Heavy Metal Contamination in Urban Agriculture: Evidence from Nairobi

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≥ 30% of Pb exposure appears to be through food

	BLL		Contribution	Food share	
	children	adults	of food	children	adults
	µg/dL	µg/dL	µg/dL		
Cameroon	8.7		3.11	0.36	
China	4.17	3.47	5.72	1.00	1.00
Egypt	8.24	10.36	2.48	0.30	0.24
India	5.22	4.42	1.47	0.28	0.33
Lebanon		4.35	0.39		0.09
Overall				**0.49**	**0.52**
Omitting China				**0.31**	**0.29**

Sources: BLL from Ericson et al. (2021), contribution of food from Carrington et al. (2019)

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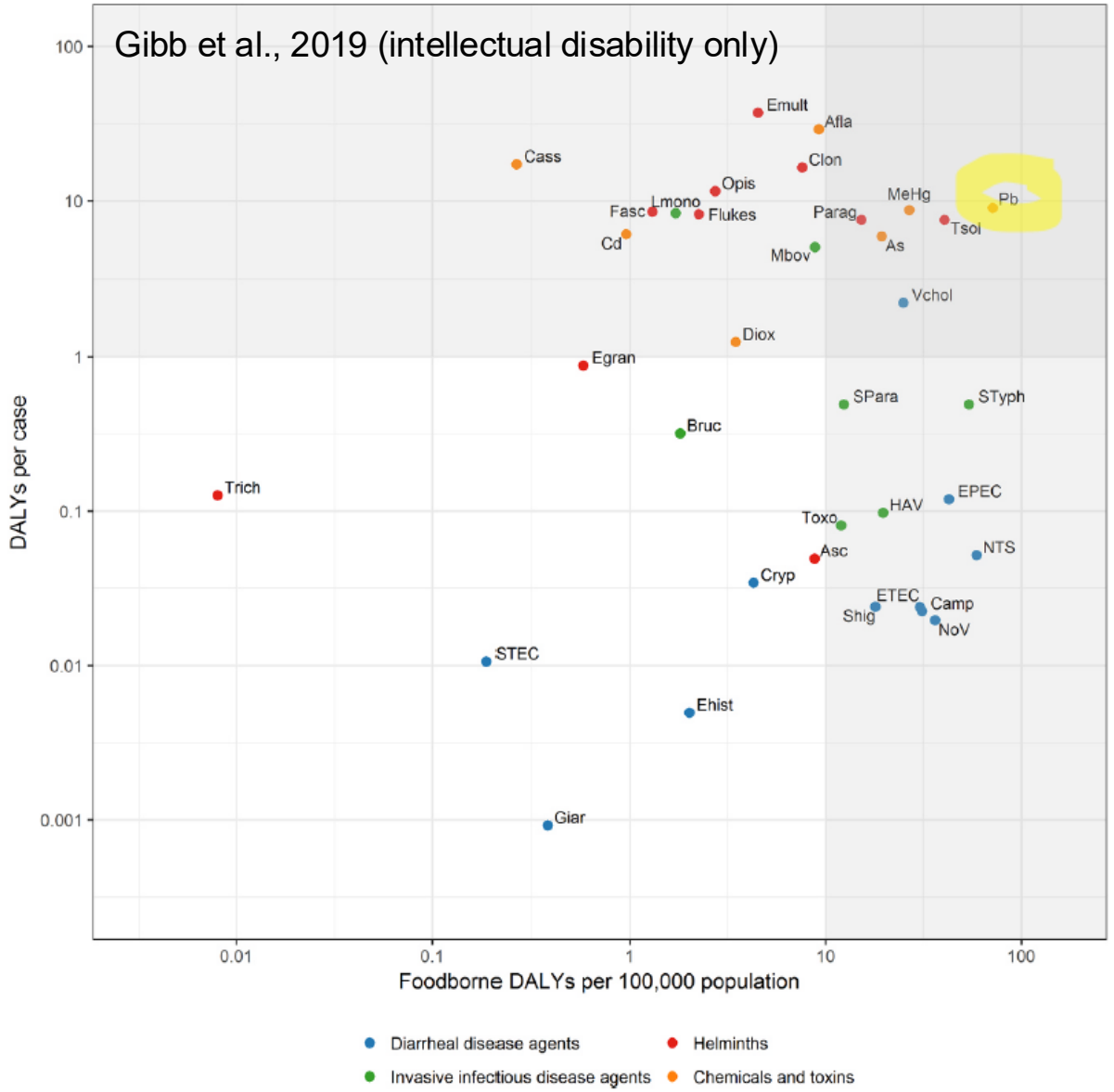
Pb → most DALYs per population of any foodborne hazard



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(Peri) urban agriculture

- Significant component of food systems
  - 11% of all irrigated cropland is within urban settlements, 60% within 20 km (Thebo et al., 2014)
  - 10-70% of urban households (15 LMICs) engage in agriculture (Zezza & Tasciotti, 2010)
  - Urban gardening interventions improve dietary diversity (Schreinemachers et al. 2025)
- Potential for heavy metal contamination
  - Potential sources: manufacturing, dumpsites, buildings (paint), road and air traffic
  - Prior studies: small N, known polluted sites (Gallaher et al., 2013, Karanja et al. 2012, Kinuthia et al., 2020)

Jakarta, *photo: Didit O. Pribadi*

Nairobi, *photo: Mary Njenga*

Addis Ababa, *photo: Diana Lee-Smith*

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Leafy greens (mostly kale) widely grown around Nairobi

