2nd International Symposium of Magnesium
Magnesium in Crop Production, Food Quality and Human Health

4-6 November 2014, São Paulo, Brazil

Within-Species Genetic Variation in Leaf Magnesium Concentration in Forage Grasses

Beth Penrose, Edward J.M. Joy, Diriba B. Kumssa, Cathy Thomas

E. Louise Ander, Nick A. Beresford, Neil M.J. Crout, Neil S. Graham, J. Alan Lovatt, Sue Walker, Michael Watts, Philip J. White, Scott D. Young, Martin R. Broadley

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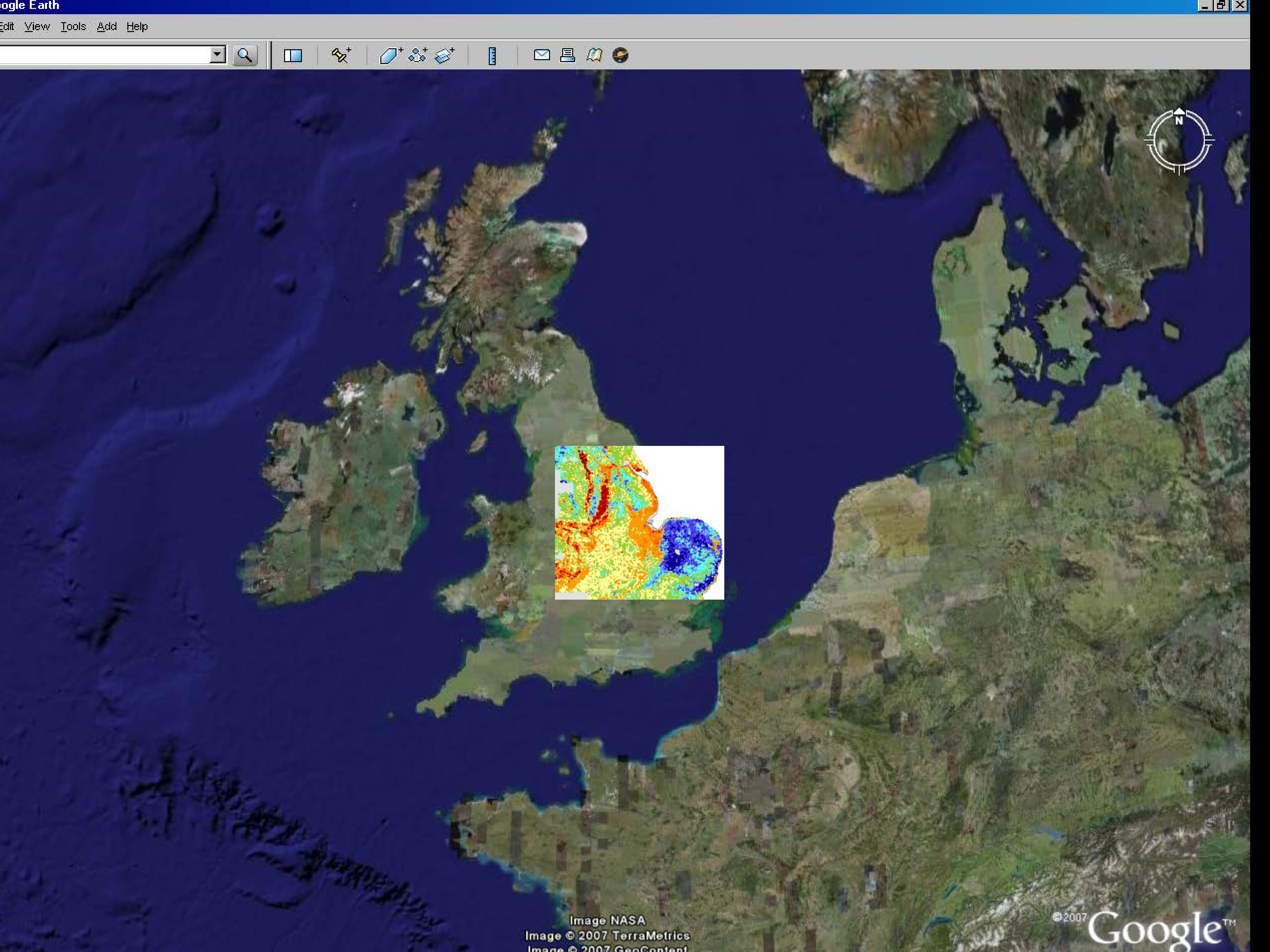
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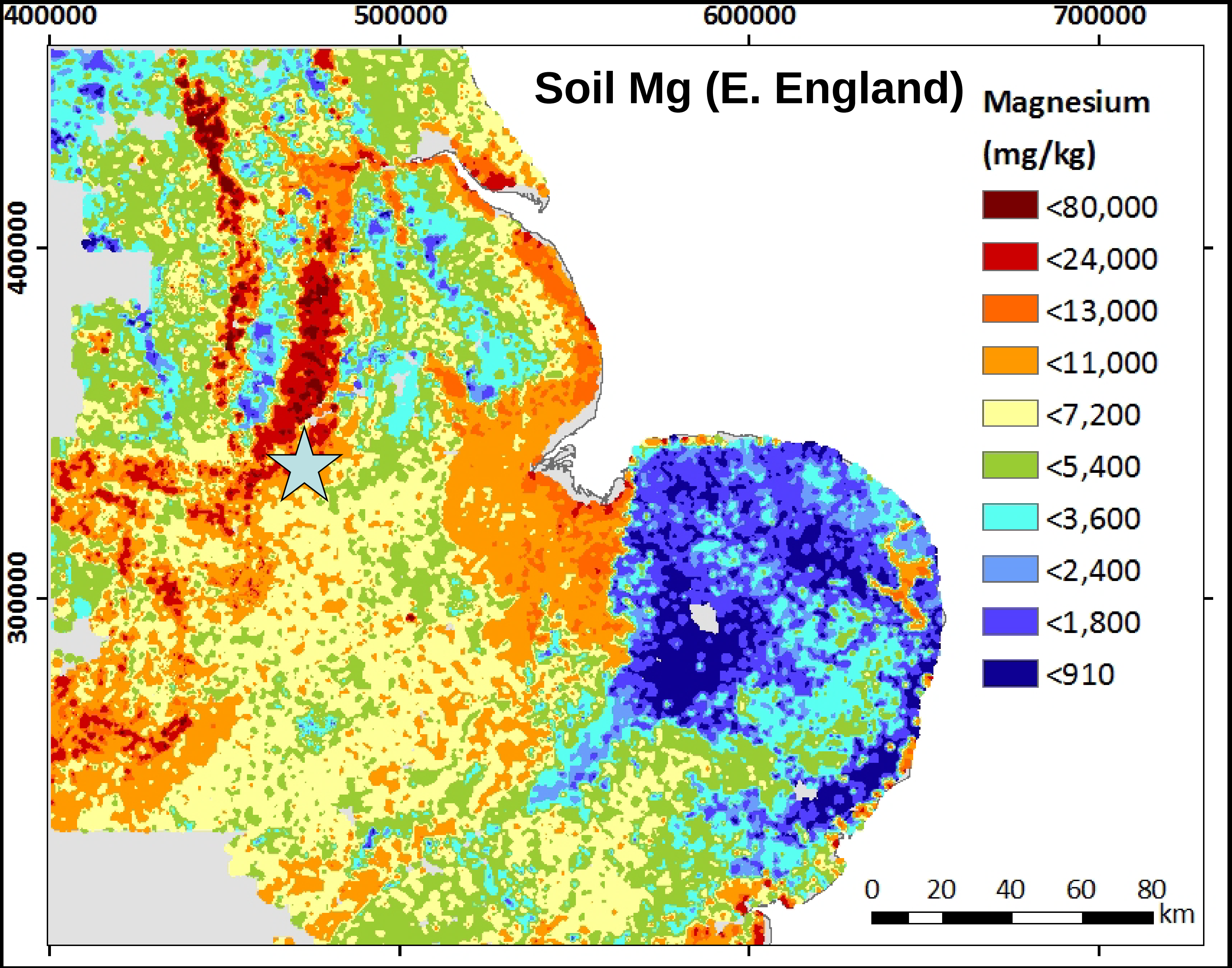


Soil Mg (E. England)
Magnesium (mg/kg)
<80,000
<24,000
<13,000
<11,000
<7,200
<5,400
<3,600
<2,400
<1,800
<910
400000
500000
600000
700000
400000
300000
0
20
40
60
80
km

Structure of talk

1. Global Mg supplies and deficiency risks
2. National Mg intakes
3. Breeding potential in crops (forage grass and brassica)
4. Breeding vs fertilisers?

Global Mg supplies

Supply = Food Balance Sheet * Food Composition Table

Food & Agriculture Organization Food Balance Sheets (FBSs):
94 food items, 145 countries (>1m), 1992-2011 (FAOSTAT)

FBSs are net supply at household level, adjusted for edible portion

Food Composition Table (FCT) for Mg from US Dept. of Agriculture

Deficiency risks based on a 'cut-point' defined by requirements, assuming 25% variation in intake (inter-individual)

Plant Soil
DOI 10.1007/s11104-012-1388-z

REGULAR ARTICLE

Risk of dietary magnesium deficiency is low in most African countries based on food supply data

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

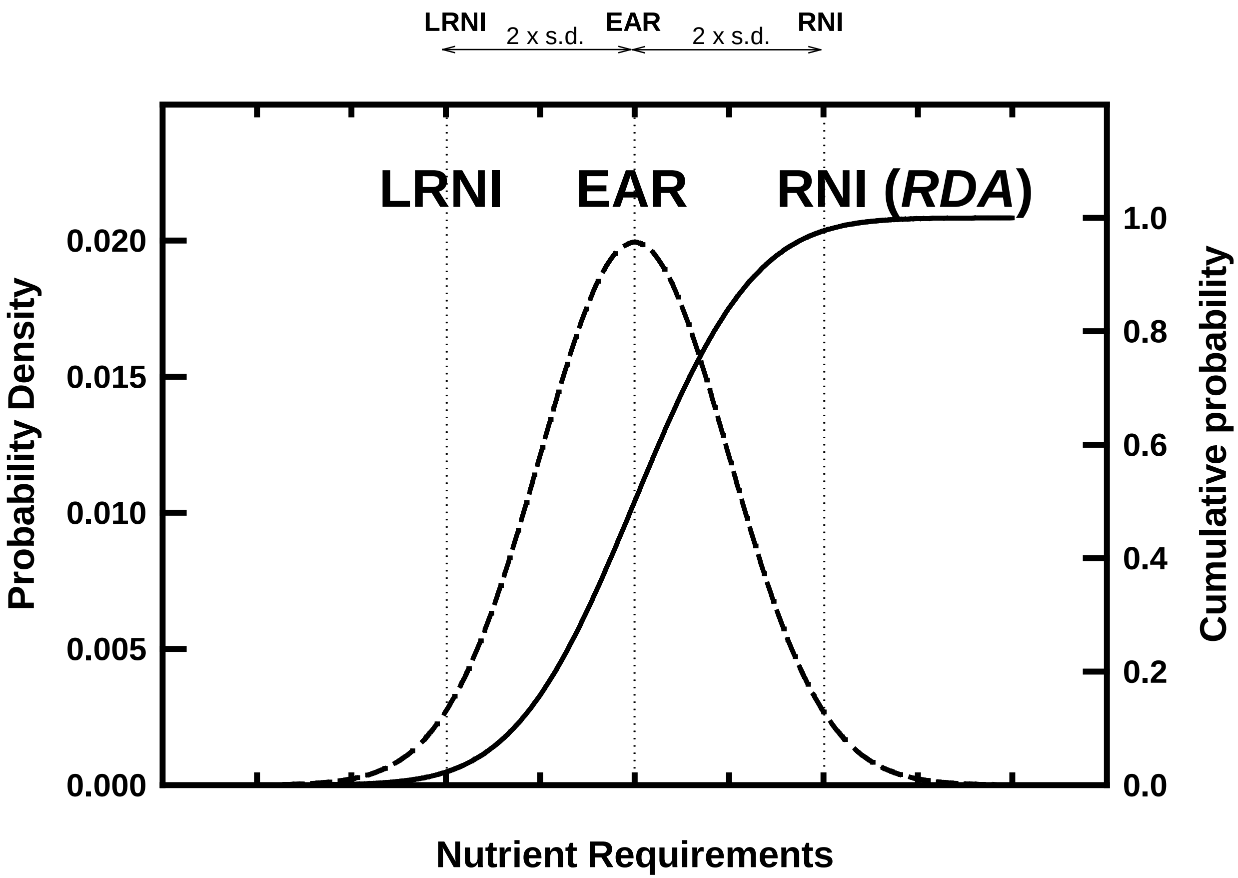
Physiologia Plantarum
An International Journal for Plant Biology
Physiologia Plantarum 151: 208–229. 2014 ISSN 0031-9317

