



June 10-11th 2026



How to combat
the illegal addition
of chemicals to
turmeric spices



Paul N. Williams

ATSDR

Agency for Toxic Substances and Disease Registry



Rank	Substance Name	Total Points
1	<u>Arsenic</u>	1670.4
2	<u>Lead</u>	1529.2
3	<u>Mercury</u>	1458.6
4	Vinyl Chloride	1359.8
5	Polychlorinated Biphenyls	1343.5
6	Benzene	1328.5
7	<u>Cadmium</u>	1318.7
8	Benzo(A)Pyrene	1304.7
9	Polycyclic Aromatic Hydrocarbons	1279.7
10	Benzo(B)Fluoranthene	1251.2

Partnership for a Lead-Free Future



FOODSAFER
business's business

June 10-11th 2026

FUTURE PERFECT

The world's spending to fight global lead poisoning just doubled

1.5 million people die from lead exposure a year. This new global partnership could change that.

by Dylan Matthews

Oct 2, 2024, 11:00 AM CMT+1



US\$ 6 trillion per year



Is turmeric a
super-food or a
super-fraud?

Nation

Bihar shelter home deaths: Food items found adulterated, action taken against 13 officials

Three inmates died and 12 others fell ill due to food poisoning at Ashra Grih, a state-run shelter home in Patna, for differently-abled women. They fell ill after consuming breakfast on November 7.



Super
Killer ?

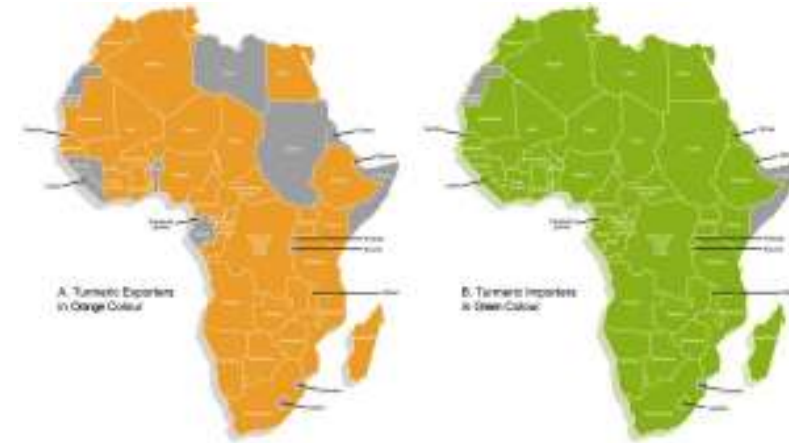


Review

Africa, an Emerging Exporter of Turmeric: Combating Fraud with Rapid Detection Systems

Wilfred Angie Abia^{1,2}, Simon A. Haughey^{1,3,*}, Radhika Radhika¹, Brandy Perkwang Taty², Heidi Russell¹, Manus Carey^{1,3}, Britt Marianna Maestroni⁴, Awanwee Petchkongkaew⁵, Christopher T. Elliott^{1,5} and Paul N. Williams¹

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 - ² Department of Biochemistry, Faculty of Science, University of Yaounde 1, Yaounde BP 812, Cameroon; tatybrandy13@gmail.com
 - ³ Co-Centre for Sustainable Food Systems, School of Biological Sciences, The Queen's University of Belfast, Belfast BT9 5DL, Northern Ireland, UK
 - ⁴ Food Safety and Control Laboratory, Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture, Department of Nuclear Sciences and Applications, International Atomic Energy Agency, Wagramerstrasse 5, A-1400 Vienna, Austria; b.m.maestroni@iaea.org
 - ⁵ International Joint Research Centre on Food Security (IJC-FOODSEC), 113 Thailand Science Park, Phahonyothin Road, Khong Luang 12120, Pathum Thani, Thailand; awanwee@hotmail.com
- * Correspondence: s.a.haughey@qub.ac.uk



Turmeric Powder Sample Sources & Emerging Markets



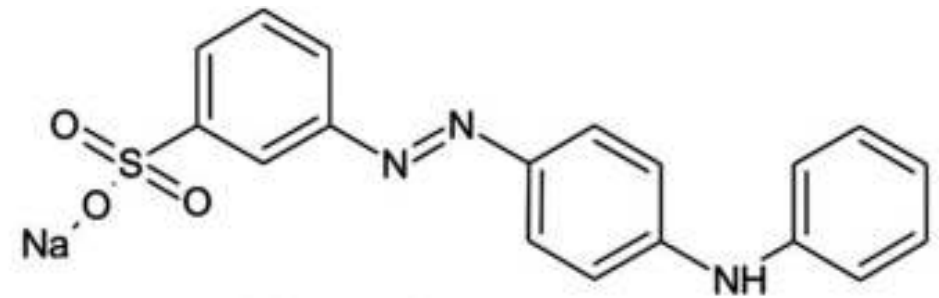
	Sample Number (N)	Max. (mg/kg)	+ve Detections (N)	>ML (1.5 mg/kg) (%)
India	293	5	24	8
Tanzania	126	4	14	11
Cameroon	118	4	23	19
Bangladesh	104	11	14	13
Ghana	34	5	7	20
Philippines	10	2	1	10
Nigeria	5	3	1	20
Vietnam	4	4	3	75
<i>UK supply chain</i>	109	1	1	0
Total	803			