- Easy to grow, continuous harvest
- Most consumed vegetable: by 74% of Kenyan households, past 7 days (Ryckman et al., 2024)
- Significant accumulator of heavy metals (Bortoloti and Baron, 2022)

Urban farmer in Kibera, Nairobi
photo: The Guardian / Patrick Mayoyo

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Grid-based sampling approach

- Most agriculture in Nairobi County uses irrigation water from the Nairobi River or tributaries
- Define two sampling areas west and east of the city center
  - Define 2,250 grid cells (~100 m^2)
  - Drop those > 1 km from Nairobi River
- Randomly select 100 cells, points within these
  - Inspect on Google maps, replace any points on structures, roads, rivers
  - Visit site: if greens present at point or within line of sight, locate owner & arrange interview, sampling

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Descriptive statistics on production

	Mean	SD	Min	Max
Number of plots cultivated	1.64	1.41	1	11
Area cultivated (acres)	1.1	1.76	0	10
Plots are irrigated	0.91	0.28	0	1
Crop: Kale	0.92	0.27	0	1
Crop: Other leafy greens	0.67	0.47	0	1
Times harvested / month	7.32	7.49	1	30
Monthly harvest (kg)	960	1836	0	9,000
Estimated monthly revenue (USD)	273	526	0	2,635
Share of production consumed (Kale)	0.09	0.17	0	1.00

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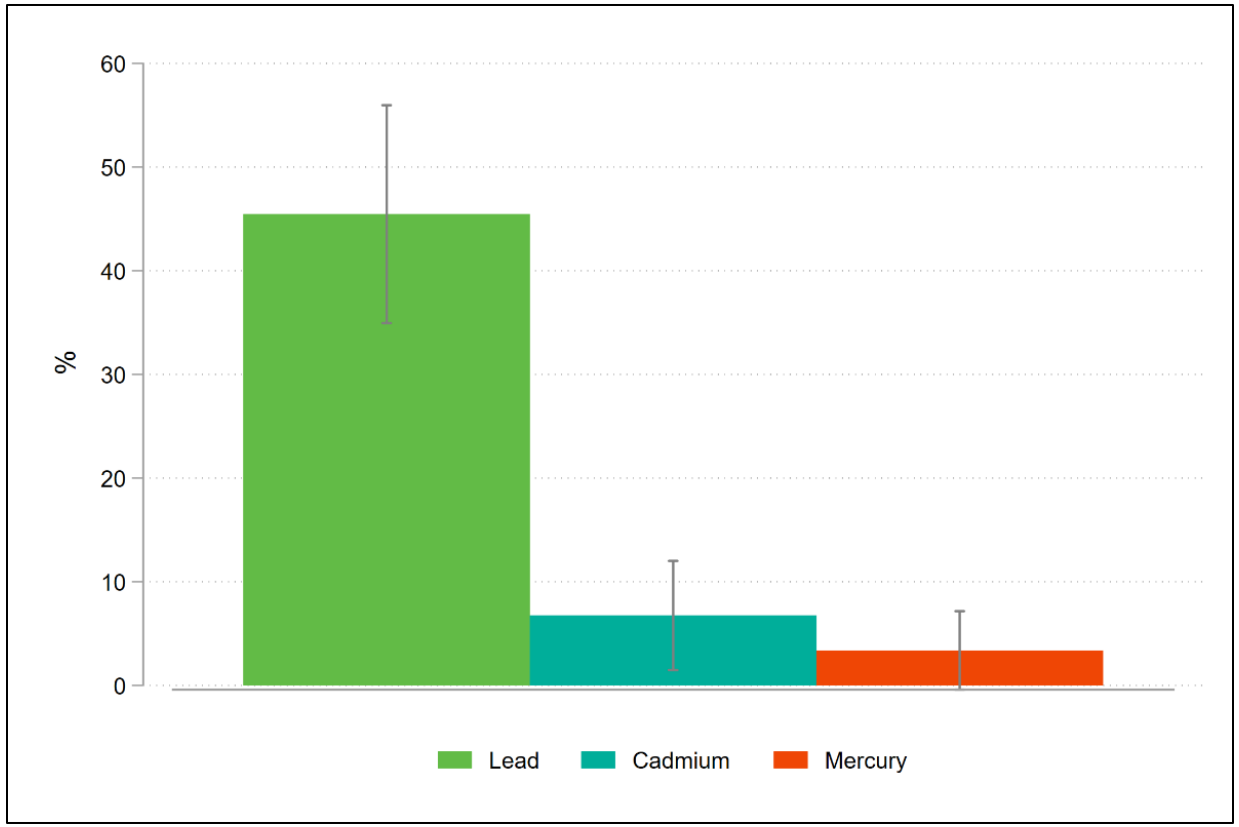
Contamination levels in kale



Share of kale samples with heavy metal detected above the Codex maximum

- Lead
  - Mean: 0.37 ppm (Codex: 0.3 ppm)
  - 90th percentile: 0.63 ppm
- Cadmium
  - Mean: 0.04 ppm (Codex: 0.2)
  - 90th percentile: 0.13 ppm
- Mercury
  - Mean: 0.11 PPM (FDA: 0.5)
  - 90th percentile: 0.32 ppm

