FERTBIO 2016

"RUMO AOS NOVOS DESAFIOS"

16 a 20 de Outubro

Centro de Convenções de Goiânia - GO

Zinc (Zn) fertiliser use and its impact in human health

Martin R. Broadley

Munir Zia, Waqar Ahmad, Diriba Kumssa, Edward Joy, Louise Ander, Michael Watts, Alexander Stein, Scott Young

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UNITED KINGDOM · CHINA · MALAYSIA

FFC
FAUJI FERTILIZER COMPANY LIMITED

FAO FIAT PANIS

LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

BGS 1835
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Zinc is as essential element for people (and plants!)

Zinc is bound within 1000s of proteins in people (and plants)

~14 / 10 mg Zn *capita*$^{-1}$ day^{-1} is required for adult males / females

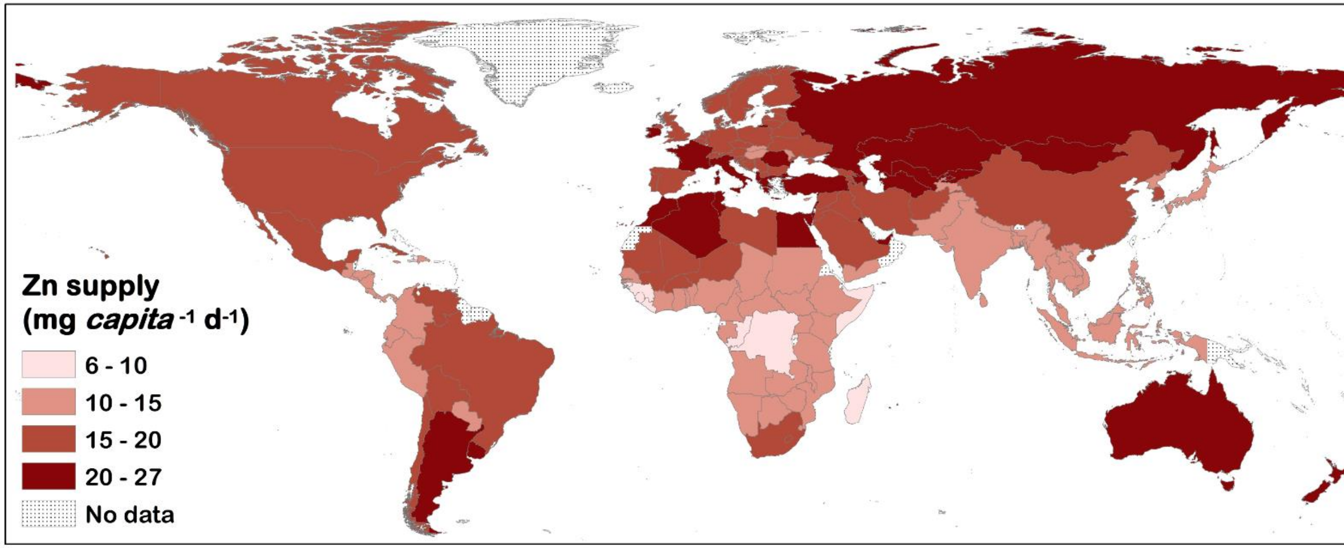
Zn deficiency (ZnD) increases:

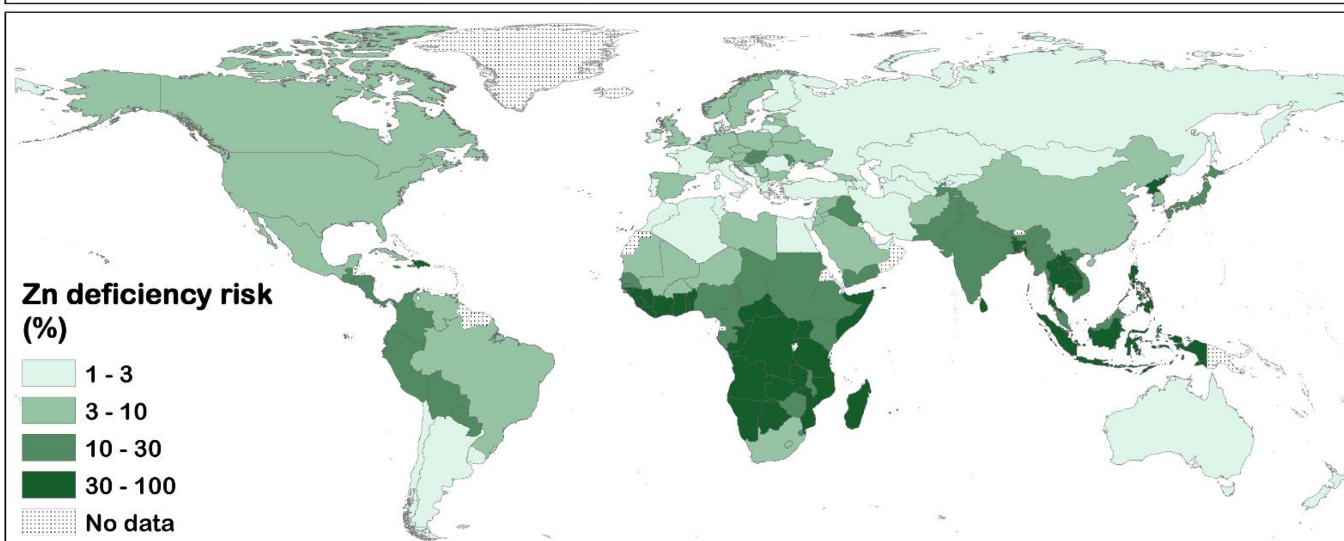
- **incidence and severity of diarrhoea**
- **respiratory tract infections (pneumonia)**
- **malarial mortality**
- **risk of childhood stunting (height-to-weight ratio)**

Biomarkers of ZnD include:

- **plasma / serum Zn concentrations**
- **stunting rates**
- **dietary intake assessments (direct or supply-based)**
- **others t.b.c.**

Dietary Zn supply: ~20% are deficient

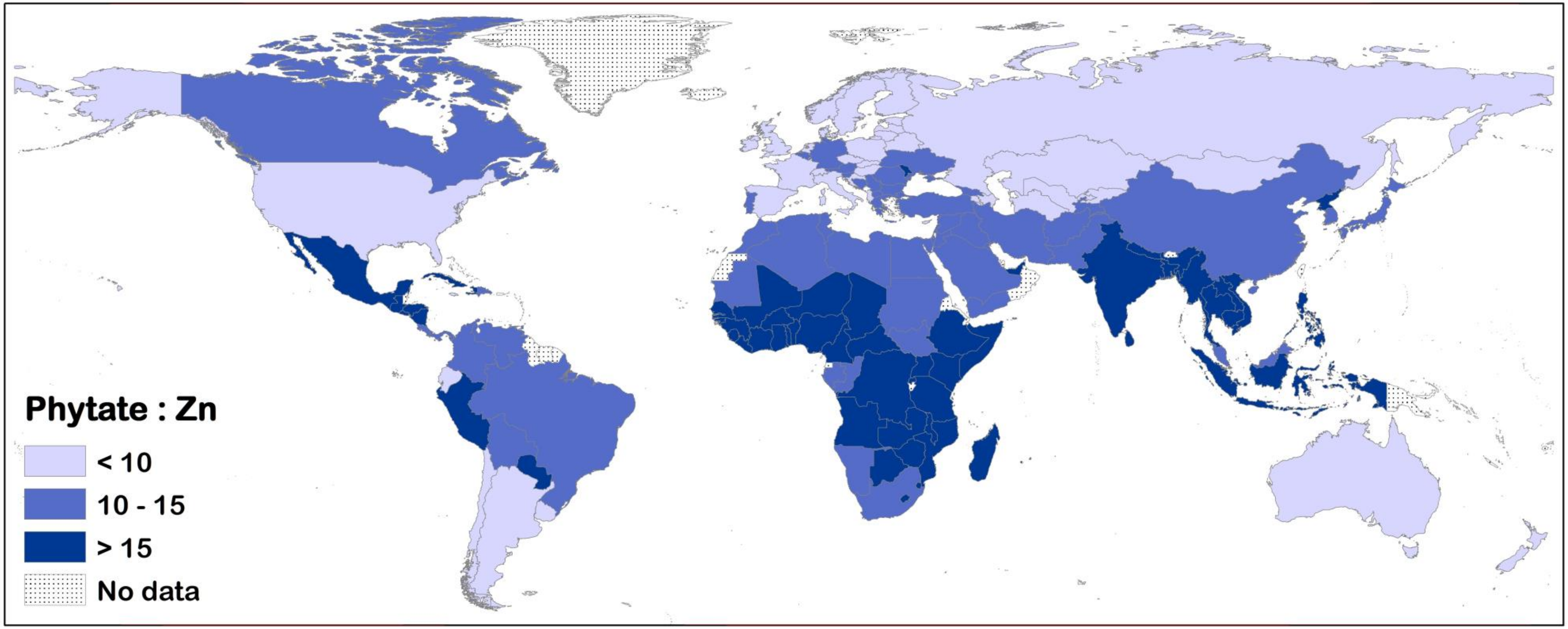




Diriba Kumssa

Kumssa DB, Joy EJM, Ander EL, Watts MJ, Young SD, Walker S, Broadley MR (2015). Dietary calcium and zinc deficiency risks are decreasing but remain prevalent. *Scientific Reports*, **5**, 10974.