Dietary mineral supplies in Africa

Edward J. M. Joy[a,b,†], E. Louise Ander[b,†], Scott D. Young[a], Colin R. Black[a], Michael J. Watts[b], Allan D. C. Chilimba[c], Benson Chilima[d], Edwin W. P. Siyame[e], Alexander A. Kalimbira[e], Rachel Hurst[f], Susan J. Fairweather-Tait[f], Alexander J. Stein[g], Rosalind S. Gibson[h], Philip J. White[i] and Martin R. Broadley[a,*]

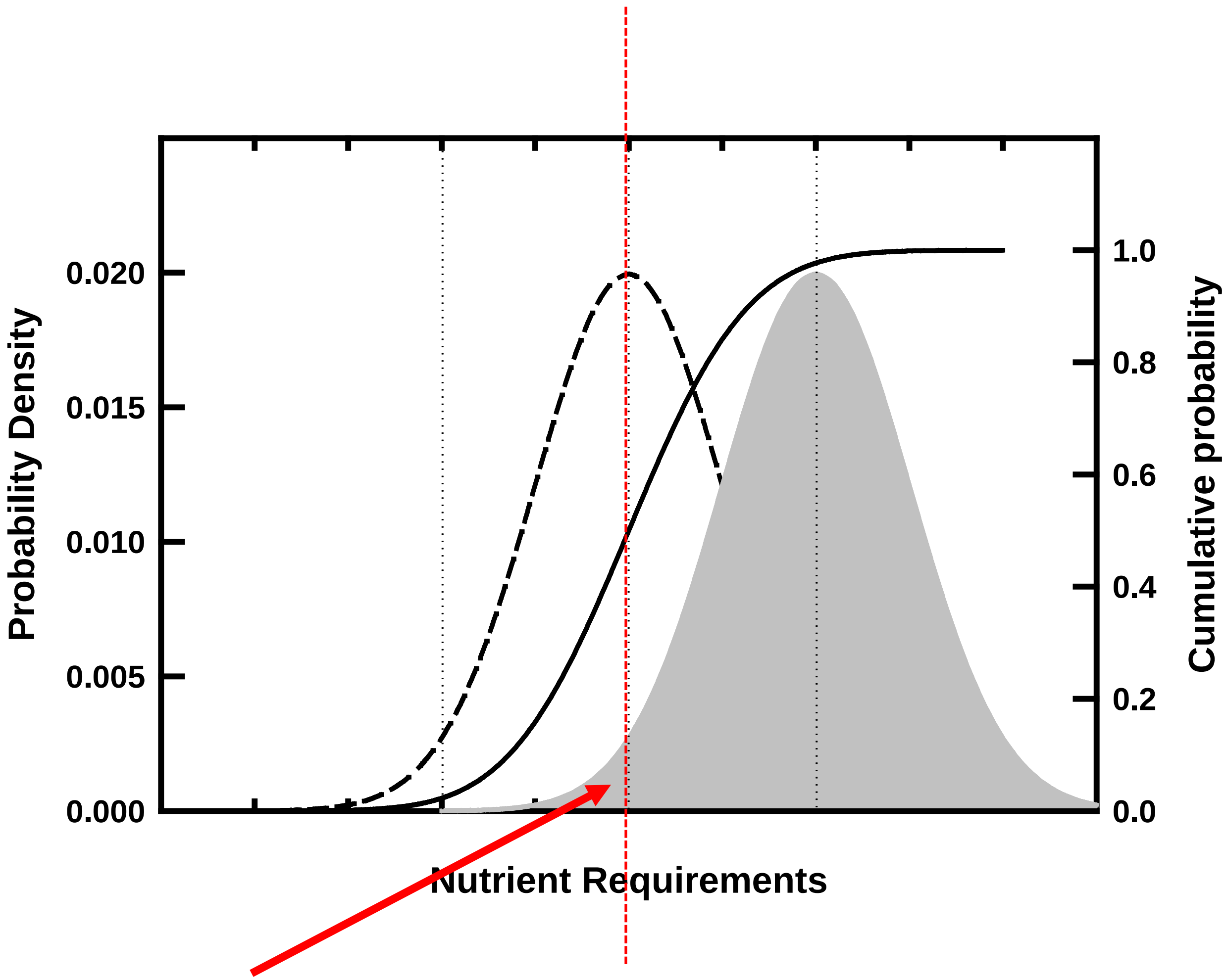
Diriba B. Kumssa et al., in prep

Estimated Average Requirement ‘cut-point’



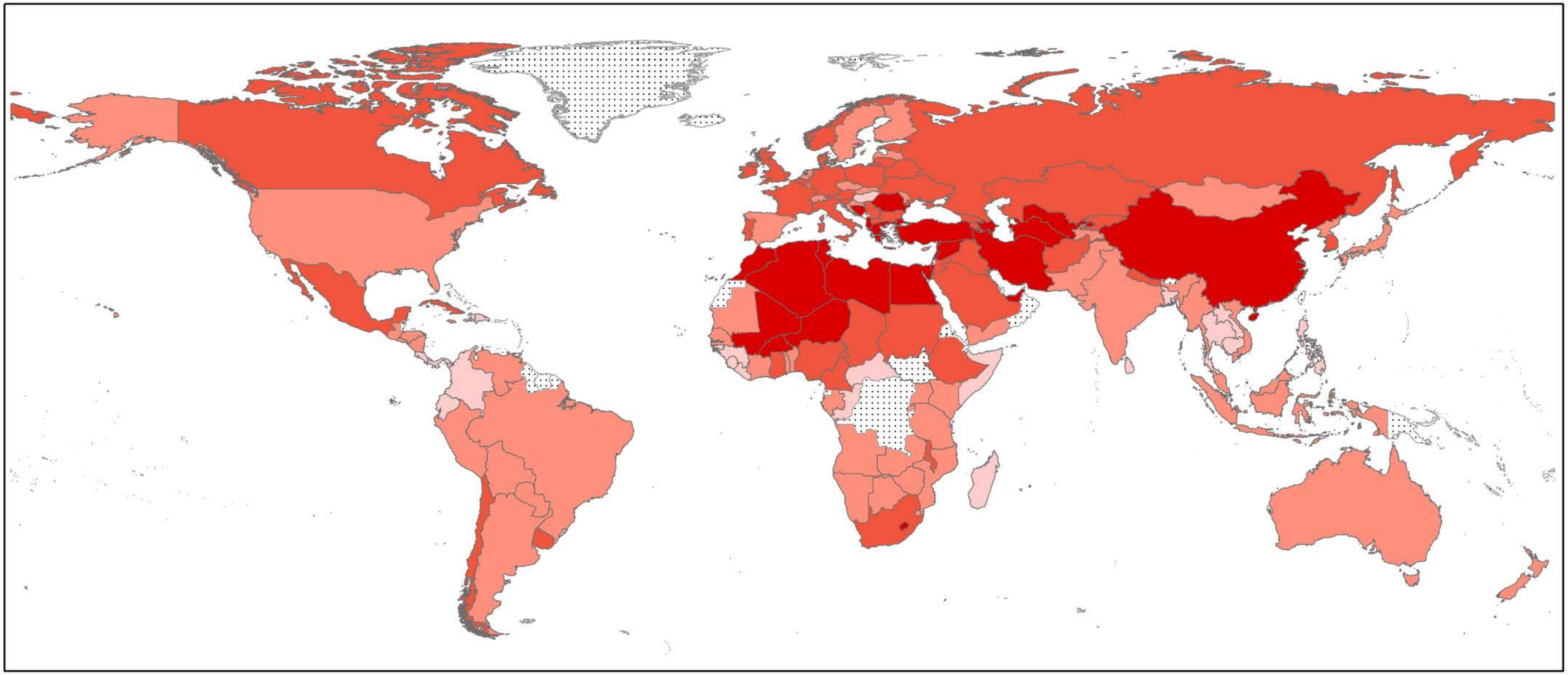
EAR = Estimated Average Requirement
(L)RNI = (Lower) Reference Nutrient Intake

Estimated Average Requirement ‘cut-point’



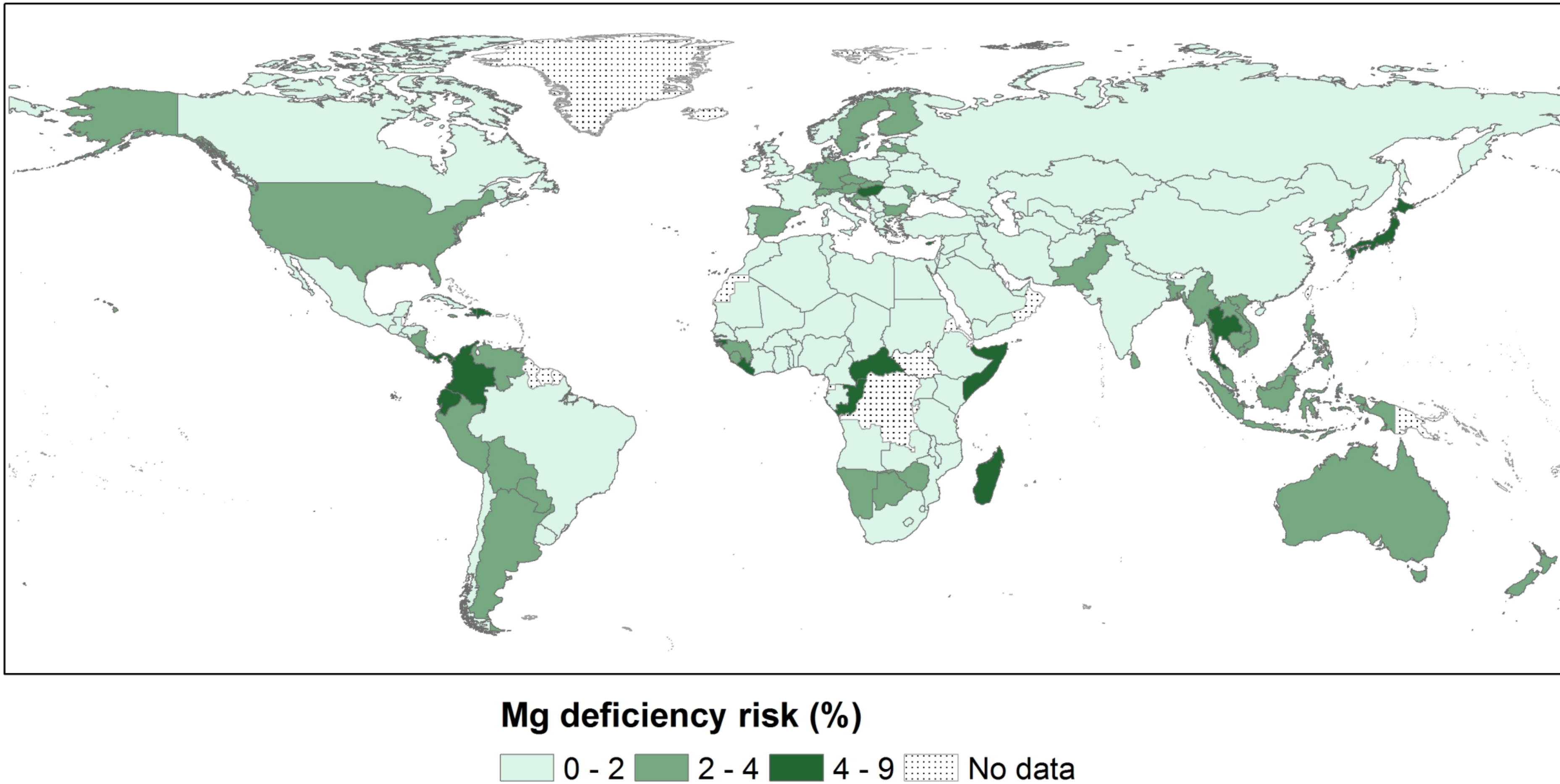
Risk of deficiency based on inadequate intake

Global Mg supply (2011)