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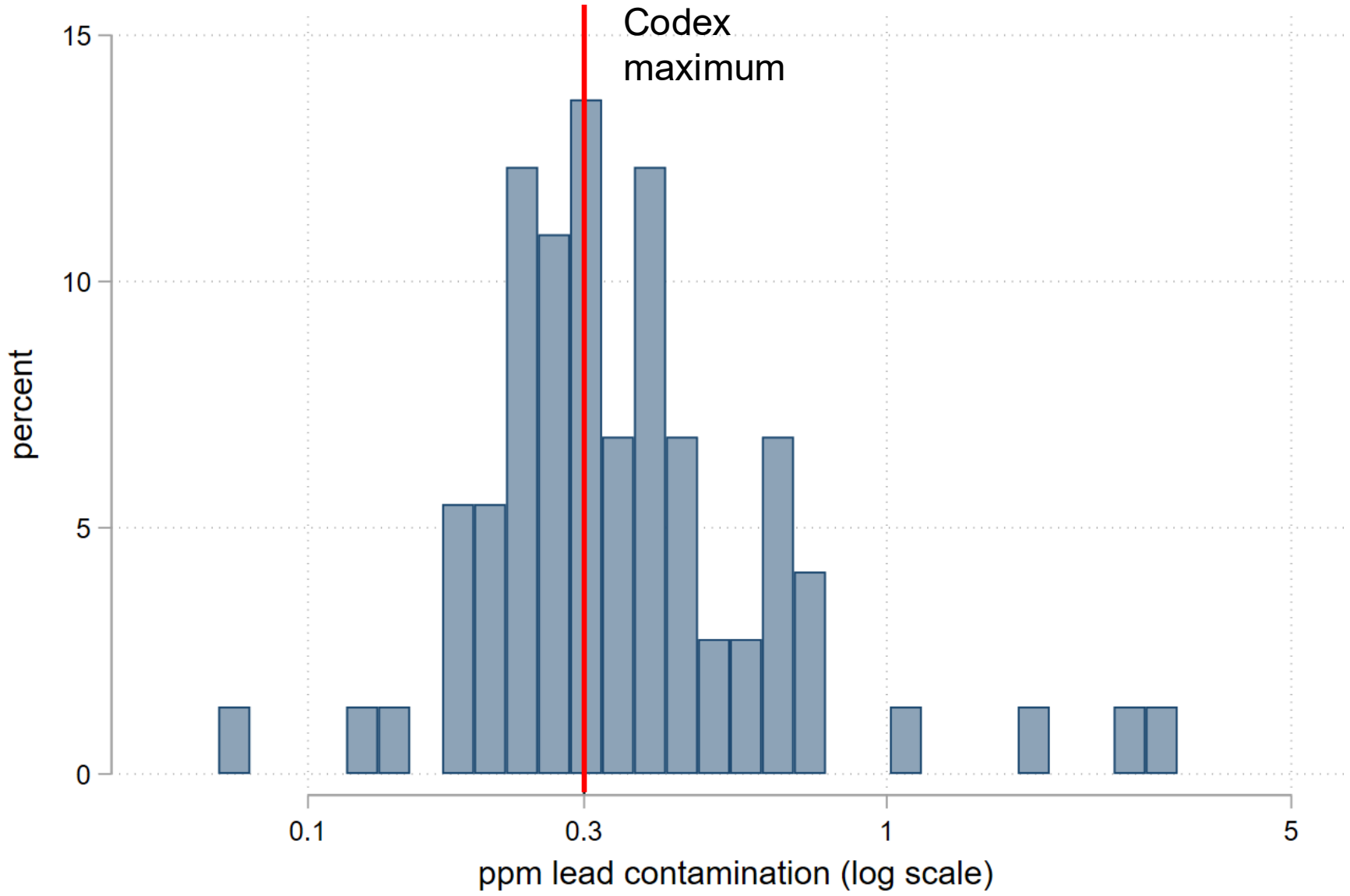
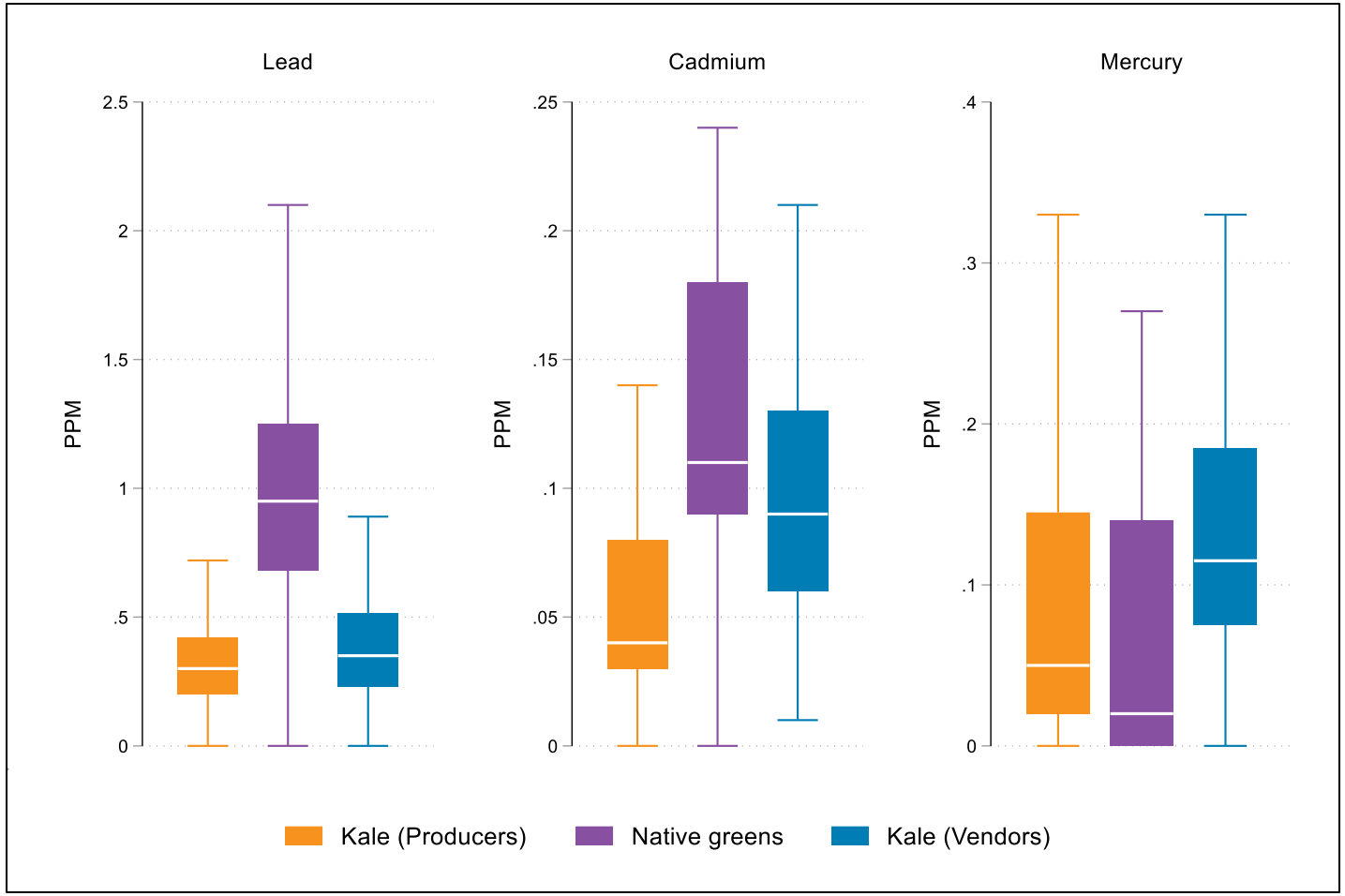
Distribution of lead contamination in kale