Zn deficiency risks increased due to phytate-P in cereal grains and legume seeds



Kumssa DB, Joy EJM, Ander EL, Watts MJ, Young SD, Walker S, Broadley MR (2015). Dietary calcium and zinc deficiency risks are decreasing but remain prevalent. *Scientific Reports*, **5**, 10974.

Improving dietary mineral supplies

1. **Diet diversification**
2. **Food fortification**
3. **Agronomy**
4. **Crop breeding**

Health Economic Analyses
(based on Disability Adjusted Life Years, DALYs)

Intervention	Cost per DALY saved (US $)	Notes	Source
Granular fertiliser	773-6457	sub-Saharan Africa	Joy et al., 2015
Foliar fertiliser	81-575	sub-Saharan Africa	Joy et al., 2015
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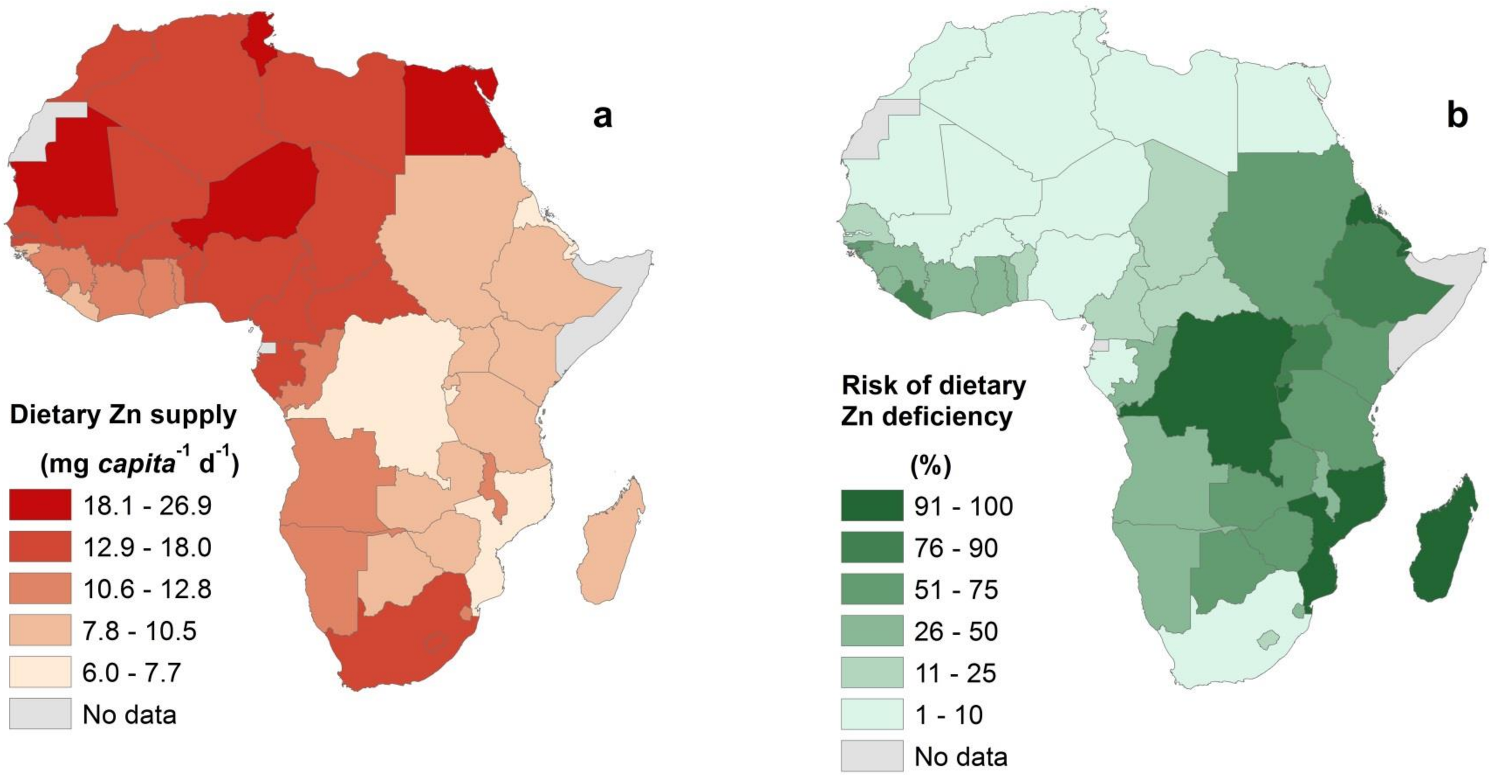
Supplements	65-2758	Prophylactic, 1-4 yrs	Fink & Heitner, 2014
Flour fortification	401	Zambia, VA, Fe, Zn	Fielder et al., 2013

Joy EJM, Stein AJ, Young SD, EL Ander, MJ Watts, Broadley MR (2015). Zinc-enriched fertilisers as a potential public health intervention in Africa. *Plant and Soil*, 389, 1-24.

Diet Diversification

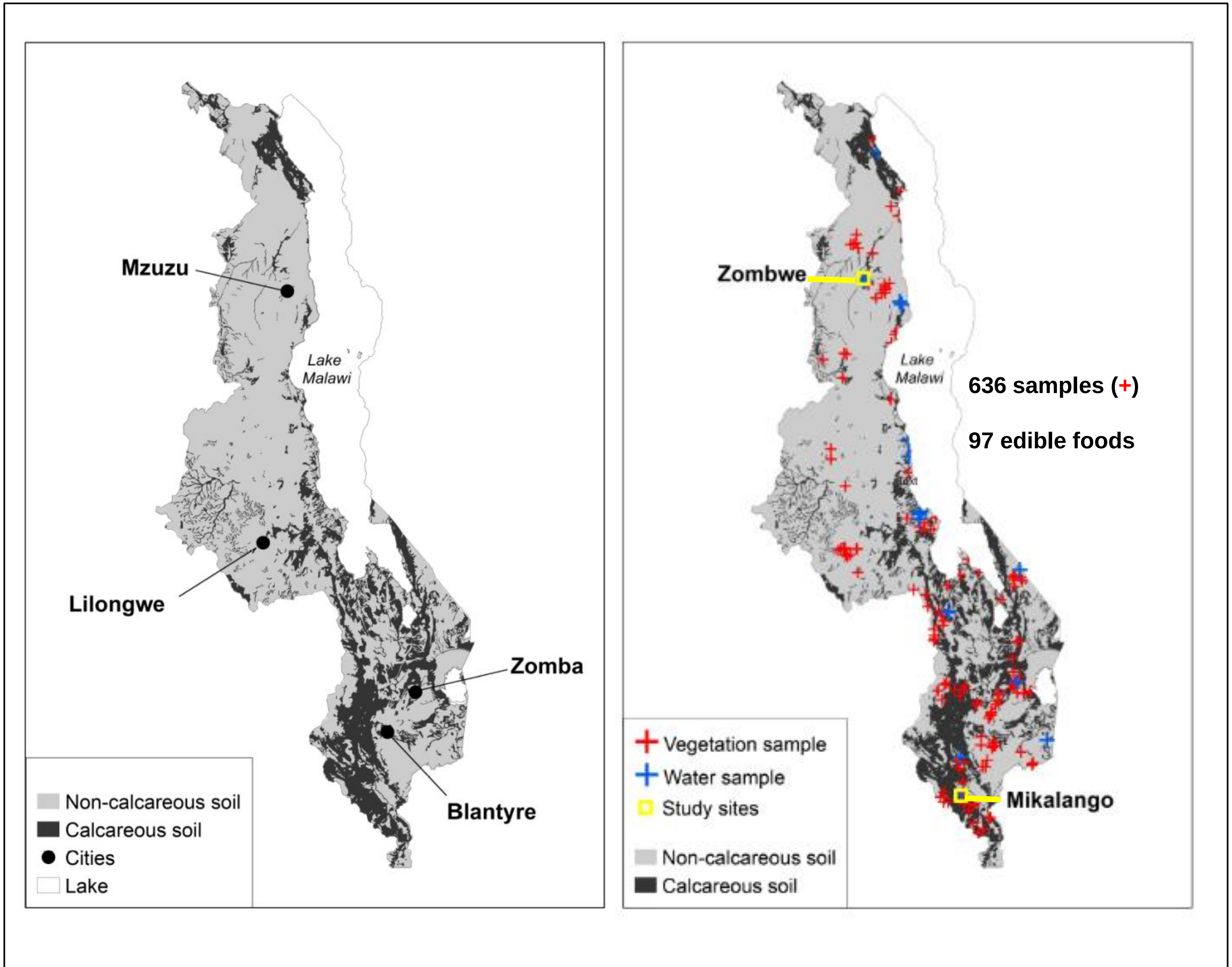
Dietary Zn supply: variable deficiency risks?