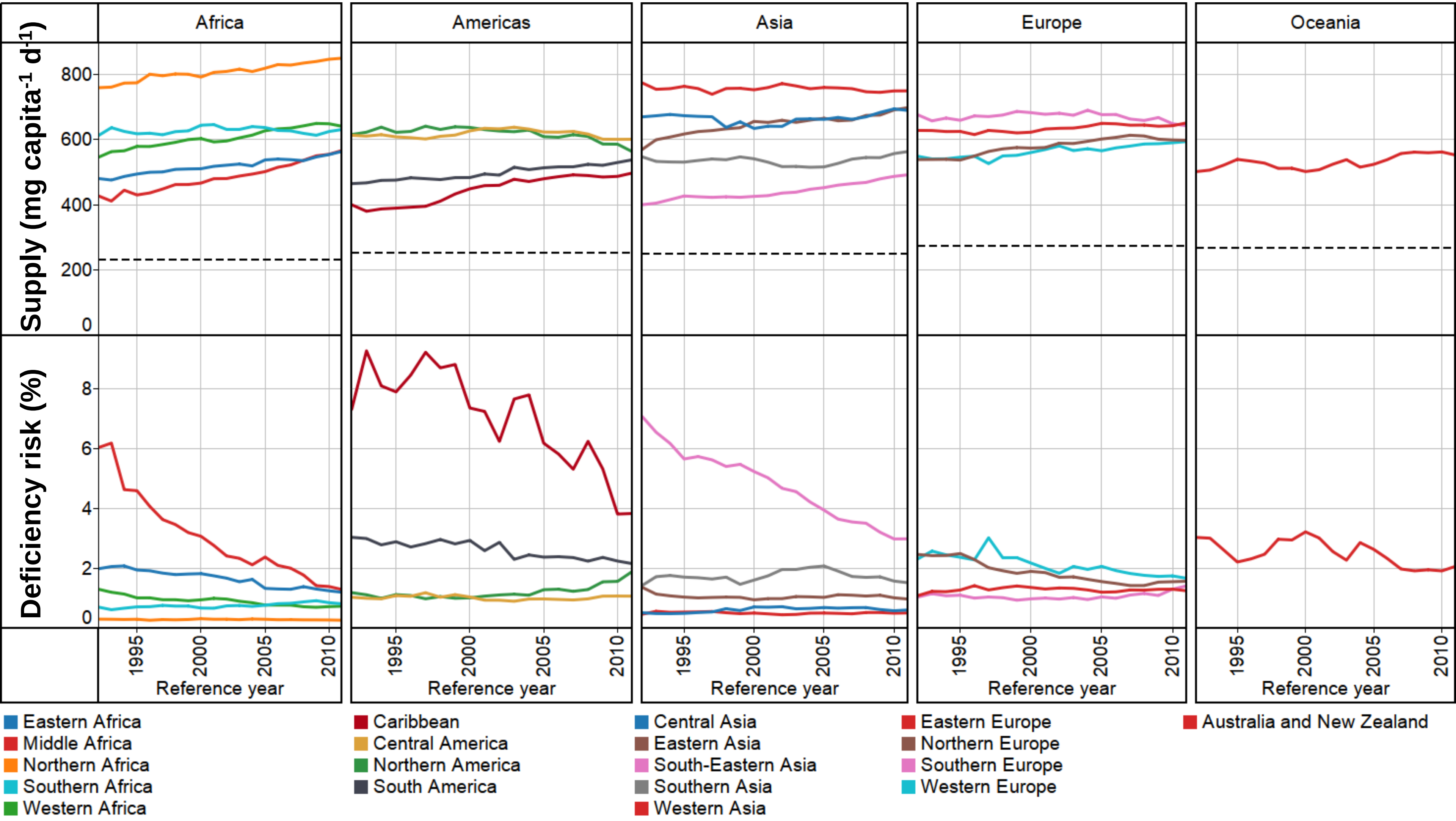
Diriba B. Kumssa et al., in prep.

Global Mg deficiency risk (2011): WtdEAR=258 mg *capita*$^{-1}$ d^{-1}



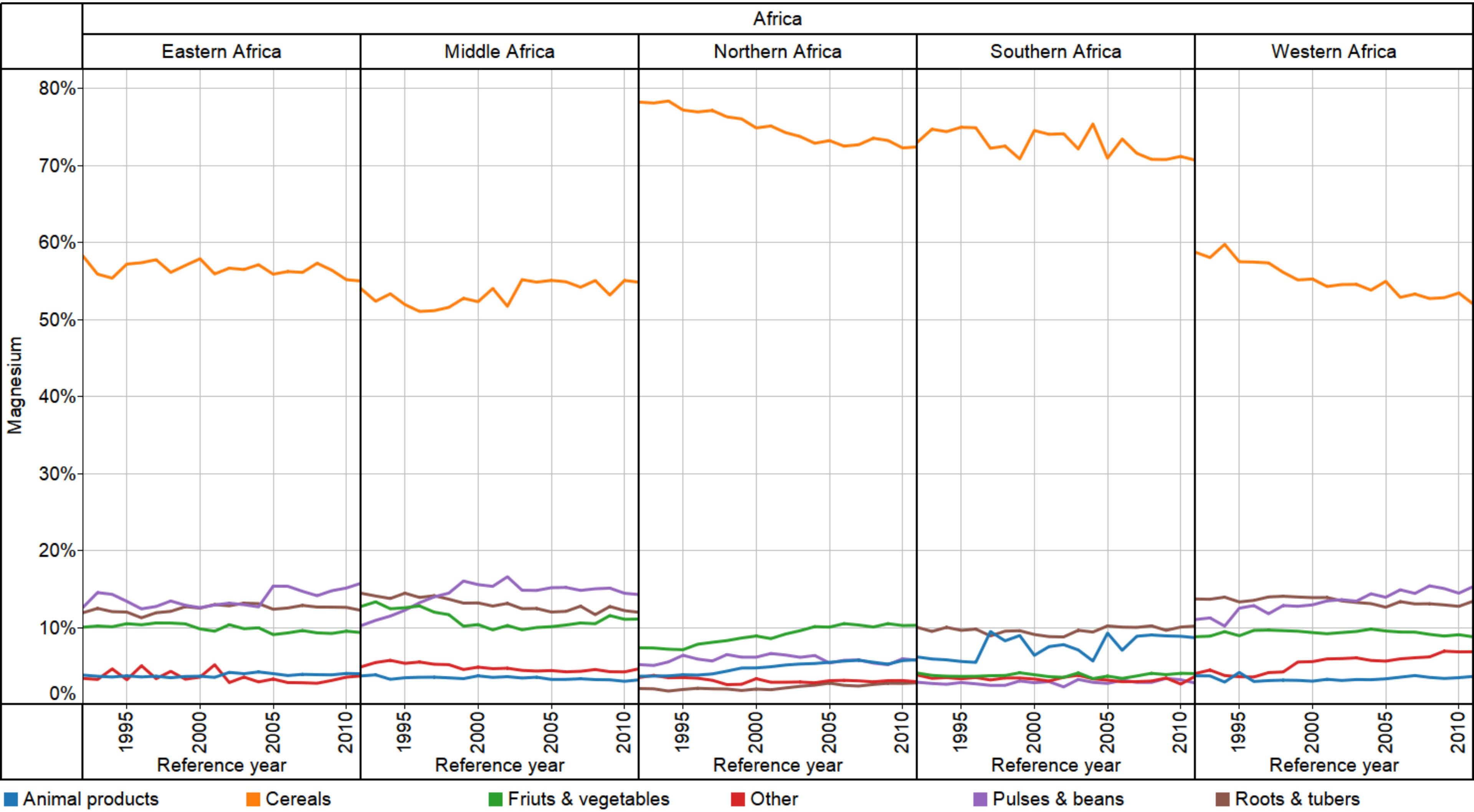
Diriba B. Kumssa et al., in prep.

Global Mg supply and deficiency risks (1992-2011)



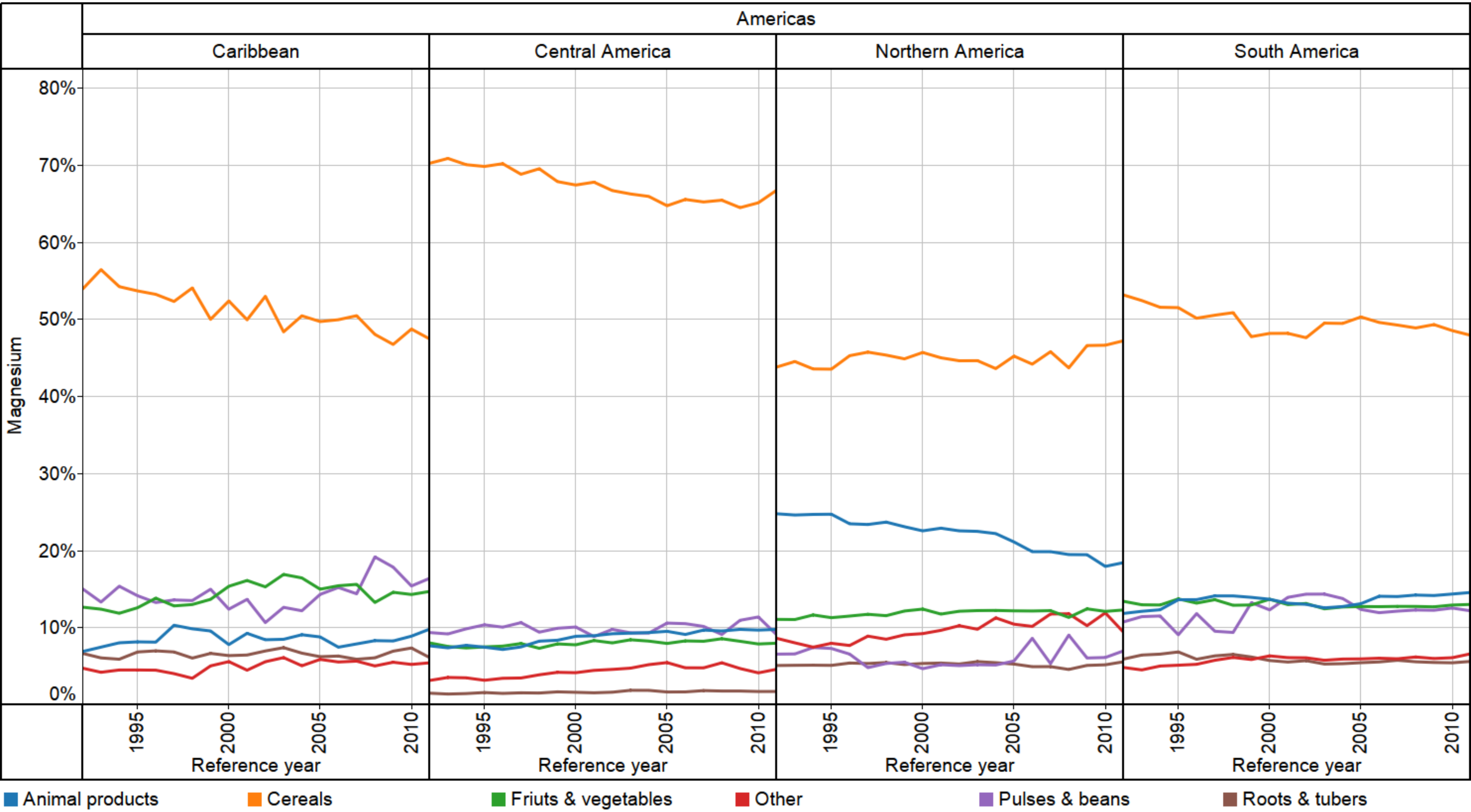
Diriba B. Kumssa et al., in prep.

Global Mg supply by food group (1992-2011): Africa



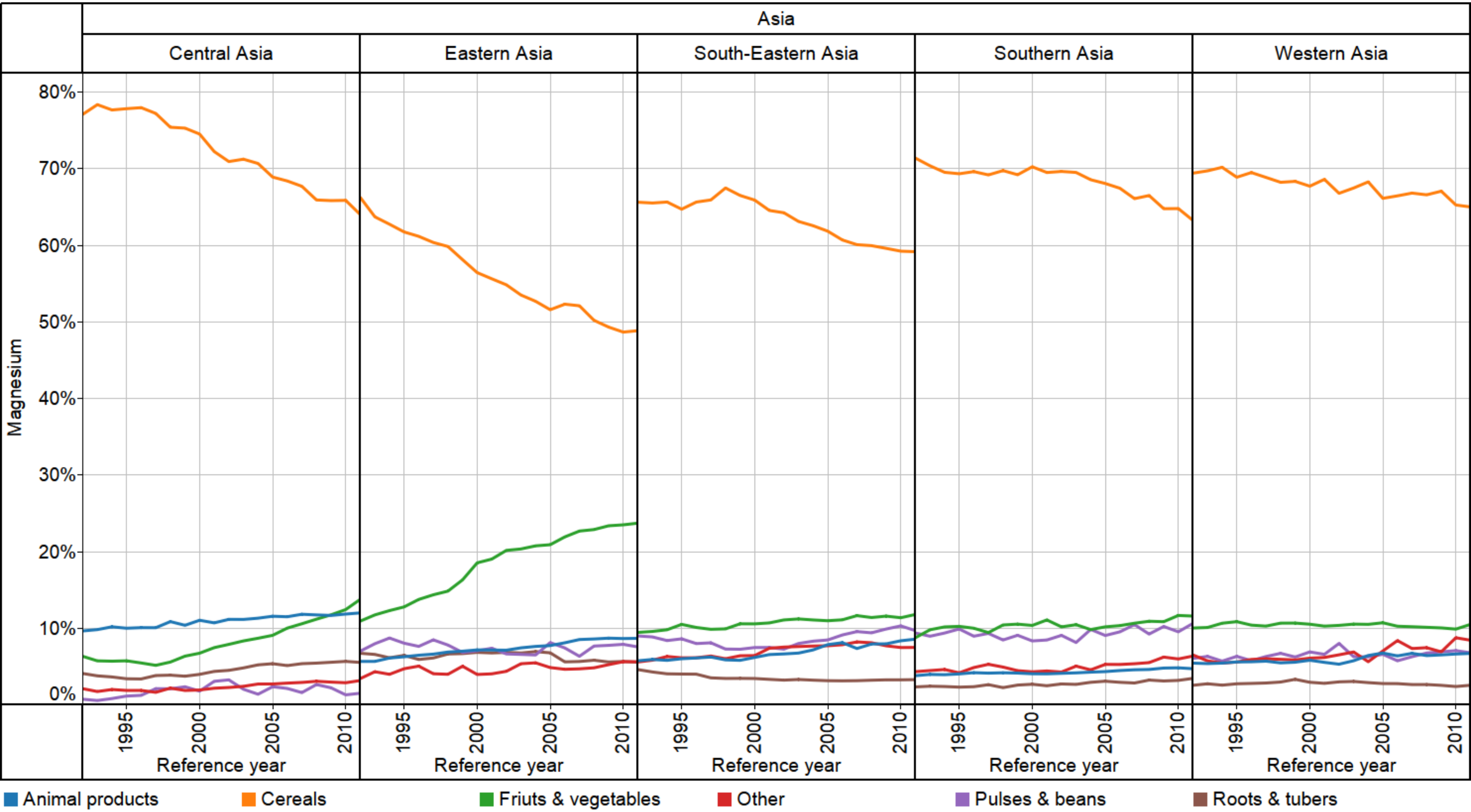
Diriba B. Kumssa et al., in prep.