Comparing alternatives

- Potential substitutes are no less contaminated
- Other greens grown by study farmers have **higher** levels of lead ($p < 0.001$), cadmium ($p < 0.001$)
- Kale samples purchased from wholesale vendors, grown outside Nairobi have similar lead, higher cadmium ($p = 0.004$)



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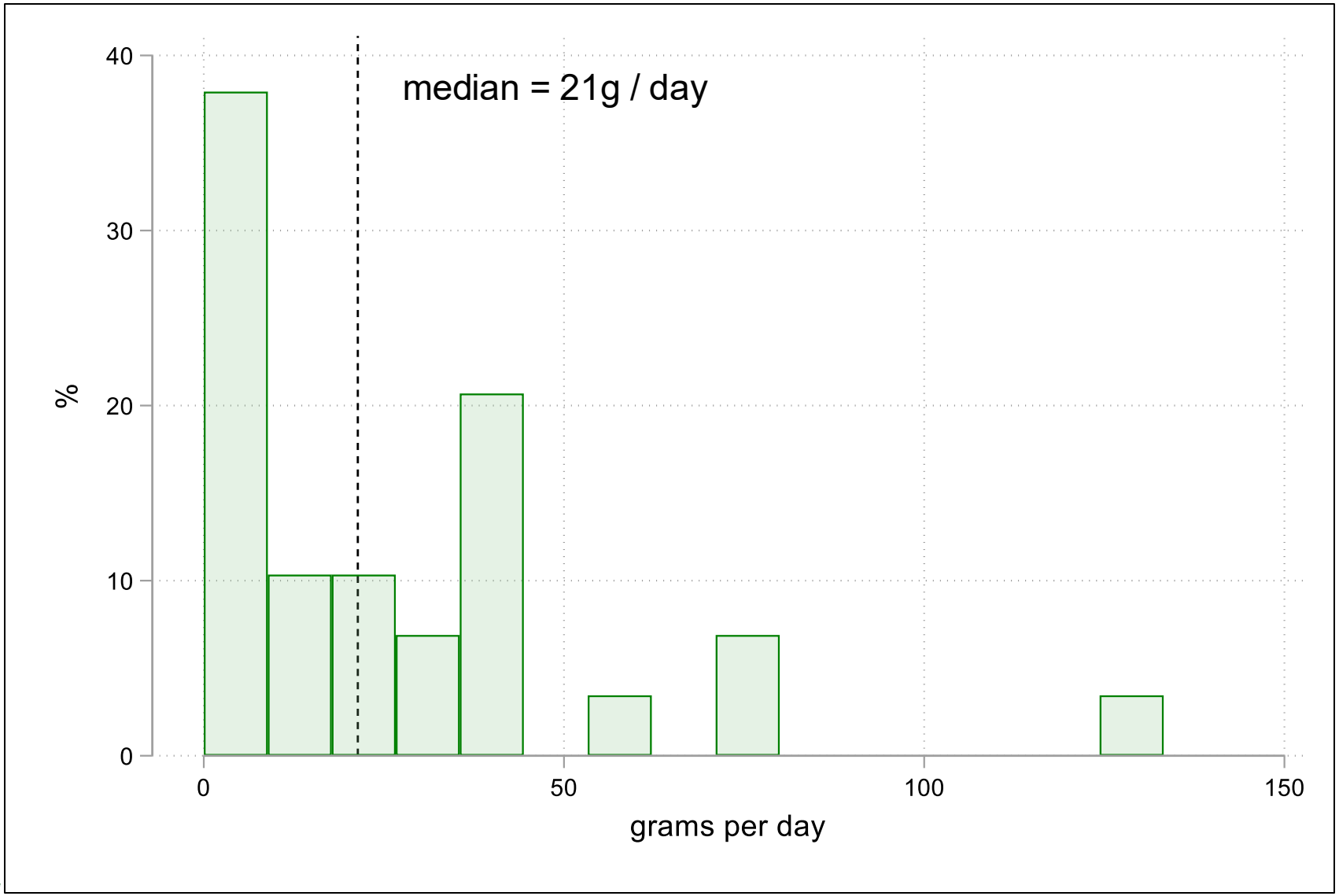
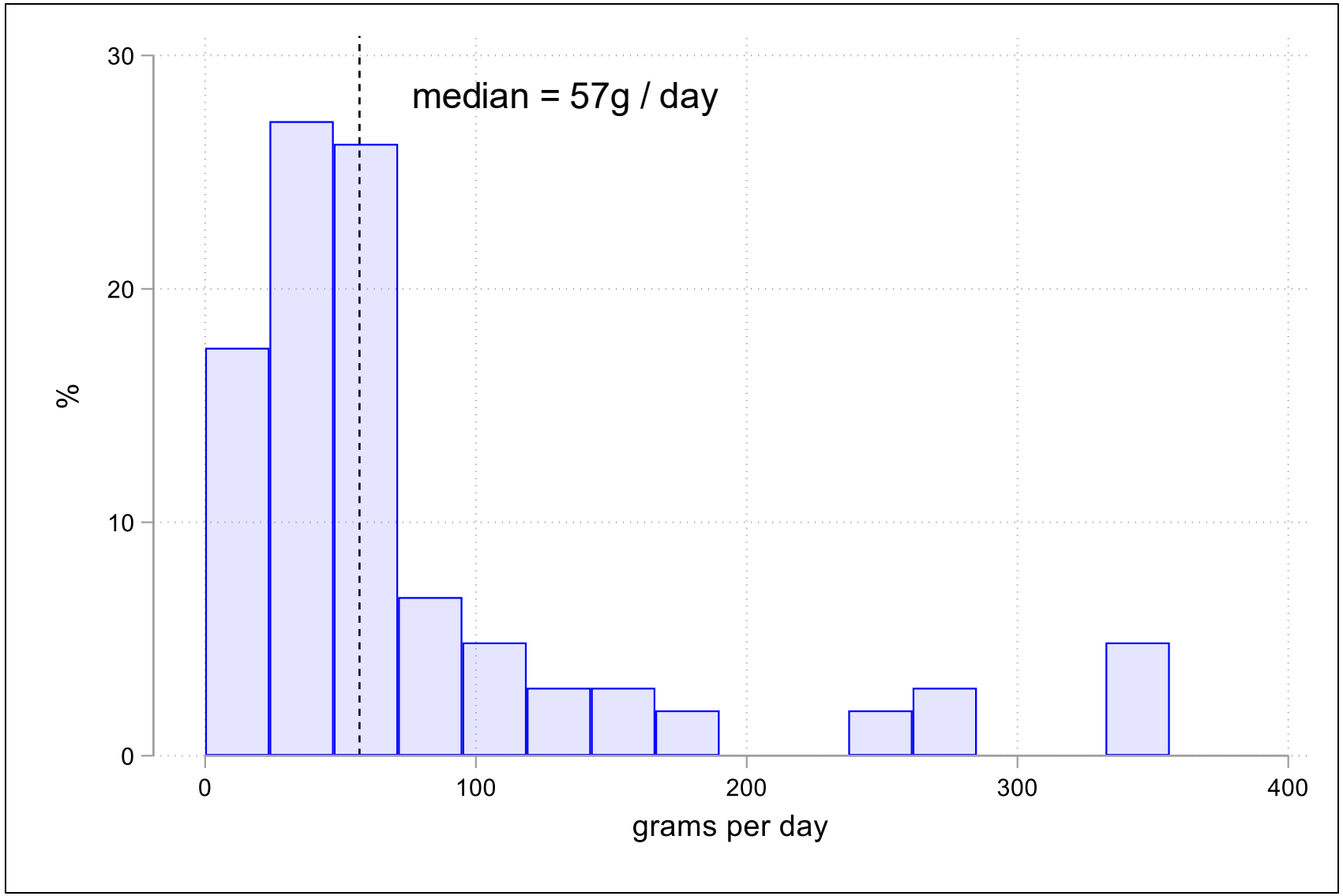
Consumption of leafy greens – under-5s



During a typical week when greens are consumed (harvested 11/12 on average)