Joy EJM, Ander EL, Young SD, Black CR, Watts MJ, Chilimba ADC, Chilima B, Siyame EWP, Kalimbira AA, Hurst R, Fairweather-Tait SJ, Stein AJ, Gibson RS, White PJ, Broadley MR (2014). Dietary mineral supplies in Africa. *Physiologia Plantarum*, **151**, 208-229.


2011-2015
DARS
Department of Agricultural Research Services
Crop Storage Research
NOVEMBER 2011
DECEMBER 2011
GERMINATION ROOM
Edward Joy
Lazarus Singano
Allan Chilimba

Geographical variation in Zn supply within Malawi



Joy EJM, Broadley MR, Young SD, Black CR, Chilimba ADC, Ander EL, Barlow TS, Watts MJ (2015). Soil type influences crop mineral composition in Malawi. *Science of the Total Environment*, **505**, 587-595.

Mineral nutrient supply from surveys (Malawi)

Data from Malawi Third Integrated Household Survey (IHS3)

>12,500 households interviewed in 2010-11

Food consumption module: households asked to recall foods consumed in past 7 d from 112 items (e.g. ‘Maize *ufa* refined (fine flour)’, ‘Dried fish’)

Joy EJM, Kumssa DB, Broadley MR, Watts MJ, Young SD, Chilimba ADC, Ander EL (2015). Dietary mineral supplies in Malawi: spatial and socioeconomic assessment. *BMC Nutrition*, **1**, 42.

Mineral nutrient supply from surveys (Malawi)

MODULE G: FOOD CONSUMPTION OVER PAST ONE WEEK

DATA ENTRY LINE NUMBER	Over the past one week (7 days), did you or others in your household consume any [. . .]? INCLUDE FOOD BOTH EATEN COMMUNALLY IN THE HOUSEHOLD AND THAT EATEN SEPARATELY BY INDIVIDUAL HOUSEHOLD MEMBERS.	G01 YES..1 NO...2>> NEXT ITEM	G02 ITEM CODE	G03 How much in total did your household consume in the past week?		G04 How much came from purchases?		G05 How much did you spend?	G06 How much came from own-production?		G07 How much came from gifts and other sources?	
				QUANTITY	UNIT	QUANTITY	UNIT	MK	QUANTITY	UNIT	QUANTITY	UNIT
1	**Cereals, Grains and Cereal Products**											
2	Maize *ufa mgaiwa* (normal flour)		101									
3	Maize *ufa* refined (fine flour)		102									
4	Maize *ufa madeya* (bran flour)		103									
5	Maize grain (not as *ufa*)		104									
6	Green maize		105									
7	Rice		106									
8	Finger millet (*mawere*)		107									
9	Sorghum (*mapira*)		108									
10	Pearl millet (*mchewere*)		109									
11	Wheat flour		110									
12	Bread		111									
13	Buns, scones		112									
14	Biscuits		113									
15	Spaghetti, macaroni, pasta		114									
16	Breakfast cereal		115									
17	Infant feeding cereals		116									
18	Other (specify)		117									
19	**Roots, Tubers, and Plantains**											
20	Cassava tubers		201									
21	Cassava flour		202									
22	White sweet potato		203									
23	Orange sweet potato		204									
24	Irish potato		205									
25	Potato crisps		206									
26	Plantain, cooking banana		207									
27	Cocoyam (*masimbi*)		208									
28	Other (specify)		209									

CODES FOR UNIT:
KILOGRAMME 1
50 KG. BAG 2
90 KG. BAG 3
PAIL (SMALL) 4
PAIL (LARGE) 5
No. 10 PLATE 6
No. 12 PLATE 7
BUNCH. 8
PIECE. 9
HEAP 10
BALE 11
BASKET (*DENGU*) (SHELLED). . . . 12
BASKET (*DENGU*) (UNSHELLED) . . 13
OX-CART (UNSHELLED) . . 14
LITRE. 15
CUP. 16
TIN. 17
GRAM 18
MILLILITRE 19
TEASPOON. 20
BASIN. 21
SATCHET/TUBE. . . .22
OTHER (SPECIFY). 23

Mineral nutrient supply from surveys (Malawi)

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>12,500 households interviewed in 2010-11

Food consumption module: households asked to recall foods consumed in past 7 d from 112 items (e.g. 'Maize *ufa* refined (fine flour)', 'Dried fish')

Enumerators recorded the amount consumed and source (i.e. 'own production', 'bought' or 'gift')

Units include standard metrics (grams, litres etc.) and local units (small plate, large plate, pail etc.)

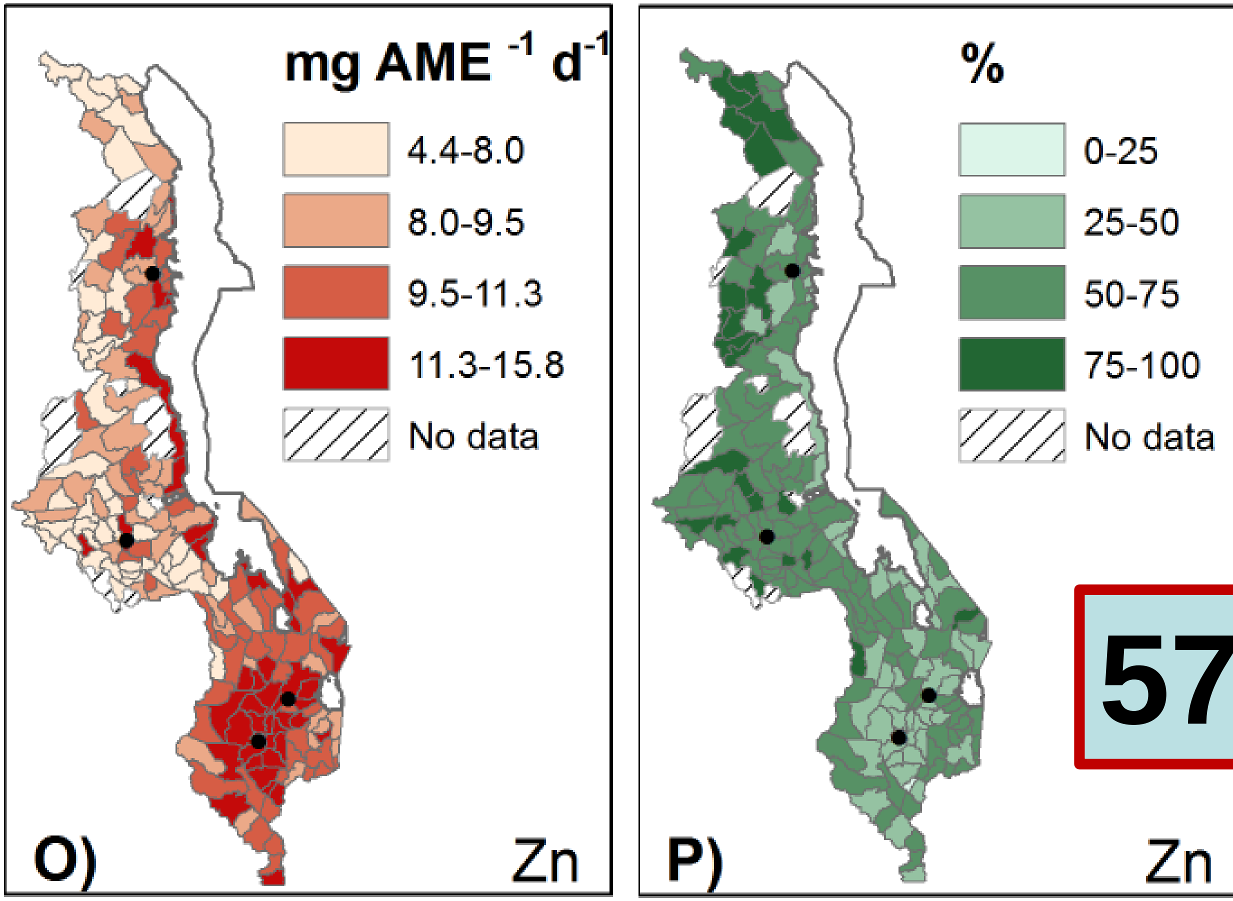
Food composition data from Joy et al. (2015)

