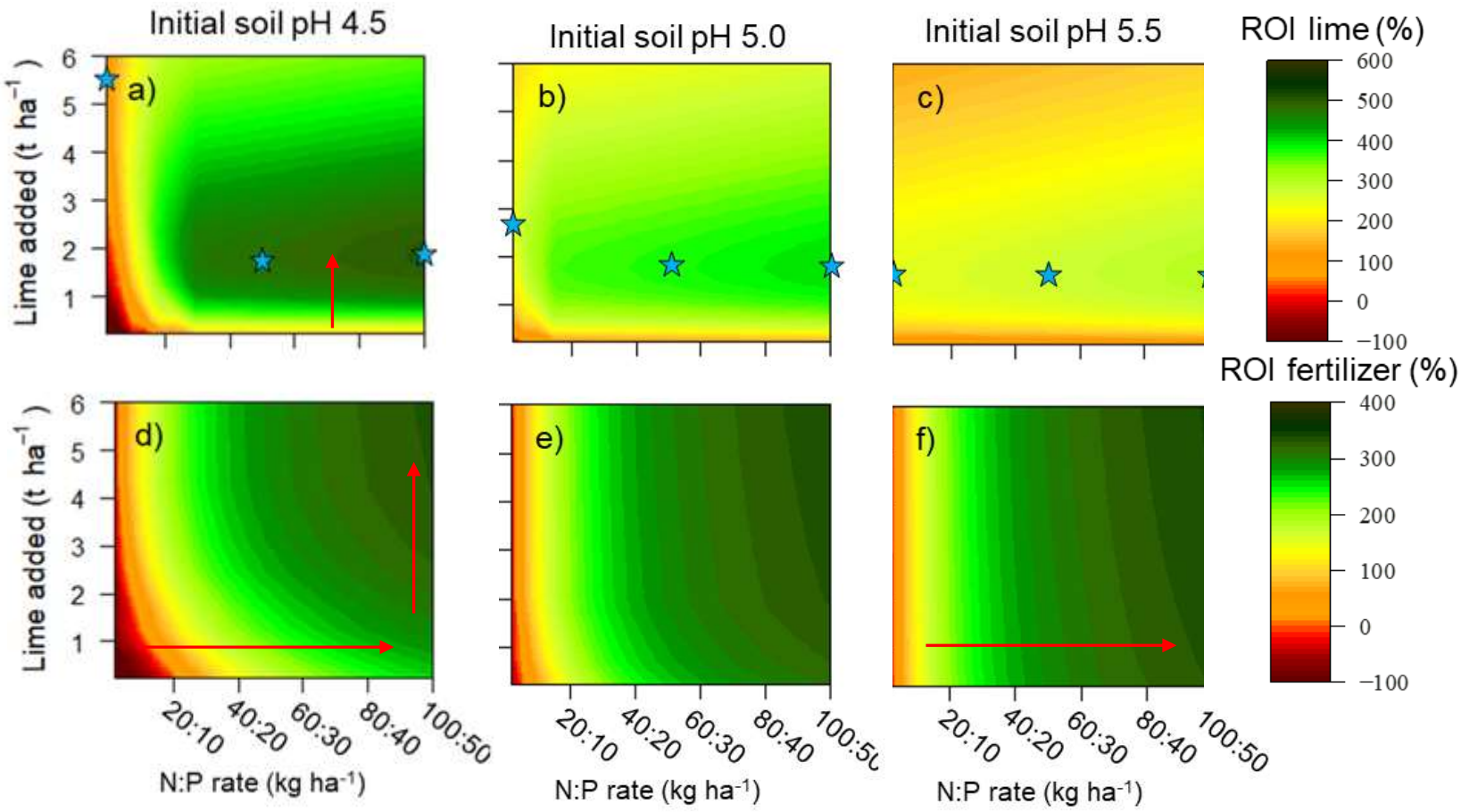
ROI (Return on Investment)

- $ROI\ lime = \left(\frac{profit\ with\ lime - profit\ without\ lime}{total\ costs\ with\ lime - total\ costs\ without\ lime}\right) * 100$

Exploration - return on investments

ROI lime:

ROI fertiliser:

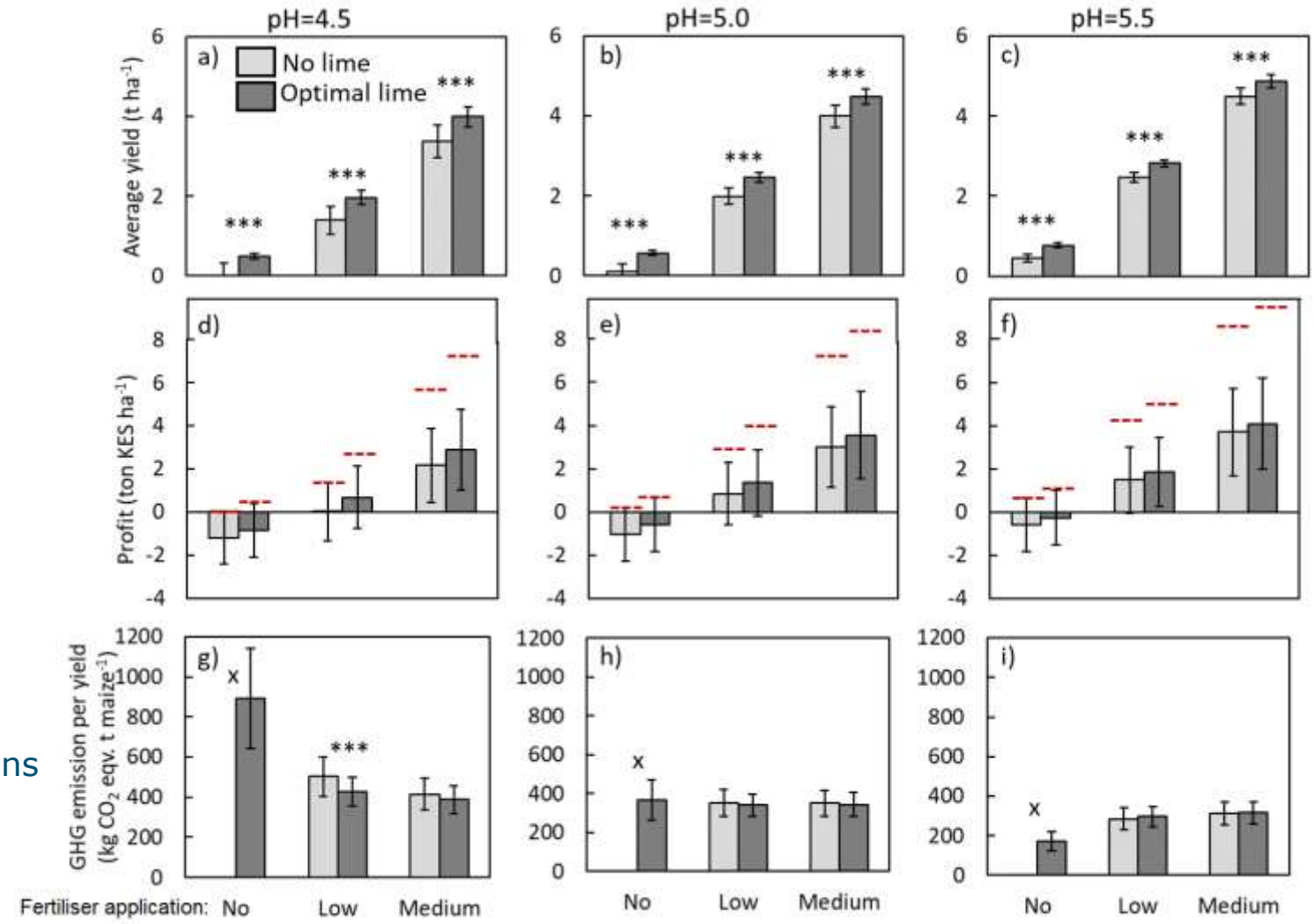


Exploration: Yield, profit and GHGs: trade-offs

yields

profit

GHG emissions



Fertiliser rate (N and P)

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Discussion & conclusion

- Liming consistently increased maize yields (on soil pH < 5.5)
- Reaching positive profits is challenging (when including labour costs)
- Fertiliser often gives more profit
- Liming related GHG emissions are offset by yield increase when assessed per tonne of grain maize
- Without (economic) incentives, lime uptake is not so likely in West Kenya

Limitations

- Confounding factors in meta-analysis: treatments with more lime tended to have more N&P application
- West Kenya: extrapolation possible?
- What-if economics change?
- Longer term view? (> 5 years no liming)
- Interaction soil acidity & N_2O emissions

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Thank you

- Keji Jindo and Tom Schut (GEODATICS) for sharing economic data
- CGIAR Research Programme Climate Change, Agriculture and Food Security (CCAFS)
- International Fertilizer Association (IFA)

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