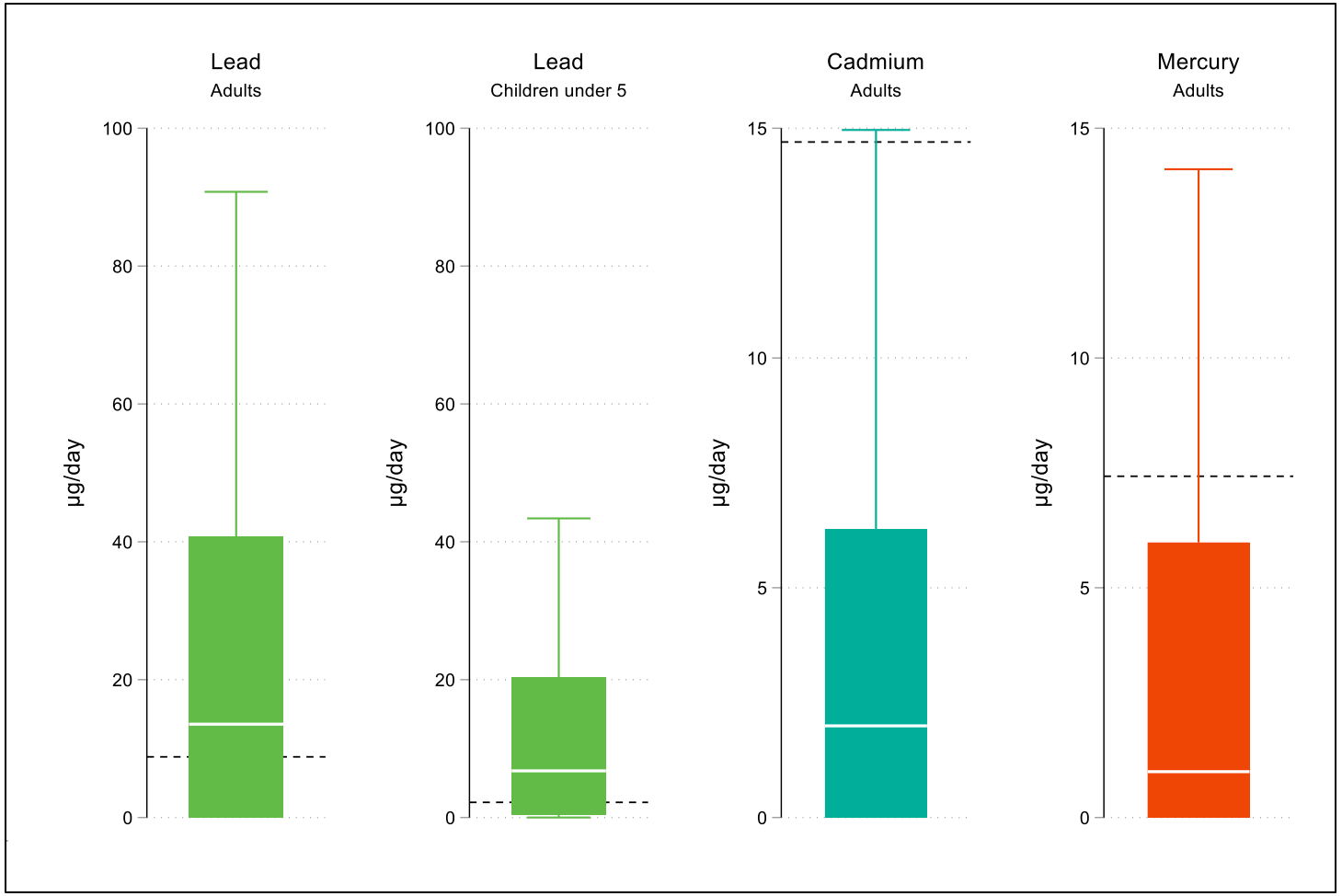
Consumption of leafy greens – adults



During a typical week when greens are consumed

Dietary exposure in producer sample households

- Lead from leafy greens alone exceeds US-FDA interim reference level for dietary exposure for most households:
  - Under-5s: 66%
  - Adults: 56%
- Other heavy metals (adults)
  - Cadmium: 11% > ref. level
  - Mercury: 21% > ref. level



Total dietary exposure from own production of leafy greens (typical week when greens are consumed)

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Dark leafy greens consumption in representative samples

- 2015-16 Kenya Integrated Household Budget Survey
  - 74% of households in Kenya consumed DLG past 7 days
  - 87% in Nairobi (vs. ~90% in our sample)
- 2022 Kenya Demographic and Health Survey
  - 57% of women aged 15-49 in Nairobi consumed DLG past 24 hours
  - 46% of caregivers fed to 6-24 months child (vs. ~60% in typical week, our sample)
- Daily consumption amounts
  - Kunyanga et al., same communities, 6 months – 5 years: 22 g (mean) 21 g (median)
    our sample: 27 g (mean) 21 g (median)
  - GAIN (2024) adult vegetable consumption, Kenya: 130 g
    our sample (greens only): 72.4 g (mean) 58 g (median)