Data integrated at an Extension Planning Area (EPA) level

Joy EJM, Kumssa DB, Broadley MR, Watts MJ, Young SD, Chilimba ADC, Ander EL (2015). Dietary mineral supplies in Malawi: spatial and socioeconomic assessment. *BMC Nutrition*, **1**, 42.

Zn supply in Malawi

AME = adult male equivalent



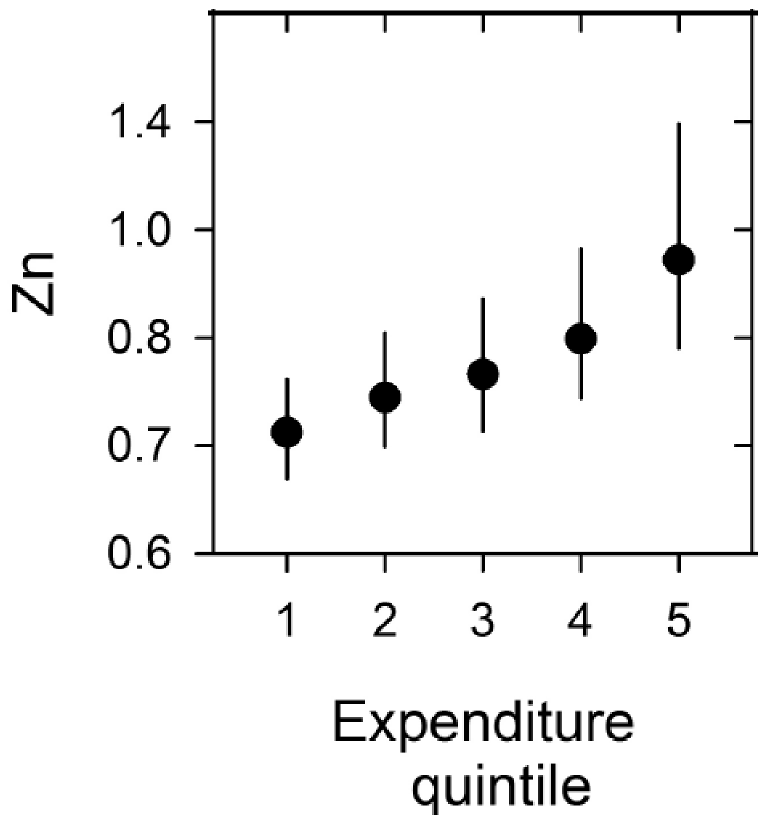
57%

Median Zn supply (per AME) = 10 mg *capita*$^{-1}$ d^{-1}
Estimated Average Requirement = ~12 mg *capita*$^{-1}$ d^{-1}

Joy EJM, Kumssa DB, Broadley MR, Watts MJ, Young SD, Chilimba ADC, Ander EL (2015). Dietary mineral supplies in Malawi: spatial and socioeconomic assessment. *BMC Nutrition*, **1**, 42.

Zn supply *vs* socioeconomic factors in Malawi

Zn supply as proportion of household requirements



Joy EJM, Kumssa DB, Broadley MR, Watts MJ, Young SD, Chilimba ADC, Ander EL (2015). Dietary mineral supplies in Malawi: spatial and socioeconomic assessment. *BMC Nutrition*, **1**, 42.

Int. J. Vitam. Nutr. Res., 83 (3), 2013, 176–187

Original Communication

A High Prevalence of Zinc- but not Iron-Deficiency among Women in Rural Malawi: a Cross-Sectional Study

Edwin W. P. Siyame[1], Rachel Hurst[2], Anna A. Wawer[2], Scott D. Young[3], Martin R. Broadley[3], Allan D. C. Chilimba[4], Louise E. Ander[5], Michael J. Watts[5], Benson Chilima[6], Jellita Gondwe[6], Dalitso Kang'ombe[7], Alexander Kalimbira[1], Susan J. Fairweather-Tait[2], Karl B. Bailey[8], and Rosalind S. Gibson[8]

[1]Department of Home Economics and Human Nutrition, Lilongwe University of Agriculture and Natural Resources, Bunda College Campus, Lilongwe, Malawi
[2]Department of Nutrition, Norwich Medical School, University of East Anglia, Norwich, UK
[3]School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough, UK
[4]Ministry of Agriculture, Irrigation and Water Development, Department of Agricultural Research Services, Lunyangwa Research Station, Mzuzu, Malawi
[5]British Geological Survey, Keyworth, Nottingham, UK
[6]Community Health Sciences Unit, Ministry of Health, Lilongwe, Malawi
[7]Nutrition Unit of Ministry of Health, Lilongwe, Malawi
[8]Department of Human Nutrition, University of Otago, Dunedin, New Zealand

Received: May 21, 2013; Accepted: August 9, 2013

Agronomy

Health Economic Analyses

Plant Soil (2015) 389:1–24
DOI 10.1007/s11104-015-2430-8

MARSCHNER REVIEW

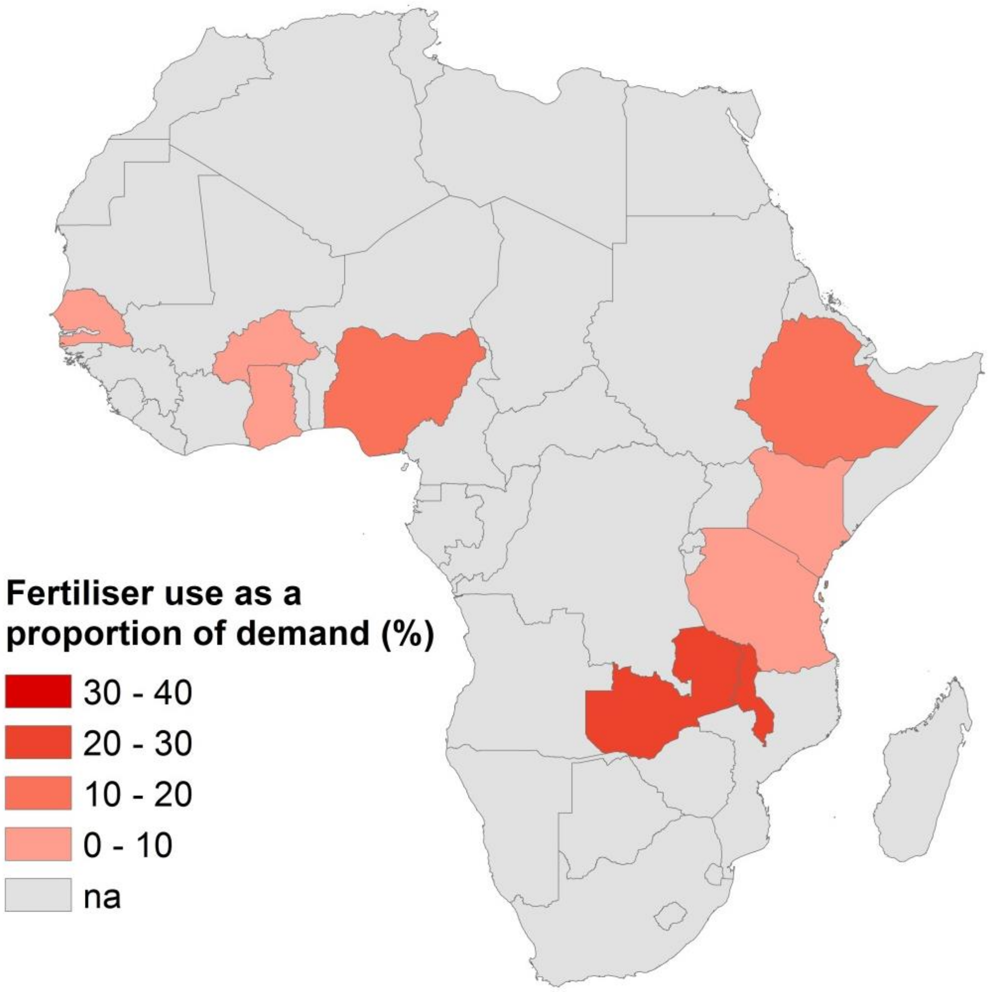
Zinc-enriched fertilisers as a potential public health intervention in Africa