Global Mg supply by food group (1992-2011): Americas



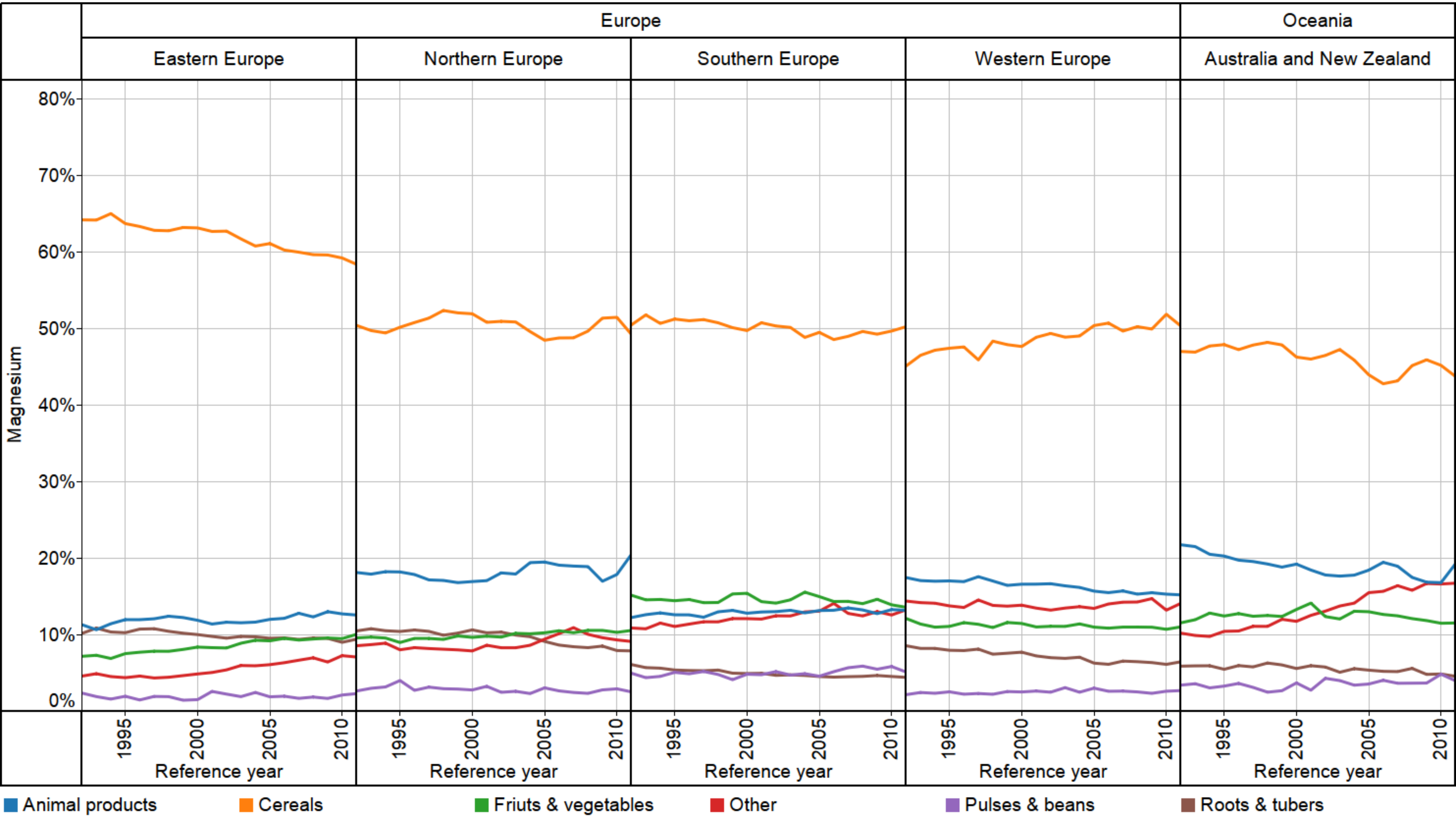
Diriba B. Kumssa et al., in prep.

Global Mg supply by food group (1992-2011): Asia



Diriba B. Kumssa et al., in prep.

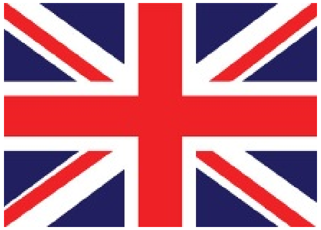
Global Mg supply by food group (1992-2011): Europe



Diriba B. Kumssa et al., in prep.

Structure of talk

1. Global Mg supplies and deficiency risks
2. <u>National Mg intakes</u>
3. Breeding potential in crops (forage grass and brassica)
4. Breeding vs fertilisers?



National Mg supply (UK)

2008/09 - 2011/12

UK energy supply (FAO FBS) in 2011: 3414 kcal *capita*$^{-1}$ d^{-1}

UK Mg deficiency risk (FAO FBS) in 2011: 1.5% (~600 mg *capita*$^{-1}$ d^{-1})

Mg intakes from rolling National Diet & Nutrition Survey (NDNS):

11% females, 16% males, 19-64 <LRNI 150/190 mg d^{-1}

53% females, 28% males, 11-18 <LRNI ~190 mg d^{-1}

(Under?)-reported energy intakes from NDNS:

females 19-64:	1613 (455)
females 11-18:	1569 (423)
males 19-64:	2111 (617)
males 11-18:	1972 (518)

Edward J.M. Joy, Diriba B. Kumssa et al., in prep.

National Mg supply (Malawi)

Food 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’)

Edward J.M. Joy, Diriba B. Kumssa et al., in prep.

Dietary intake surveys in 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	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?	
			ITEM CODE	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

National Mg supply (Malawi)

Food 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’)

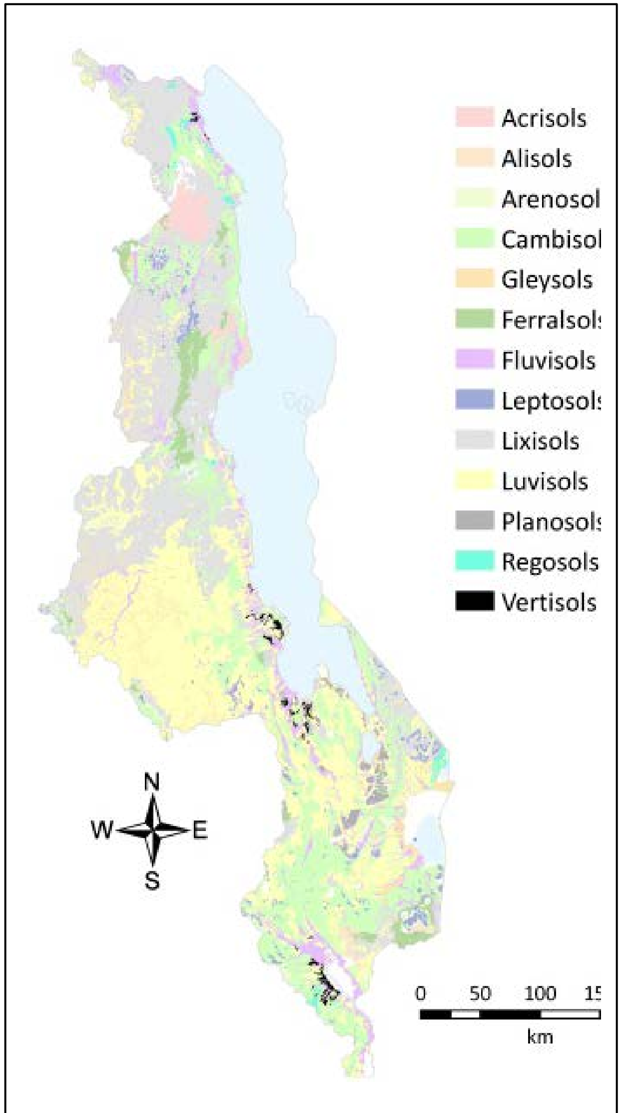
Enumerators recorded the amount consumed and source (i.e. ‘own production’, ‘bought’ or ‘gift’)

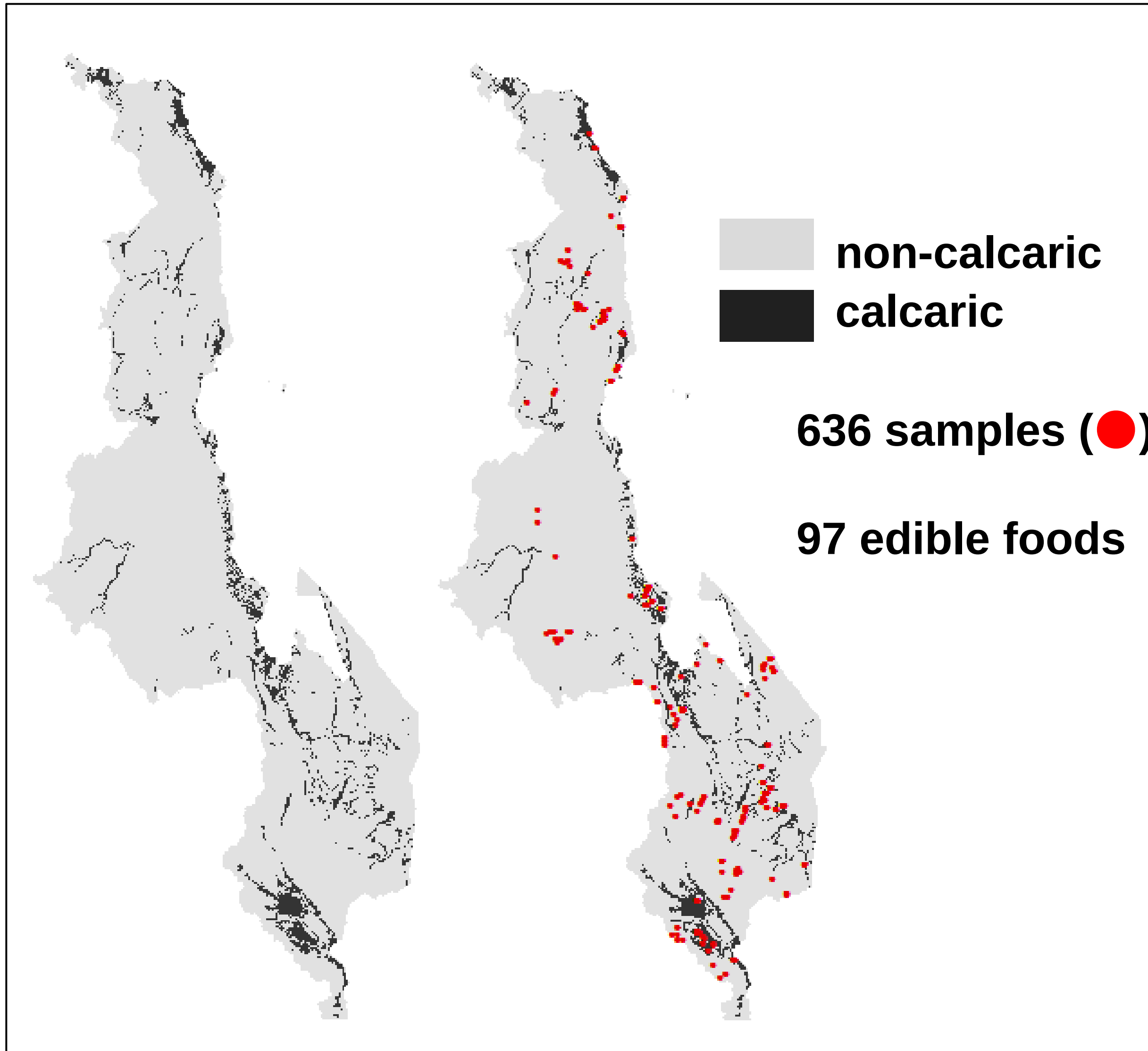
Units include standard metrics (grams, litres etc.) and local units (small plate, large plate, small bucket, large bucket, basin etc.)

Food composition data from Joy et al. (2015)

Edward J.M. Joy, Diriba B. Kumssa et al., in prep.