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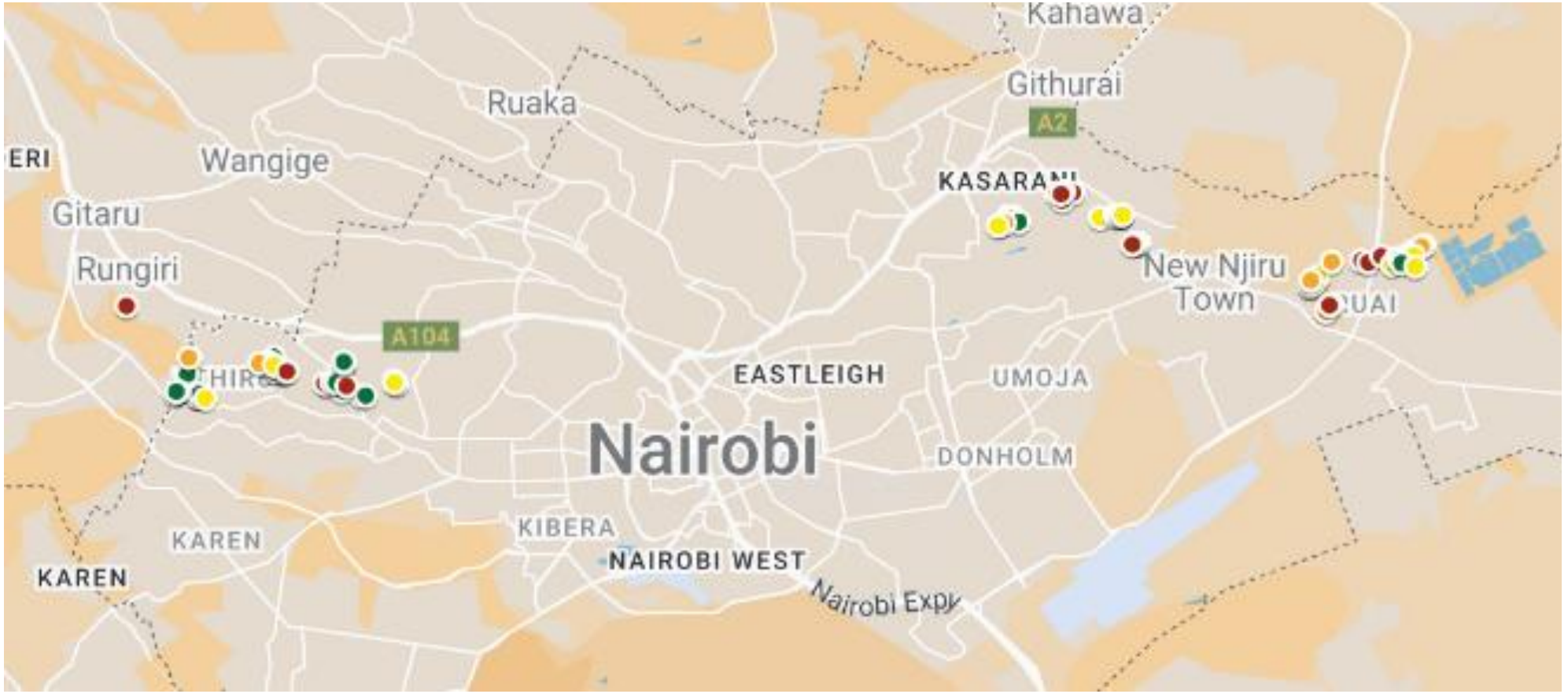
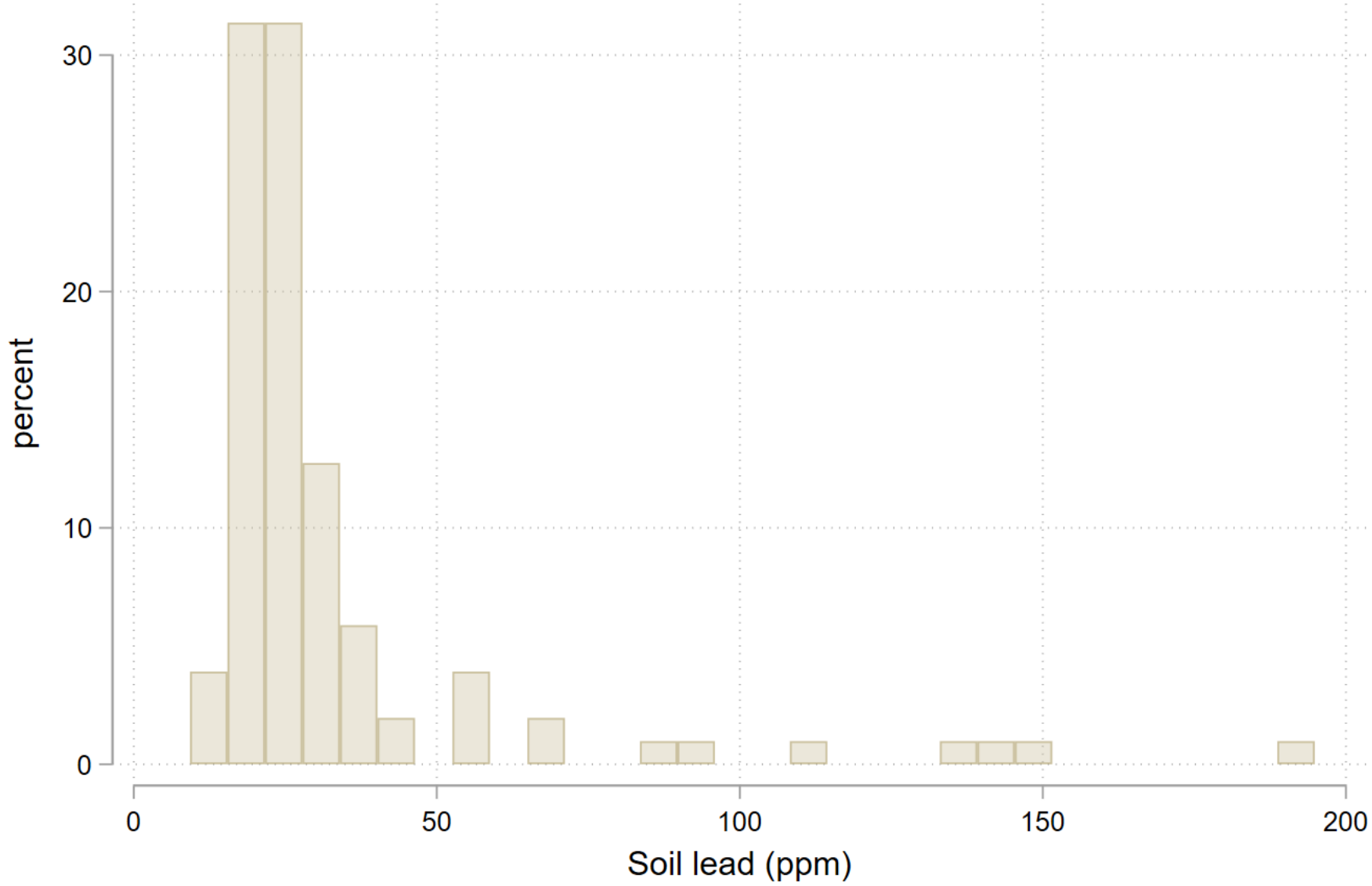
Where is contamination coming from?