Edward J. M. Joy · Alexander J. Stein · Scott D. Young · E. Louise Ander · Michael J. Watts · Martin R. Broadley

Received: 28 November 2014 / Accepted: 23 February 2015 / Published online: 8 March 2015

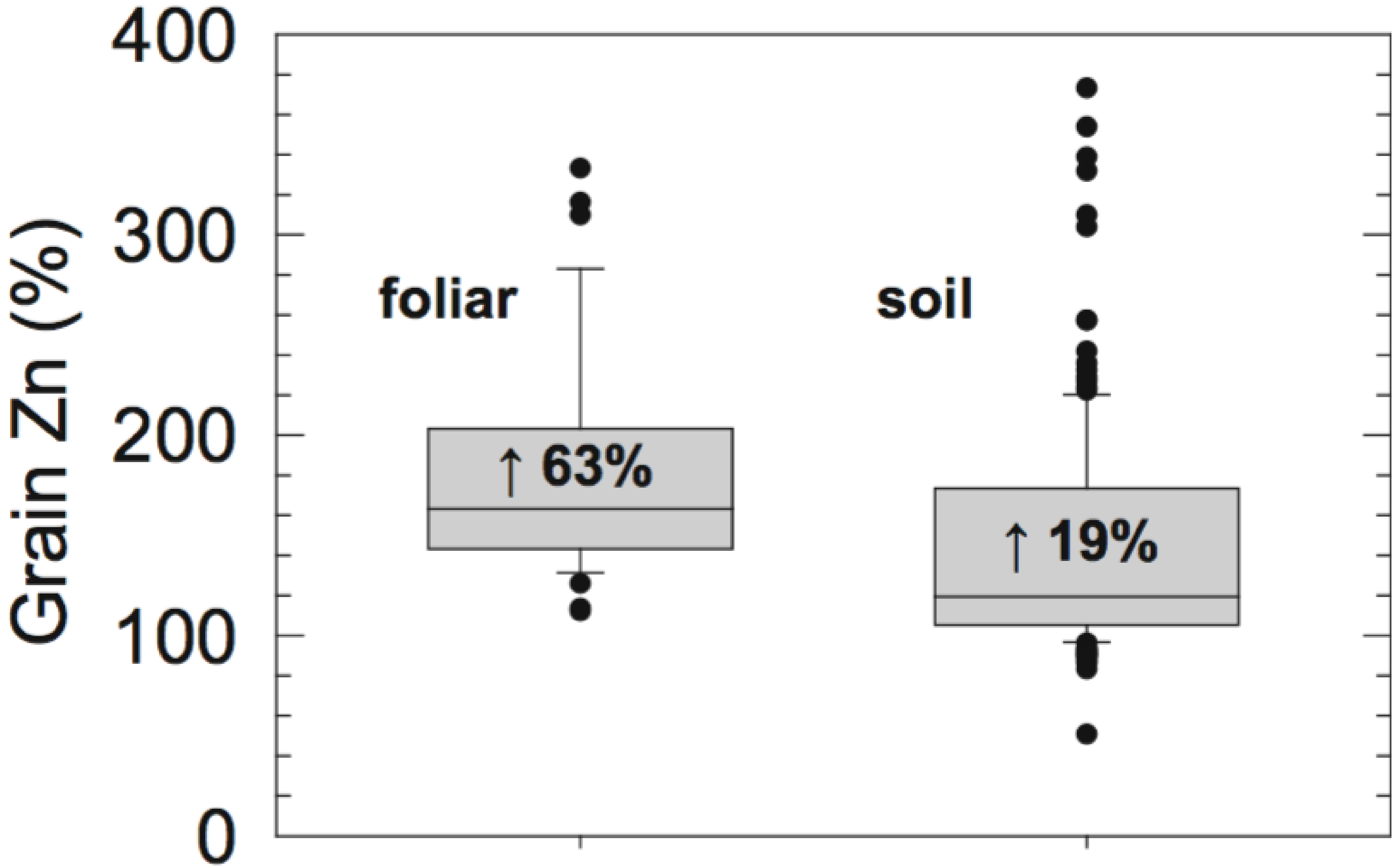
Joy EJM, Stein AJ, Young SD, Ander EL, Watts MJ, Broadley MR (2015). Zinc-enriched fertilisers as a potential public health intervention in Africa. *Plant and Soil*, 389, 1-24.

Fertiliser-use in sub-Saharan African countries with subsidies



Data from NEPAD/IFDC (2013) Practices and policy options for the improved design and implementation of fertilizer subsidy programs in sub-Saharan Africa. https://ifdcorg.files.wordpress.com/2015/01/sp-41_rev.pdf [October 2015]

Increases in grain Zn concentration as a result of Zn fertilisation (literature-survey; Joy et al., 2015)



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Foliar Zn fertiliser application to maize on a smallholder farm, Zimbabwe, 2009 (photo, Prof. Florence Mtambanengwe, University of Zimbabwe)

Health Economic Analyses
(based on Disability Adjusted Life Years, DALYs)

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Health AND Yield Economic Analyses

Plant Soil
DOI 10.1007/s11104-016-2961-7

REGULAR ARTICLE

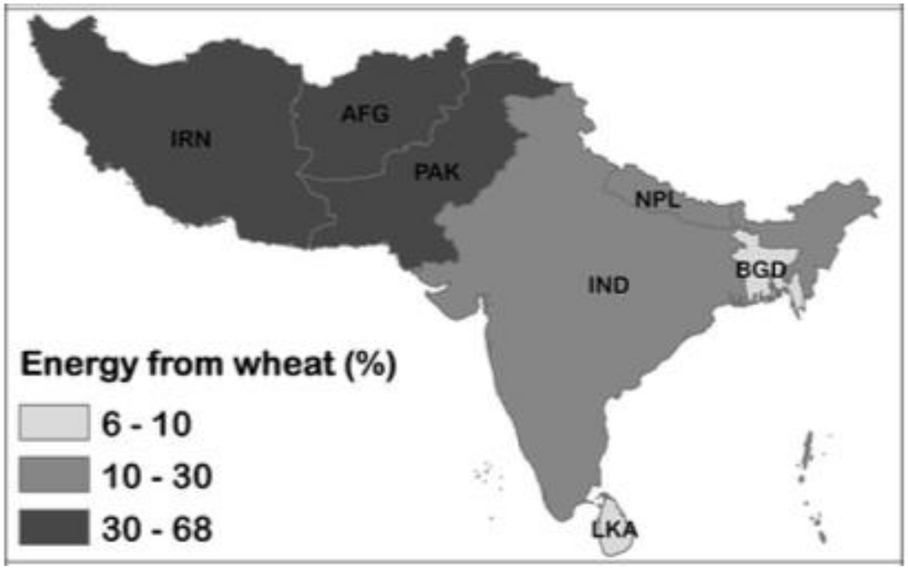
Valuing increased zinc (Zn) fertiliser-use in Pakistan