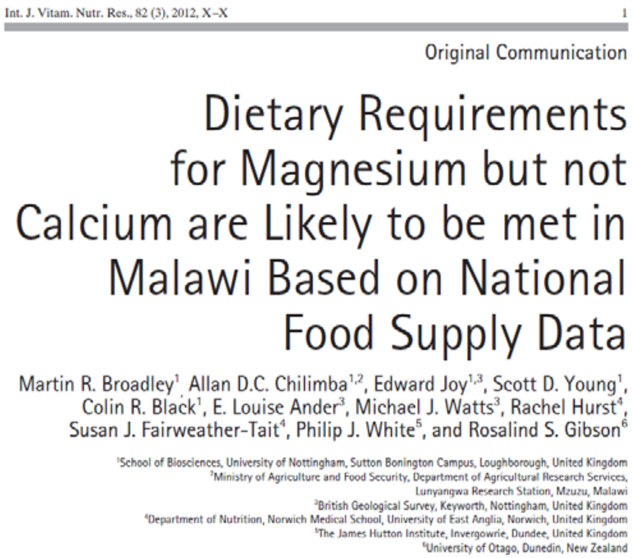
Food composition data (Malawi): 97 food types





Joy et al. (2015)

Food composition data (Malawi): maize



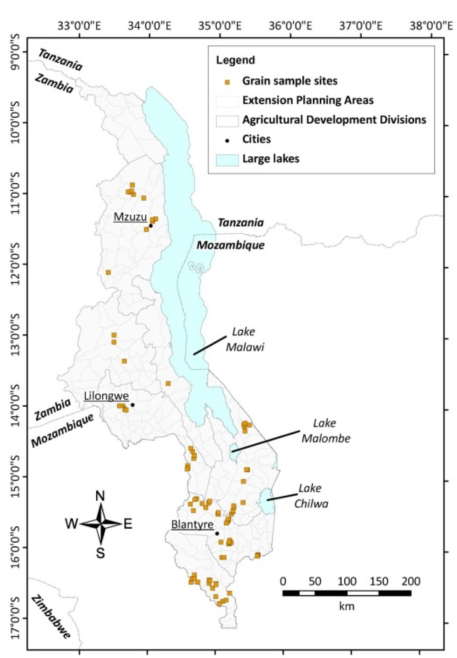
Int. J. Vitam. Nutr. Res., 82 (3), 2012, X–X 1

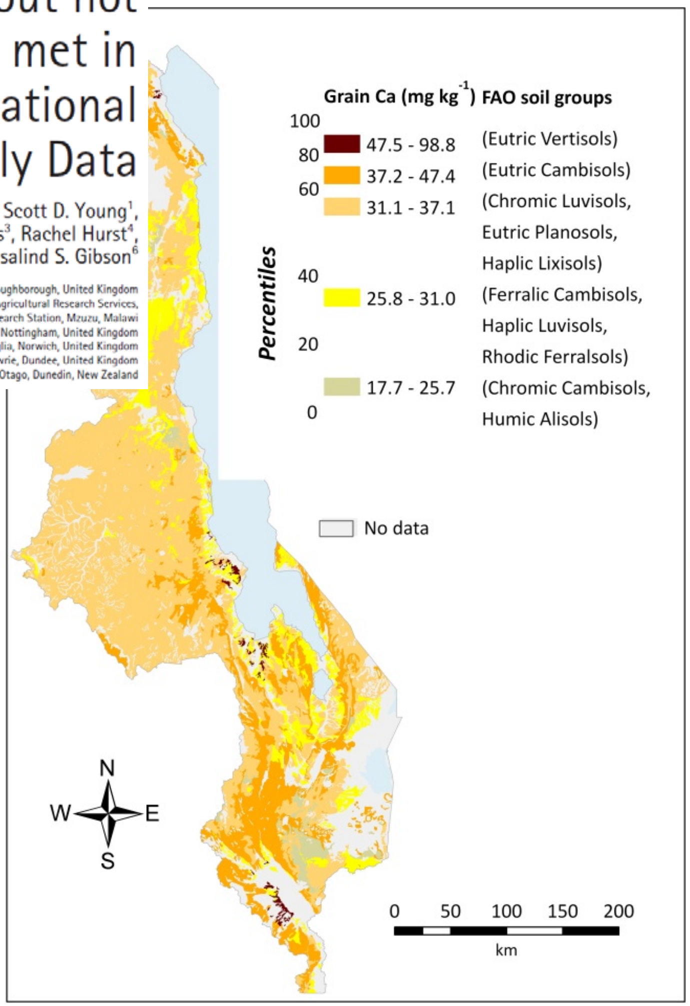
Original Communication

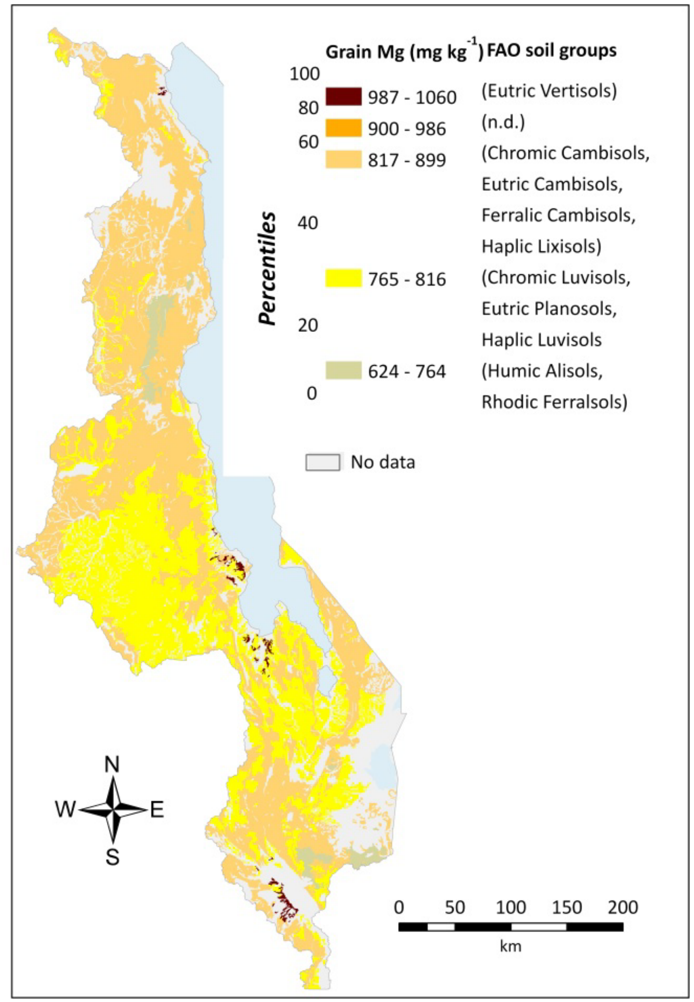
Dietary Requirements for Magnesium but not Calcium are Likely to be met in Malawi Based on National Food Supply Data

Martin R. Broadley[1], Allan D.C. Chilimba[1,2], Edward Joy[1,3], Scott D. Young[1], Colin R. Black[1], E. Louise Ander[3], Michael J. Watts[3], Rachel Hurst[4], Susan J. Fairweather-Tait[4], Philip J. White[5], and Rosalind S. Gibson[6]

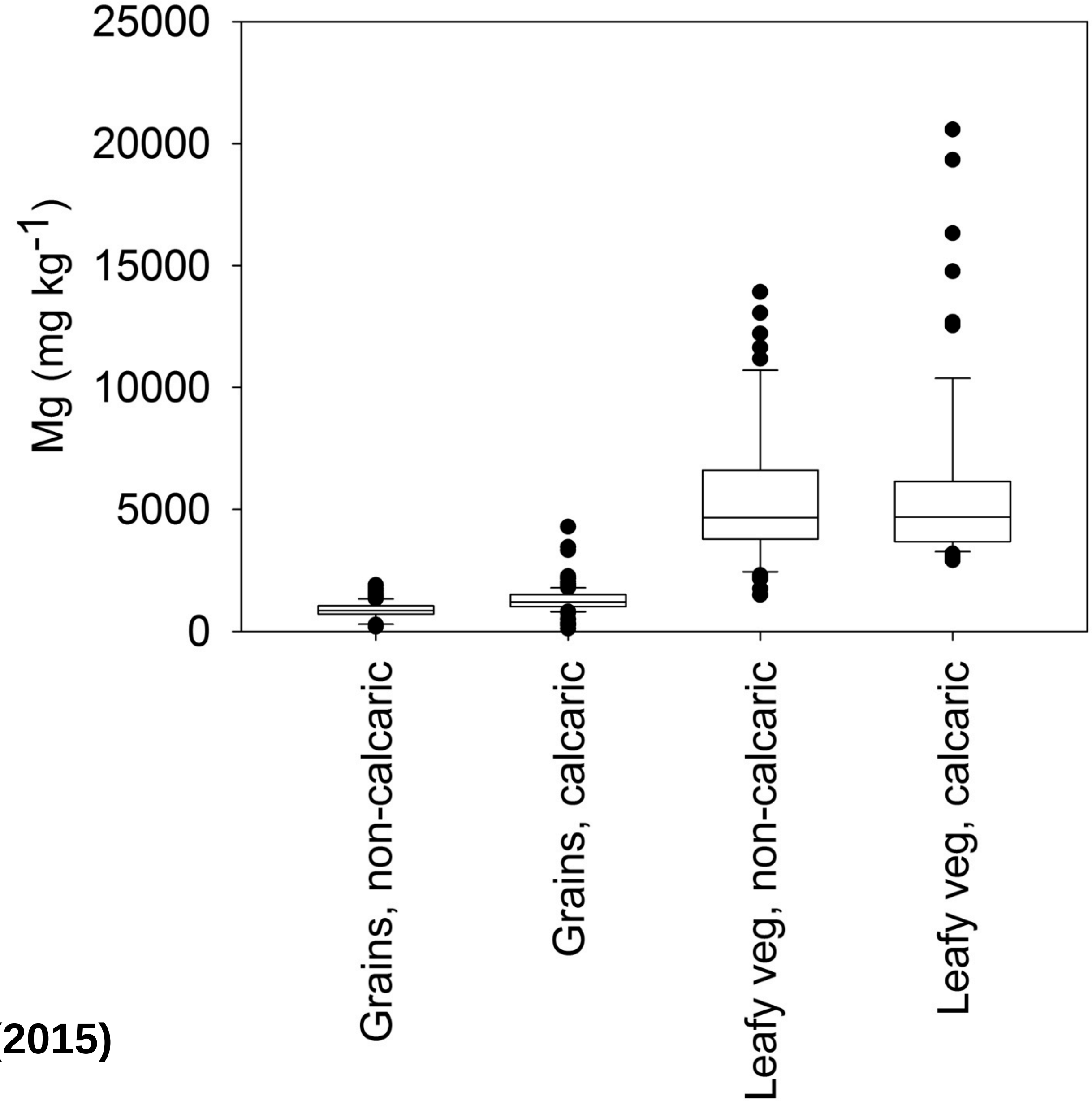
[1]School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough, United Kingdom
[2]Ministry of Agriculture and Food Security, Department of Agricultural Research Services, Lunyangwa Research Station, Mzuzu, Malawi
[3]British Geological Survey, Keyworth, Nottingham, United Kingdom
[4]Department of Nutrition, Norwich Medical School, University of East Anglia, Norwich, United Kingdom
[5]The James Hutton Institute, Invergowrie, Dundee, United Kingdom
[6]University of Otago, Dunedin, New Zealand