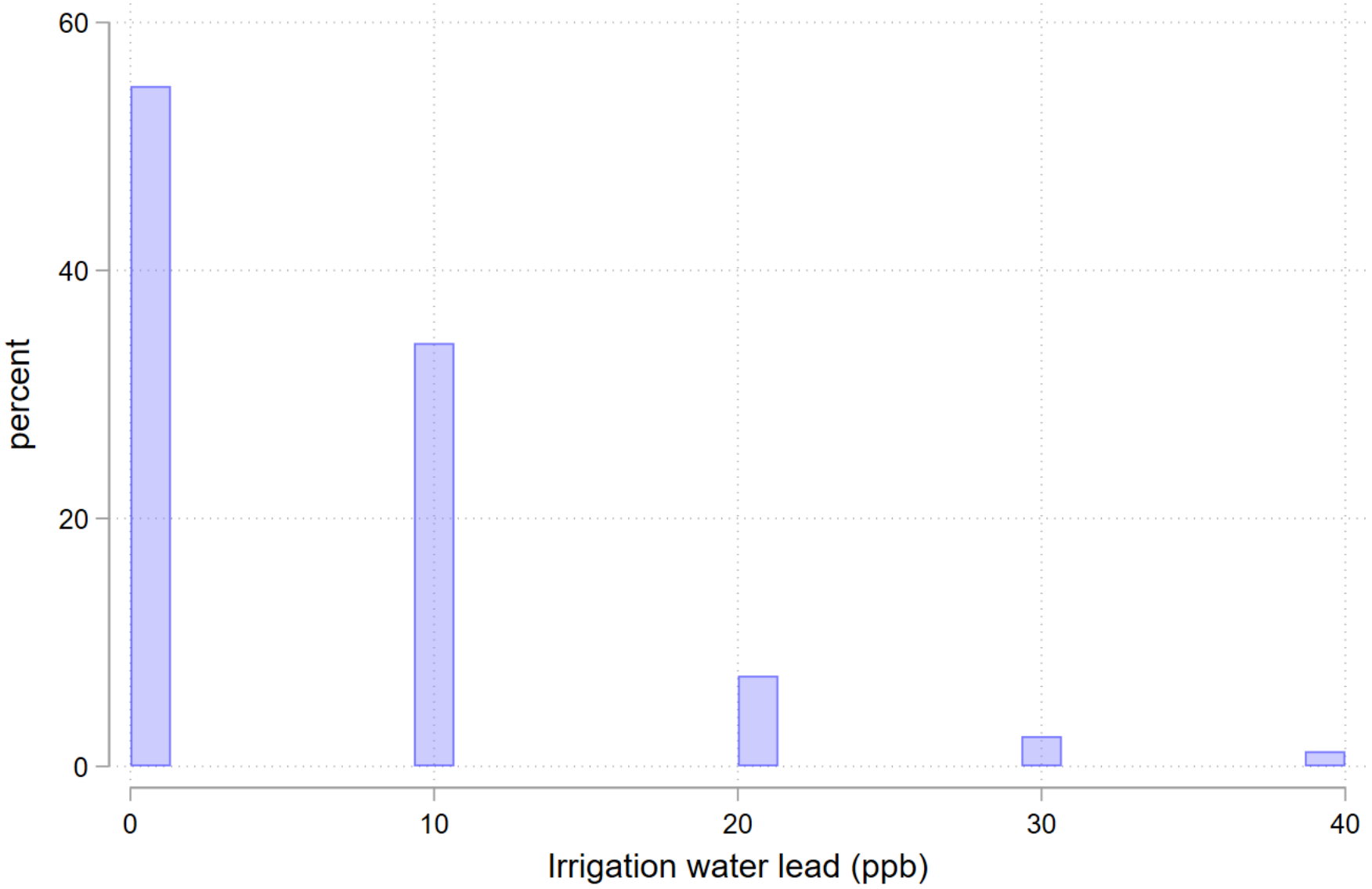


Geographical distribution of leafy greens contamination

Soil levels are not that high….



Irrigation water looks okay….



No clear line from soil & irrigation water to crop contamination

	Lead	Cadmium	Mercury
	(1)	(2)	(3)
Soil contamination (ppm)	-0.00	0.02	0.01
	(0.01)	(0.10)	(0.00)
	[0.786]	[0.874]	[0.259]
Water contamination (ppb)	-0.01	0.01	0.01*
	(0.02)	(0.01)	(0.01)
	[0.791]	[0.125]	[0.091]
Soil moisture level	0.02	-0.00	-0.00
	(0.03)	(0.00)	(0.00)
	[0.551]	[0.664]	[0.493]
Constant	0.36	0.10**	0.16**
	(0.74)	(0.05)	(0.08)
	[0.632]	[0.034]	[0.041]
Observations	78	78	78

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Conclusion and next steps

- Leafy greens grown and sold in Nairobi County are highly contaminated
  - Lead exposure through greens > IRL for 66% of under-5s in sample
- Most-consumed vegetable nationally, promoted as a nutritional “best buy”
  - Lead exposure / nutritional trade-offs?
- Contamination is widely spatially distributed, across and beyond Nairobi
  - Source of contamination unclear
- Next steps: identify sources of this contamination through isotopic analysis
  - Collaboration with Pure Earth, Columbia University METAL Lab, KEPHIS

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Thank you!

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RESEARCH PROGRAM ON

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