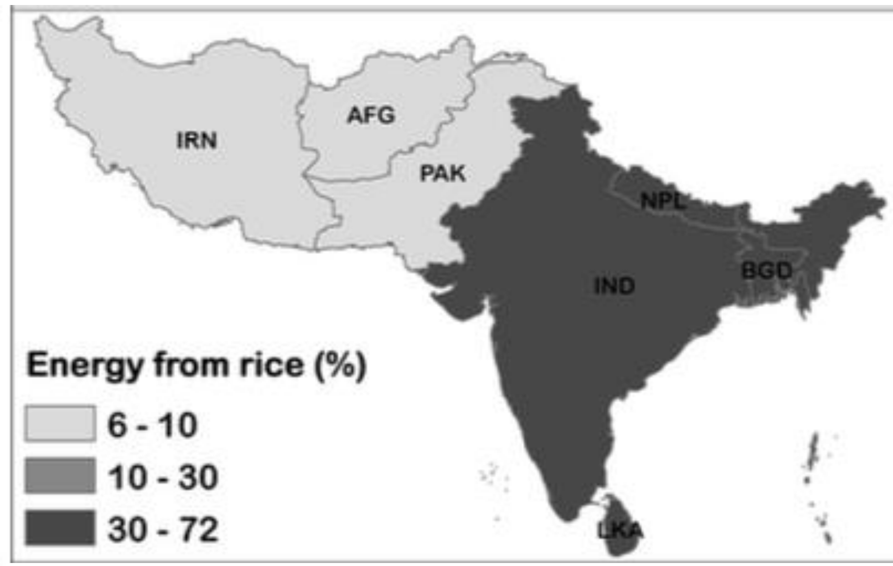
Edward J. M. Joy · Waqar Ahmad · Munir H. Zia · Diriba B. Kumssa · Scott D. Young · E. Louise Ander · Michael J. Watts · Alexander J. Stein · Martin R. Broadley

Received: 12 February 2016 / Accepted: 13 June 2016

Joy EJM, Ahmad W, Zia MH, Kumssa DB, Young SD, Watts MJ, Stein AJ, Broadley MR (2016). Valuing increased zinc (Zn) fertiliser-use in Pakistan. *Plant and Soil*, doi: 10.1007/s11104-016-2961-7.

Valuing Zn fertiliser use in Pakistan





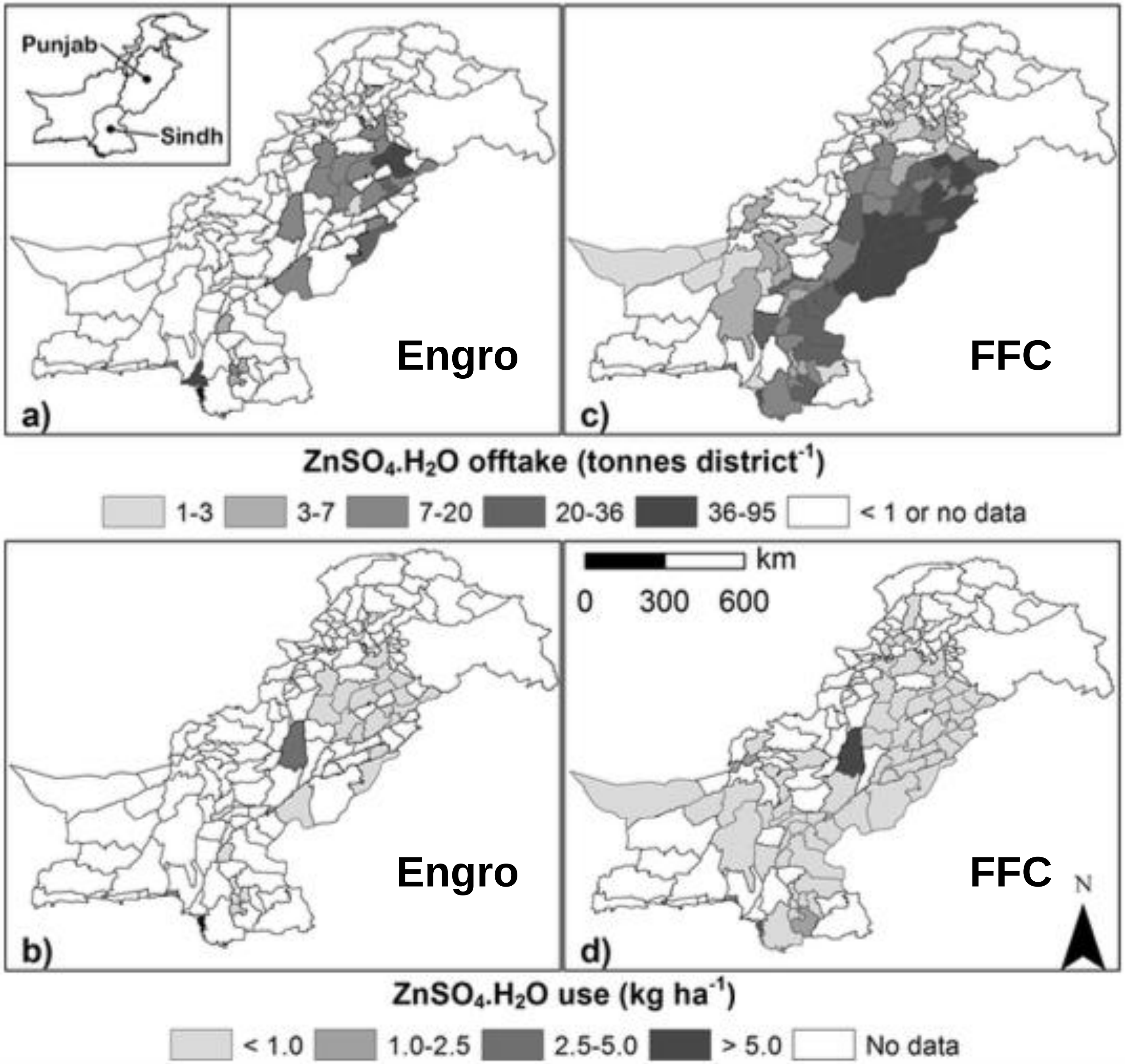
Joy EJM, Ahmad W, Zia MH, Kumssa DB, Young SD, Watts MJ, Stein AJ, Broadley MR (2016). Valuing increased zinc (Zn) fertiliser-use in Pakistan. *Plant and Soil*, doi: 10.1007/s11104-016-2961-7.

Wheat is the major crop of Punjab and Sindh Provinces

Area	Cropped area, wheat (Mha)	Wheat production (Mt)	Wheat yield ($t\ ha^{-1}$)
Punjab	7.5	18.4	2.5
Sindh	1.9	3.5	1.9
Pakistan	~10	~25	~2.7

Source. PBS Agriculture Census 2010 (p. 36); N.B. 90/97% of wheat is irrigated in Punjab/Sindh (p.39)

Industry estimates of Zn-use in Pakistan



NFDC

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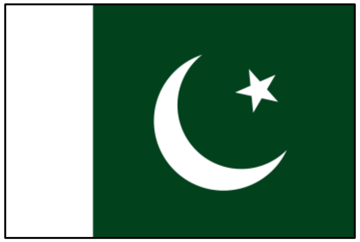


Agricultural Zn-use baselines in Pakistan

Based on rapid farmer surveys

Farmers surveyed in Punjab (n=1193), and Sindh (n=1338) Provinces

Farmers asked about their crop-specific fertiliser-usage and yields
wheat, rice, cotton, sugarcane, maize, 'other'