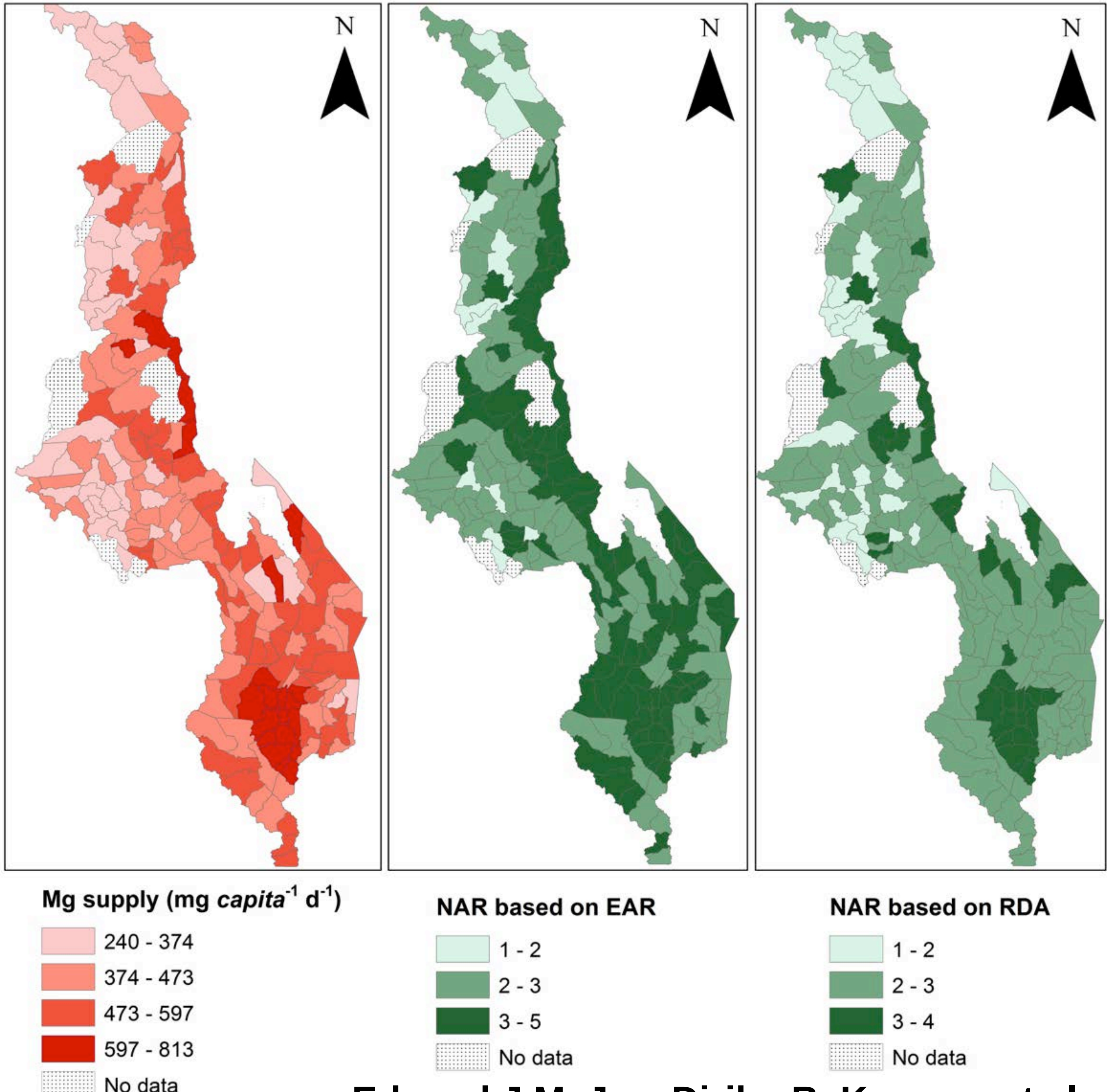




Food composition data (Malawi)

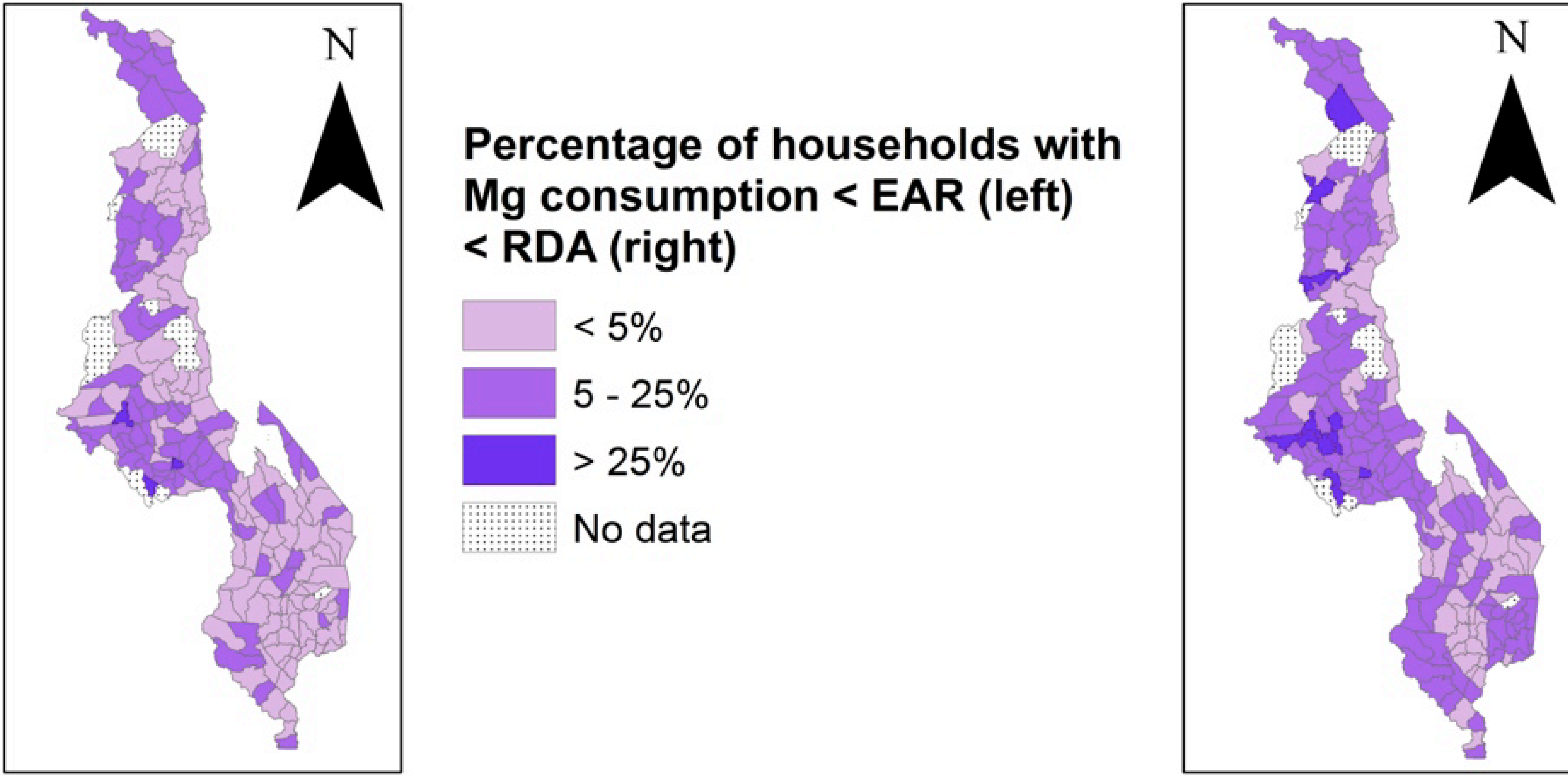


Joy et al. (2015)



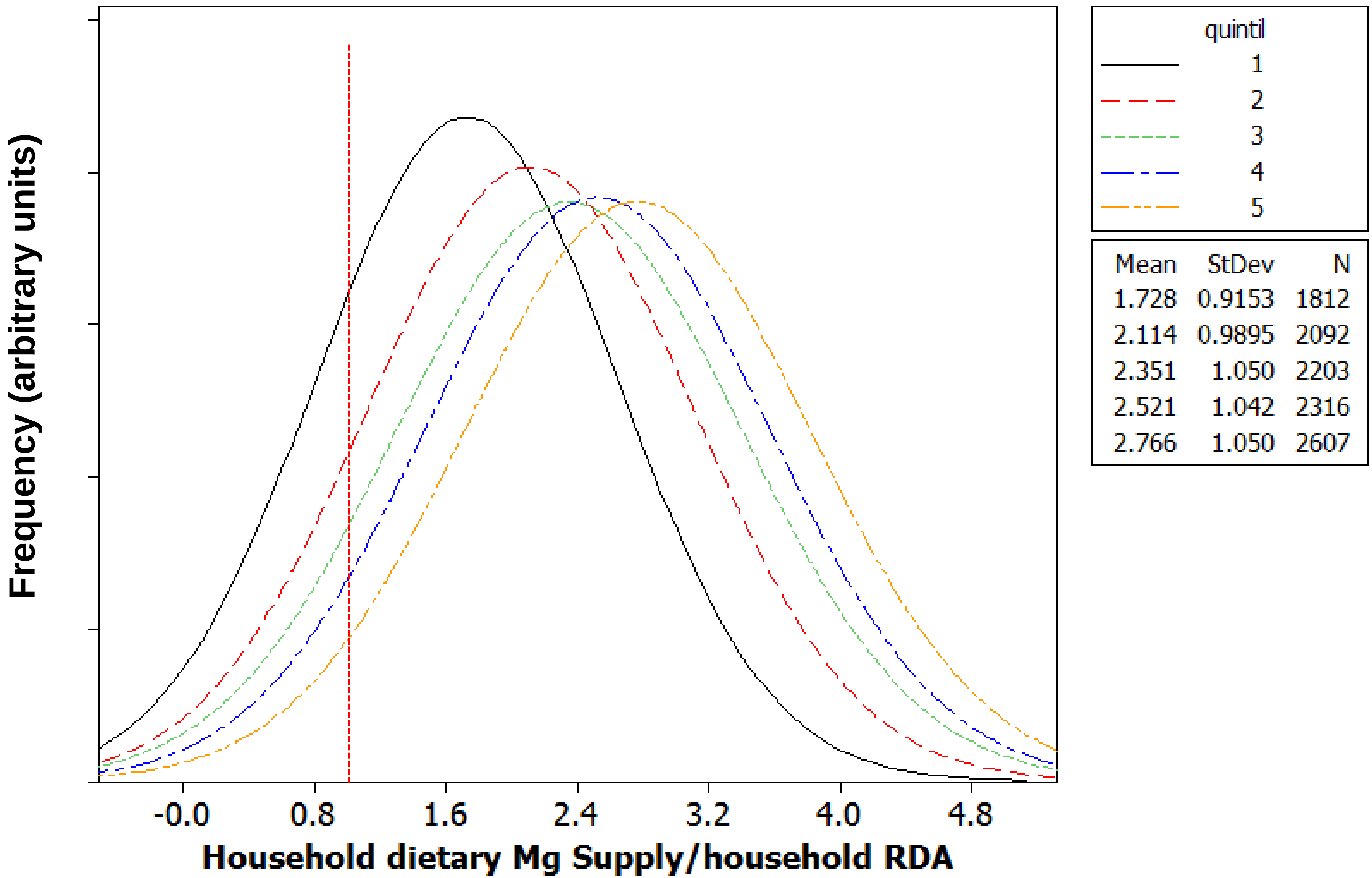
Edward J.M. Joy, Diriba B. Kumssa et al., in prep.

Risk of Mg deficiency is >> than predicted by FBSs



Edward J.M. Joy, Diriba B. Kumssa et al., in prep.

Mg intakes *versus* income in Malawi



Edward J.M. Joy, Diriba B. Kumssa et al., in prep.

Structure of talk

1. Global Mg supplies and deficiency risks
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3. <u>Breeding potential in crops (forage grass and brassica)</u>
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Breeding potential in forage grasses

Hypomagnesaemia-related conditions long-recognised in ruminants

Cows: 1-4% in Europe affected, 20-30% within individual herds

Sheep: 20-40 hypomagnesaemia outbreaks per year in the UK

Mg absorbed through rumen wall in ruminants, not in small intestine

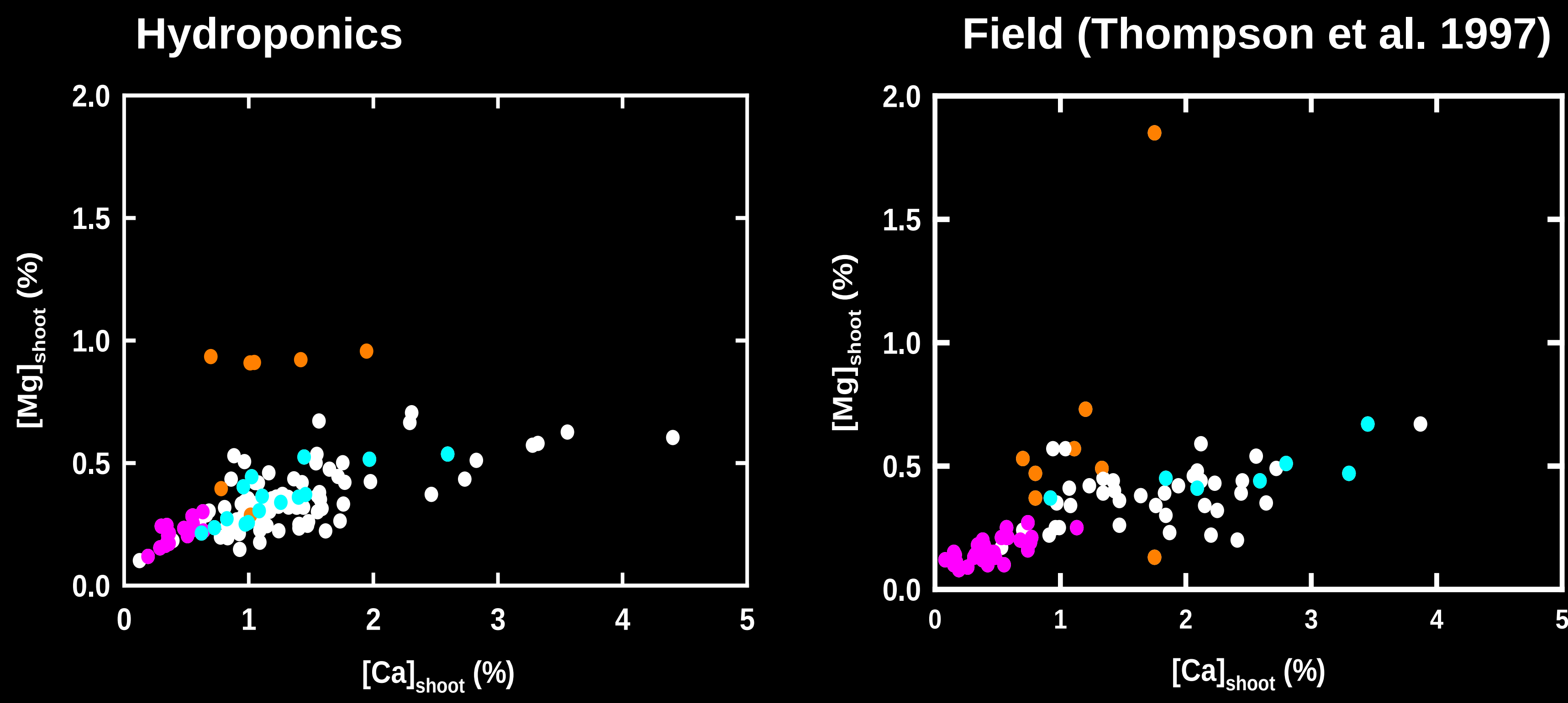
Can occur at lactation due to increased Mg requirements; accompanied by / confused with, hypocalcaemia (milk fever), affecting ~7-8% of UK cows