Only data for wheat are used in this study

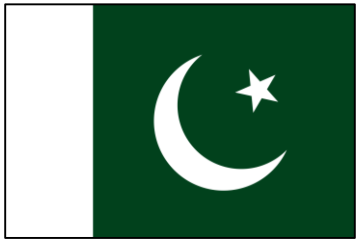
NFDC

FAUJI FERTILIZER COMPANY LIMITED

Rapid farmer survey in Punjab and Sindh

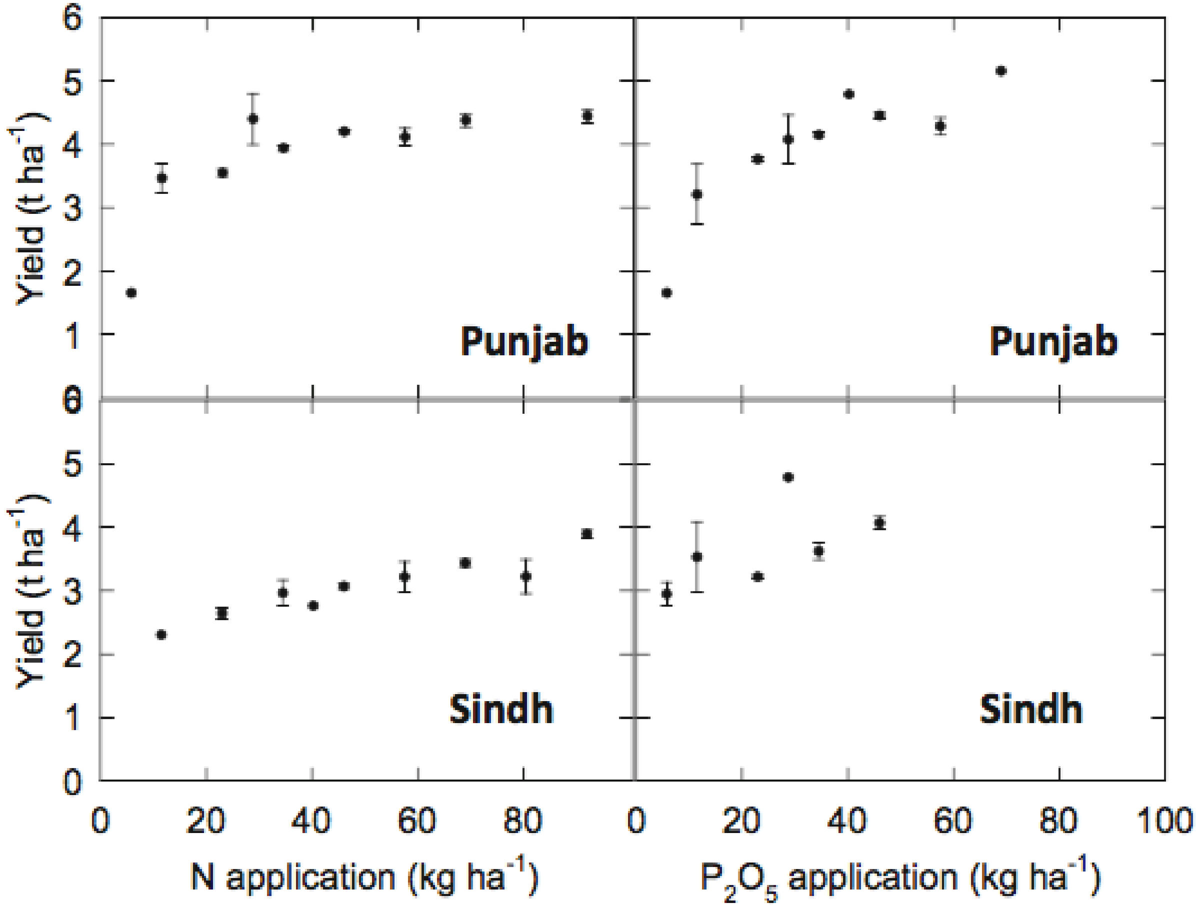
Area	Farmers surveyed		
Punjab	1,193		
Sindh	1,338		
Combined	2,531		

Source. W. Ahmad et al. (2015), unpublished survey data.



Rapid farmer survey in Punjab and Sindh

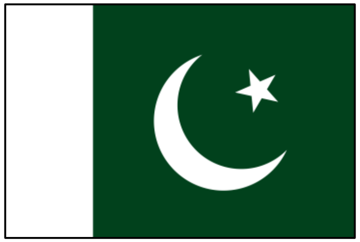
Yield-response of wheat to N (urea) and P_2O_5 (di-ammonium phosphate, DAP)



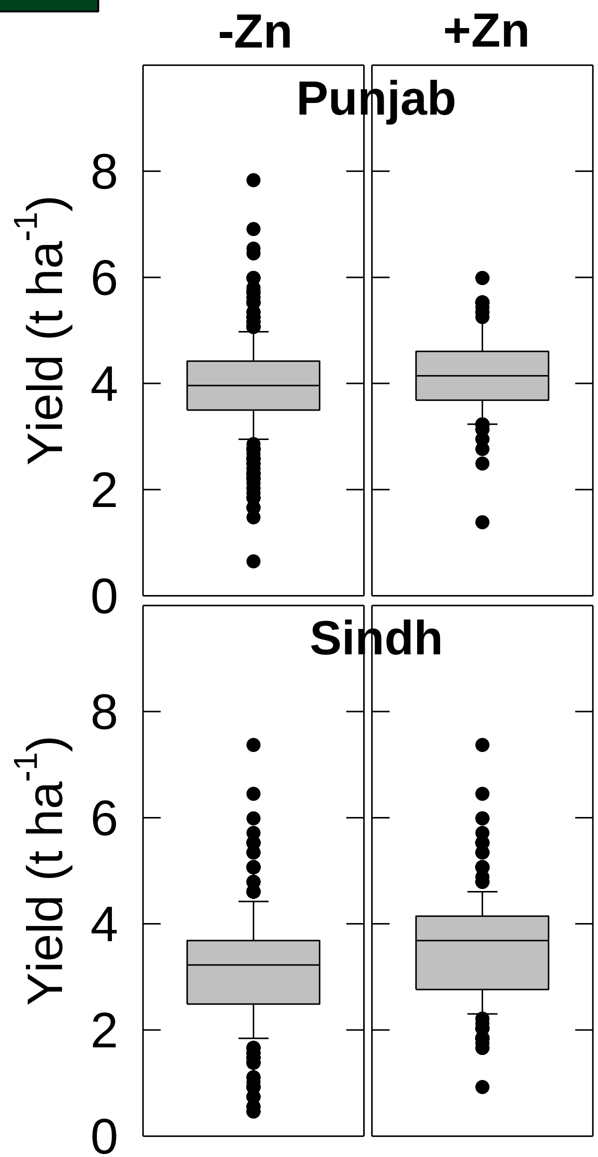
Joy EJM, Ahmad W, Zia MH, Kumssa DB, Young SD, Watts MJ, Stein AJ, Broadley MR (2016). Valuing increased zinc (Zn) fertiliser-use in Pakistan. *Plant and Soil*, doi: 10.1007/s11104-016-2961-7.

Zn fertilisers are currently used by a proportion of (progressive) farmers

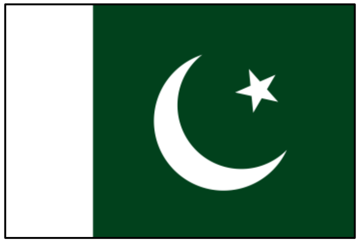
Area	Farmers surveyed	Using Zn fertilisers	Using Zn fertilisers? (%)
Punjab	1,193	172	14
Sindh	1,338	310	23
Combined	2,531	482	19



Yield response to Zn fertiliser



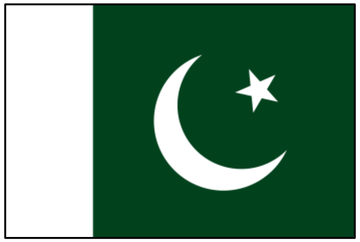
Area	-Zn mean yield (t ha^{-1})	+Zn mean yield (t ha^{-1})	%	*P*
Punjab	4.0	4.3	108	<0.001
Sindh	3.1	3.6	114	<0.001



Value of increased Zn fertiliser-use in Pakistan

Assumptions used to value Zn fertiliser-use:

1. **Baseline Zn-use 7.3 kt y^{-1} at 4.8 kg ha^{-1} ($ZnSO_4.H_2O$ eq. @ 33% Zn)**
2. **Constant granular:foliar ratio of 0.7:0.3**
3. **Wheat support price: \$312 USD t^{-1}**
4. **Cost of $ZnSO_4.H_2O$: \$1600 USD t^{-1}**
5. **Scenario: ↑ Zn fertilisers are distributed to 100% wheat in Punjab, Sindh**
6. **Benefit:Cost Ratios (BCRs) estimated for ↑ yield**
7. **Health economic impact of ↓ in DALYs lost, due to an ↑ in grain Zn concentration from national baseline surveys of wheat**