Tetany (grass staggers) occurs in spring-time when grasses have low dry matter, high protein, high soluble carbohydrate, high K^+

Forages low in Mg due to genotypic factors, soil conditions / other cations

Feed supplements and fertilisers (calcined magnesite, $MgO/MgCO_3$; kieserite, $MgSO_4$; dolomitic limestone, $CaCO_3.MgCO_3$) used at high rates / costs

Grasses have inherently low Mg concentrations



- All other taxa (e.g. roses, legumes)
- Caryophyllales (e.g. sugar beet, carnation)
- Poales (e.g. the grass / cereal family, Poaceae)
- Asterales (e.g. the daisy / sunflower family Asteraceae)

MR Broadley *et al.* (2004). *Journal of Experimental Botany*, 55, 321-336.

Assessing variation in [Mg] among four grass species

Lolium perenne
(n=280)

Lolium multiflorum
(n=17)

Hybrid ryegrass
(n=101)

Festuca arundinacea
(n=10)

Beth Penrose et al., in prep.

Assessing variation in [Mg] among four grass species

596
plots near
Edinburgh

1612
plots near
Aberystwyth

Plots sown 2010-12

Beth Penrose et al., in prep.

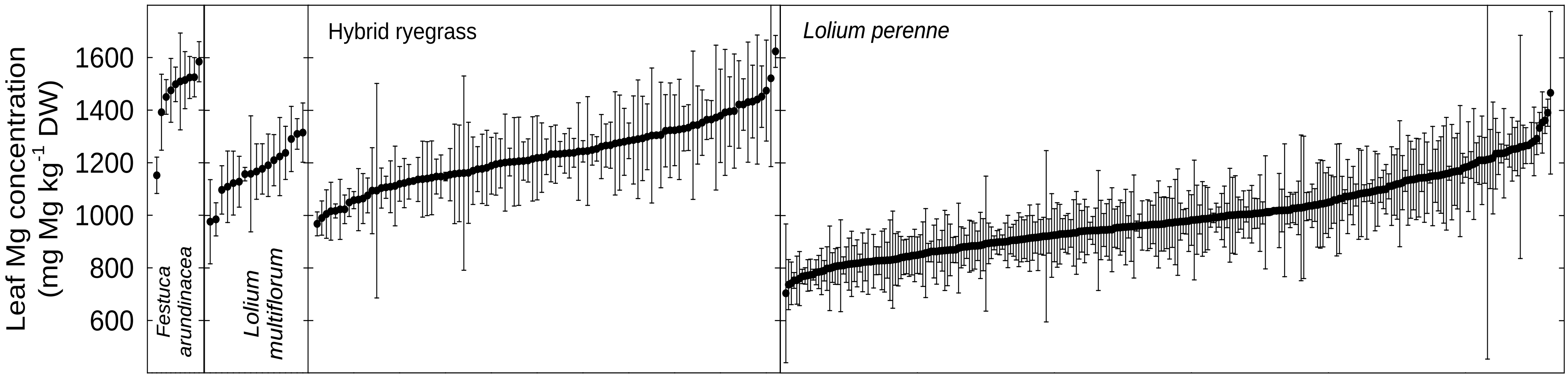
Multiple cuts taken in 2013 and 2014

Beth Penrose et al., in prep.

Multiple cuts taken in 2013 and 2014

Beth Penrose et al., in prep.

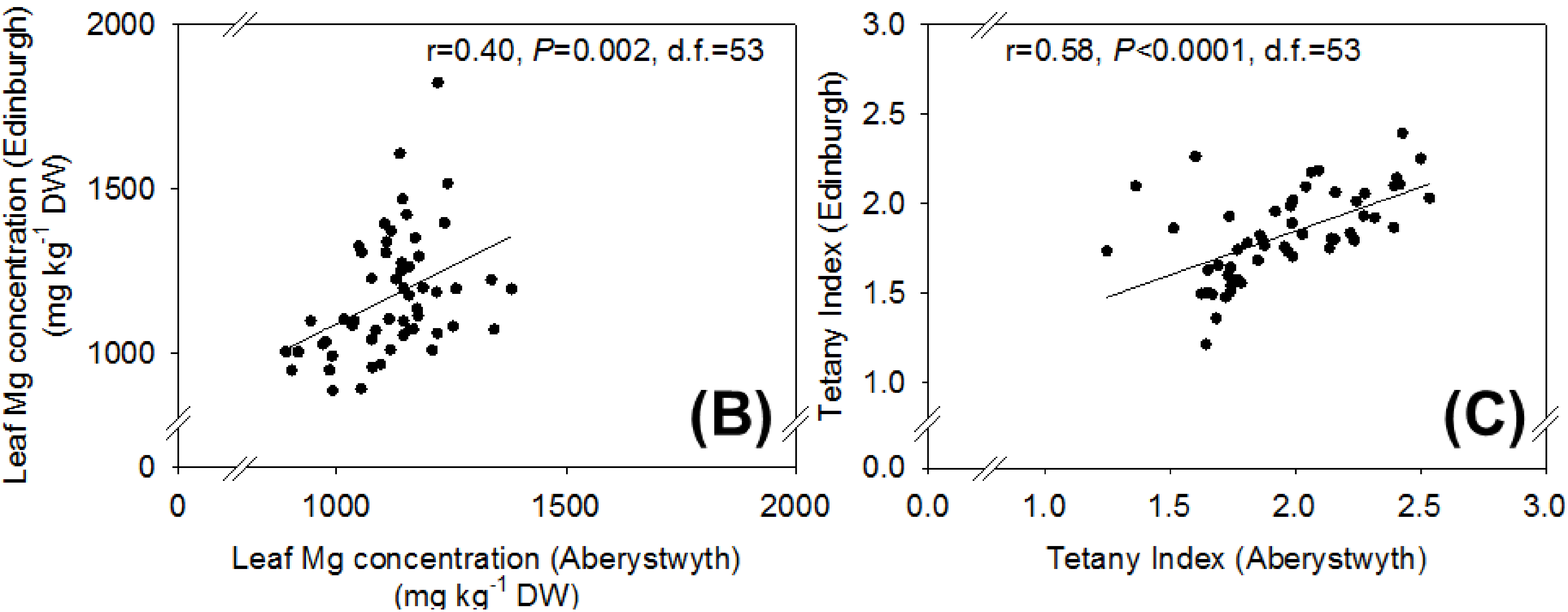
Up to two-fold variation in leaf Mg concentrations among four species of forage grass



Arithmetic cultivar-means for all plots, ± 1 standard deviation.

Beth Penrose et al., in prep.

Consistency in leaf Mg concentrations and leaf 'Tetany Index' at different sites



55 varieties of forage grass (varietal means); a Tetany Index >2.2. is considered to lead to higher risks of hypomagnesaemia

Beth Penrose et al., in prep.

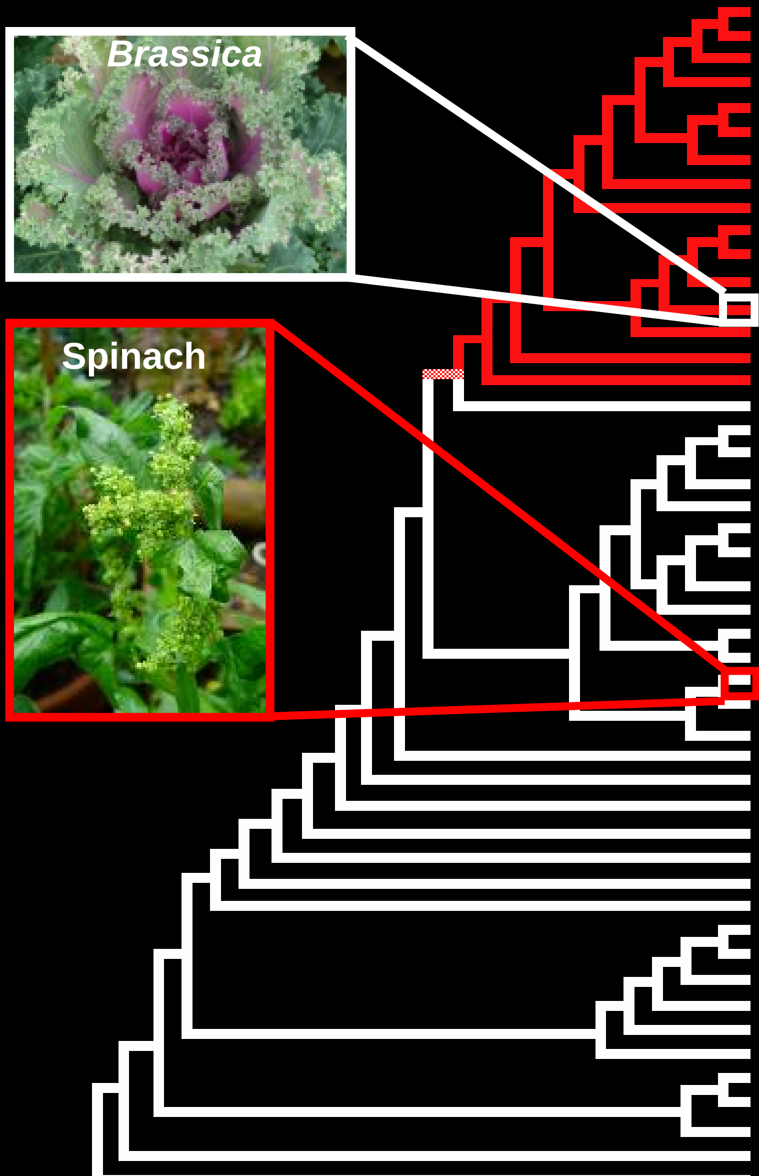
Breeding potential in forage grasses – revisited?

Binnie, R.C., Johnston, D.T. and Chestnutt, D.M.B. (1996) The effect of a high-magnesium perennial ryegrass variety on the magnesium status of sheep. *Grass Forage Sci.* 51: 456-463

Crawford, R.J., Massie, M.D., Sleper, D.A. and Mayland, H.F. (1998) Use of an experimental high-magnesium tall fescue to reduce grass tetany in cattle. *J. Prod. Agric.* 11: 491-496

Moseley, G. and Baker, D.H. (1991) The efficacy of a high magnesium grass cultivar in controlling hypomagnesaemia in grazing animals. *Grass Forage Sci.* 46: 375-380

Breeding potential in *Brassica*



Phylogenetic analyses among angiosperms

Broadley MR et al. (2003). *Journal of Experimental Botany*, 54, 1431-1446

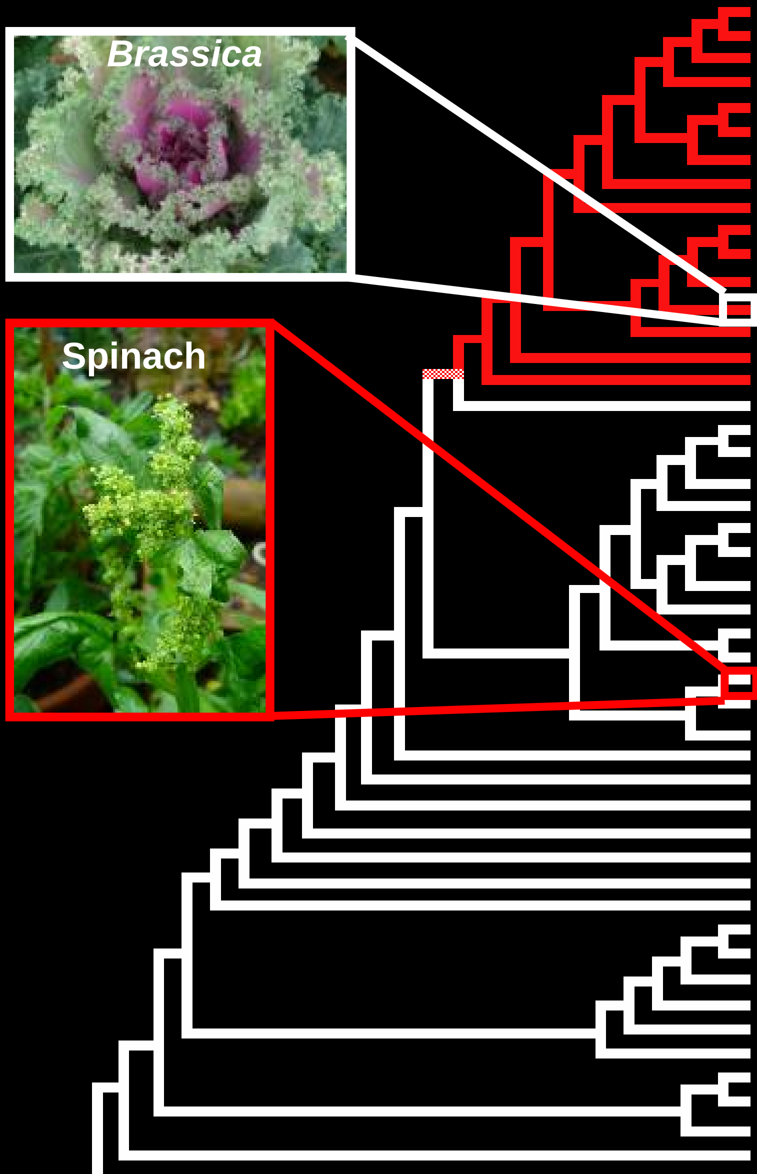
White PJ & Broadley MR (2003). *Annals of Botany*, 92, 487-511

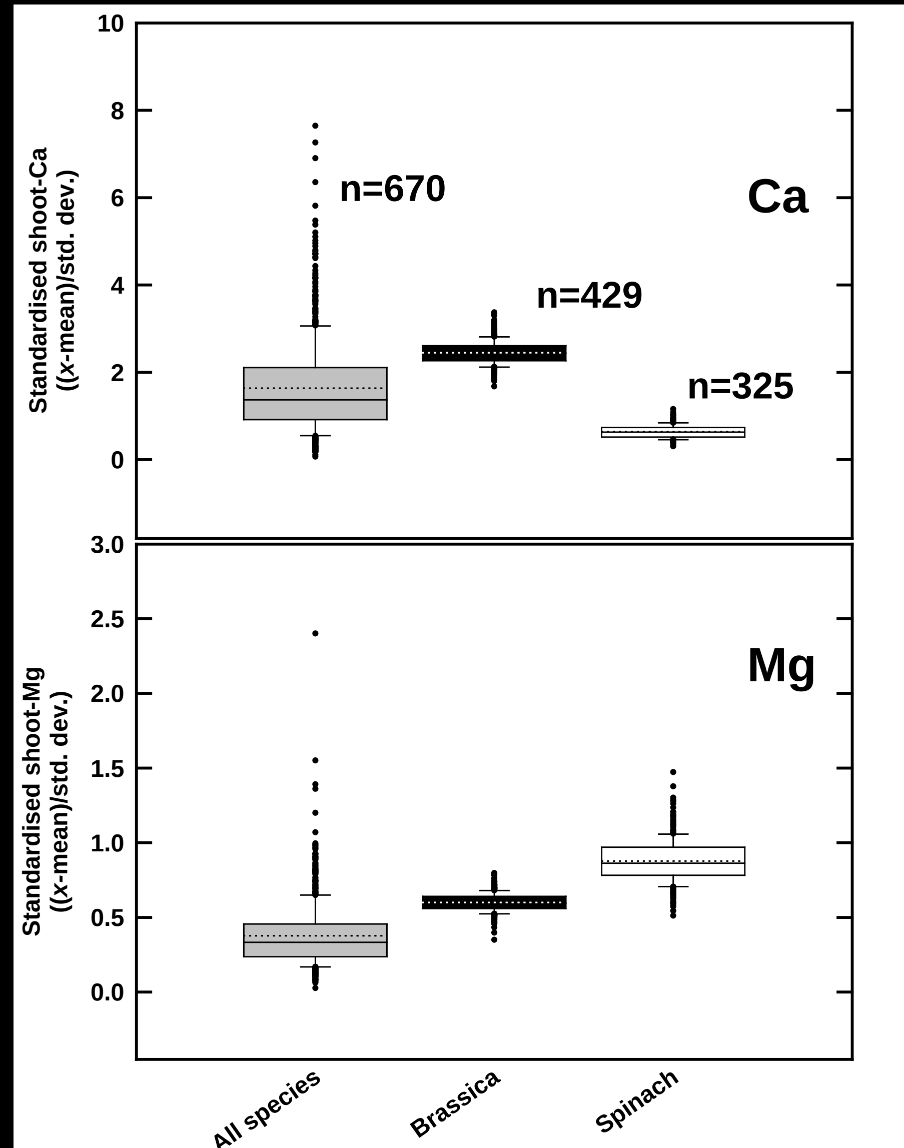
Broadley MR et al. (2004). *Journal of Experimental Botany*, 55, 321-336

White PJ et al. (2004). *Journal of Experimental Botany*, 55, 1927-1937

Watanabe T et al. (2007). *New Phytologist*, 174, 516-523

Brassica have inherently high leaf Mg concentrations

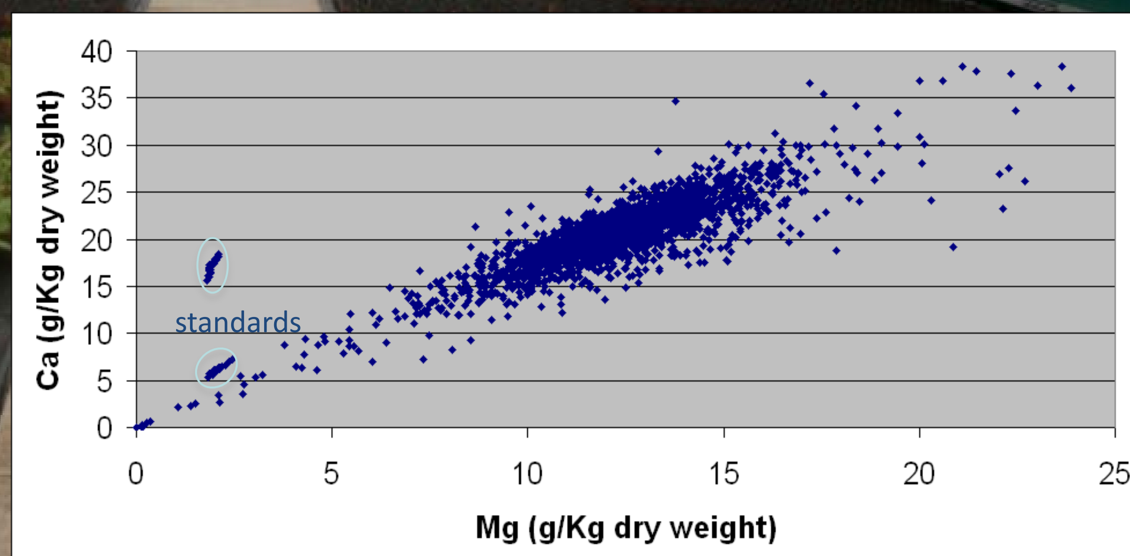




Broadley MR et al. 2008. *Plant Physiology*, 146, 1707-1720

Forward screens of chemically-mutagenised *Brassica*

- *Brassica rapa* R-o-18 tilling population (3464 M_2s, 4 WT, n=5)
- Leaf mineral concentration 3*siblings, ~30 elements)



Slightly-delayed flowering…

Mg mutant

Wild Type

M_4 generation plants growing in the glasshouse

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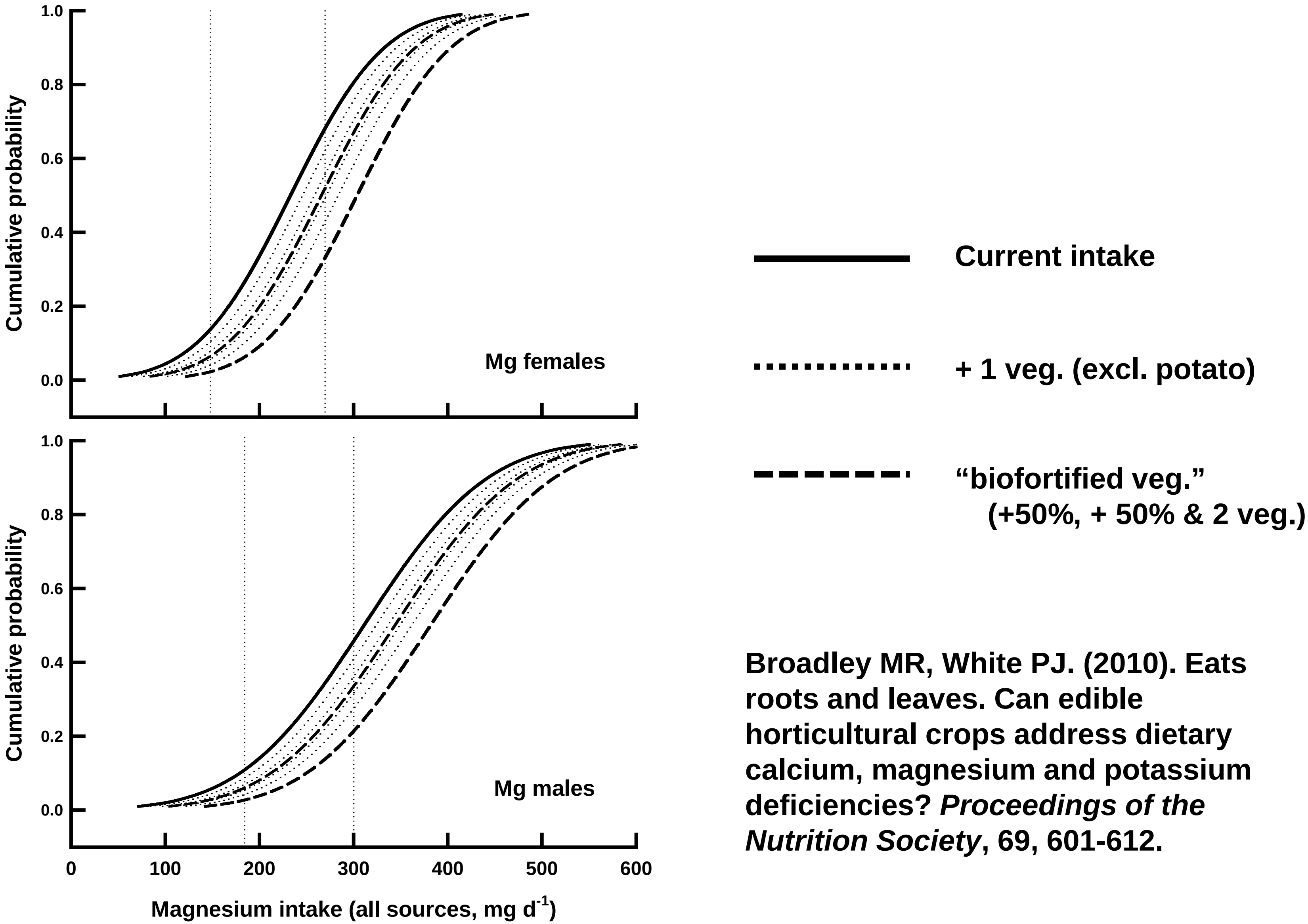
Breeding or fertilisers for humans ?

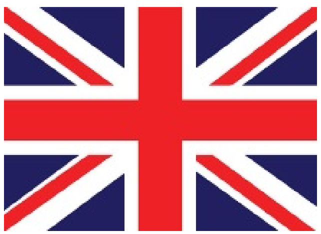


Broadley MR, White PJ. (2010). Eats roots and leaves. Can edible horticultural crops address dietary calcium, magnesium and potassium deficiencies? *Proceedings of the Nutrition Society*, 69, 601-612.

Breeding or fertilisers for humans?

Numbers of UK adults <LRNI to >LRNI as a consequence of intervention (2002 data)

	+2 veg.	***+50% biofort.***	***both***
Magnesium	**1.4m**	**2.0m**	**4.0m (75%)**



Broadley MR, White PJ. (2010). Eats roots and leaves. Can edible horticultural crops address dietary calcium, magnesium and potassium deficiencies? *Proceedings of the Nutrition Society*, 69, 601-612.

Acknowledgements

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John Hammond	University of Reading
Rory Hayden	University of Nottingham
Rachel Hurst	University of East Anglia
Dalitso Kang'ombe	Malawi Ministry of Health
Alexander Kalimbira	Lilongwe University of Agriculture & Natural Resources, Malawi
Nigel Kendall	University of Nottingham
Graham King	Southern Cross University, Lismore, Australia
Joachim Lammel	Yara GmbH, Germany
Alexander Stein	Agricultural Economist
Edwin Siyame	Lilongwe University of Agriculture & Natural Resources, Malawi
Lolita Wilson	University of Nottingham