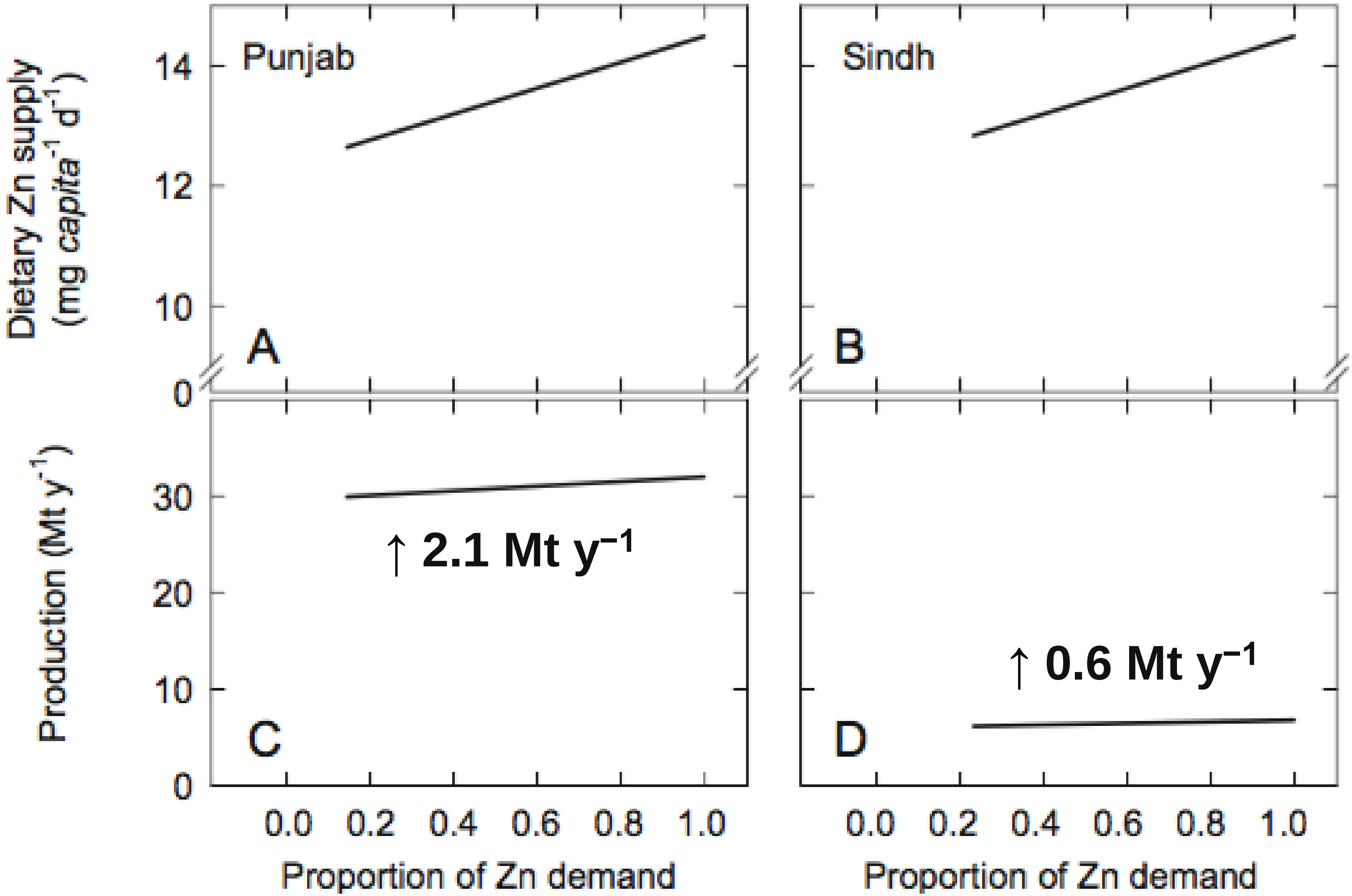
Value of increased Zn fertiliser-use in Pakistan

Assumptions used to value Zn fertiliser-use:

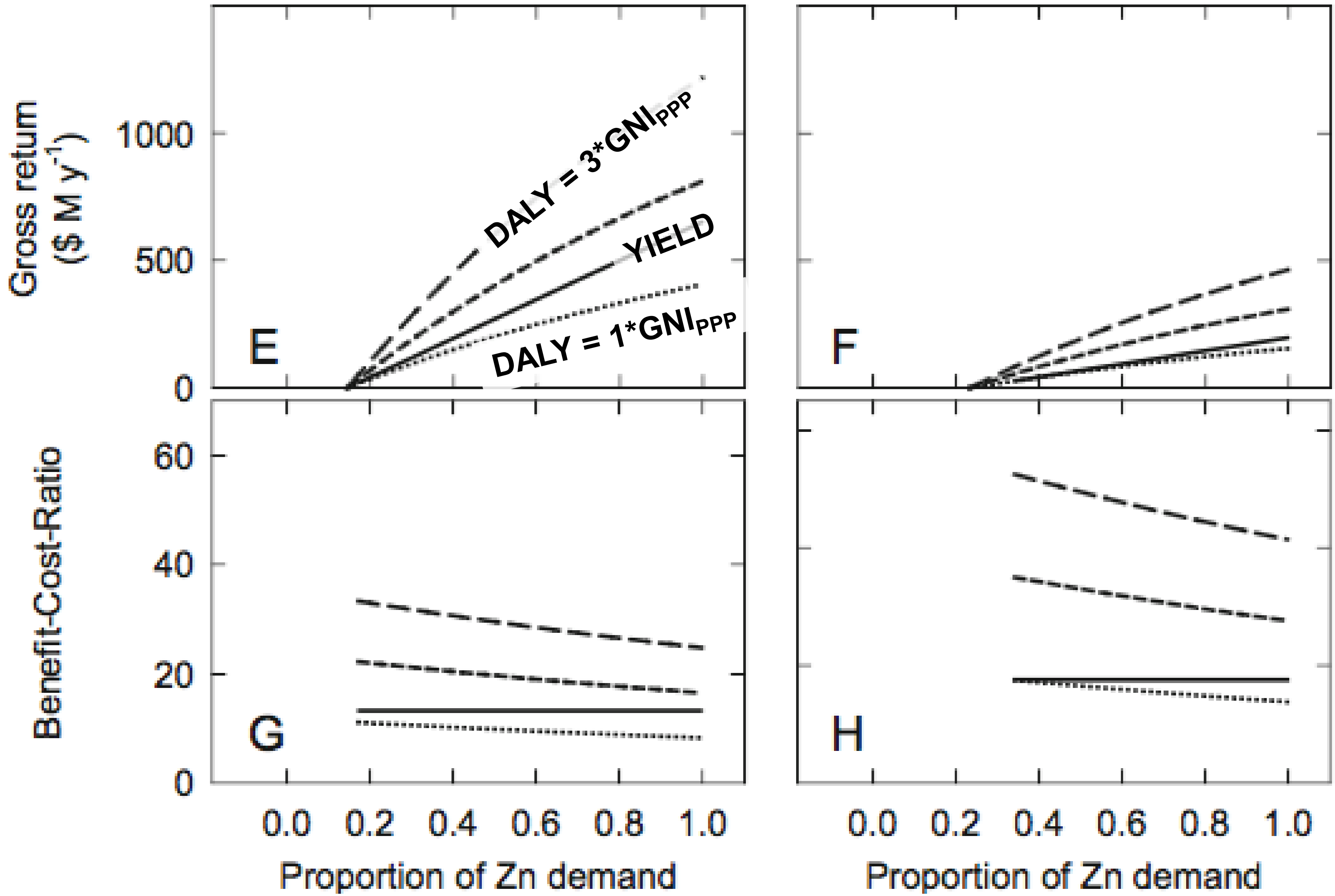
8. **4.8 kg ha^{-1} soil-Zn, ↑ grain Zn by 19% to 29.6 mg kg^{-1}**
9. **4.8 kg ha^{-1} foliar-Zn, ↑ grain Zn by 63%, to 40.6 mg kg^{-1}**
10. **Value of 1 DALY = *x* * Gross National Income-PPP, i.e. *x* * I$ 5,110**
    PPP=parity purchasing power: I$ based on 2011 International Comparison Program*
11. **BCRs for ↑ yield and ↓ in DALYs lost are additive**
12. **No discounting**

*http://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD

Valuing Zn fertiliser use in Pakistan (Zn supply, yield)



Valuing Zn fertiliser use in Pakistan (Zn supply, yield)



Valuing Zn fertiliser use in Pakistan (yield + DALYs)

Cost per DALY saved:

Punjab = $392-549 USD

Sindh = $256-349 USD

Health Economic Analyses
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Conservative BCRs

Used 24% Zn deficiency prevalence, likely to be >40%
Zn fertiliser effects can persist for 3-4 subsequent crops

Strong drivers for private and public investment in Zn fertilisers

Blending Zn and granular fertiliser in Punjab, Pakistan (photo, Dr Munir Zia, Fauji Fertiliser Company)

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Other soil improvements will increase yield further

P, K, and B fertilisers are under-utilised in Pakistan

Many saline/sodic soils

Breeding for increased grain Zn concentration adds further ‘value’

Funding Acknowledgements

FAO
FIAT PANIS

NATURAL ENVIRONMENT RESEARCH COUNCIL

E·S·R·C
ECONOMIC & SOCIAL RESEARCH COUNCIL

DFID Department for International Development

THE ROYAL SOCIETY

BBSRC
bioscience for the future

Funding Acknowledgements

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"RUMO AOS NOVOS DESAFIOS"

16 a 20 de Outubro

Centro de Convenções de Goiânia - GO

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