Them and Us

**10-20%
High Pb**

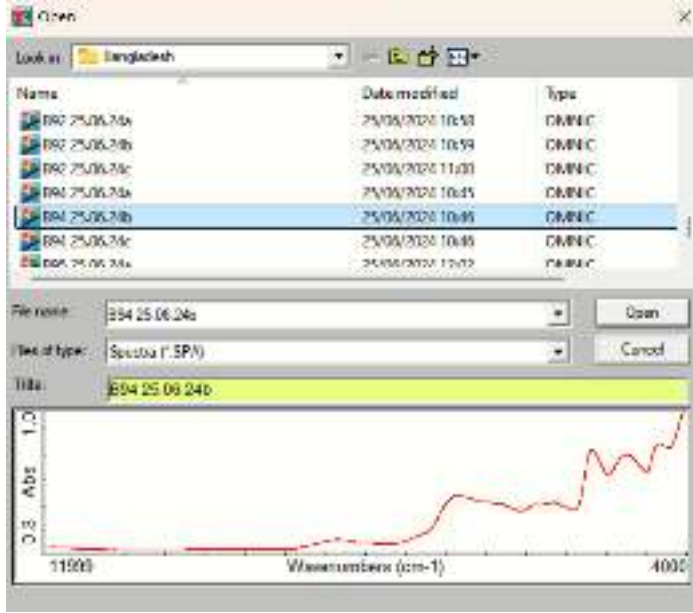
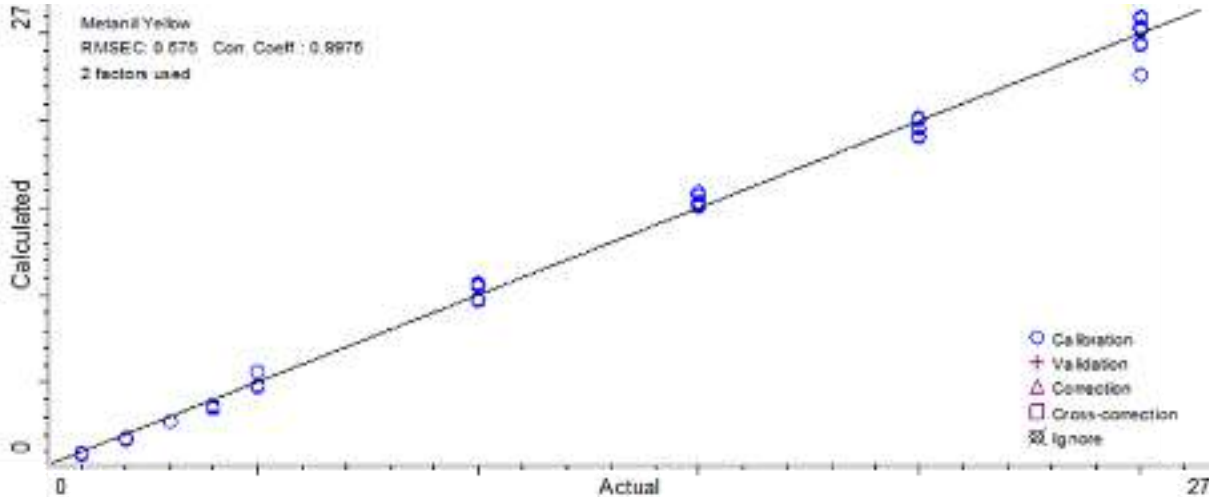
Metanil Yellow

- Toxic azo dye
- Class II potent carcinogen compound
- India- Biggest producer in world



Adapted from Sahu et al., 2020

RESULTS - NIR & Metanil Yellow



Quantify

Method file: D:\Tumesci\Analysis\All spikes calibration.qnt
 Method file name: D:\Tumesci\Analysis\All spikes calibration.qnt
 Revision: 3 Saved on: Thu Aug 22 12:44:56 2024 (GMT+01:00)
 Spectrum file: B94_25.06.24b
 Spectrum file name: D:\Tumesci\England\B94_25.06.24b.SPV
 Spectrum date: Tue Jun 25 10:46:00 2024 (GMT+01:00)
 Full spectrum fit: 98.5 Measurement region fit: 99.0

Index	Component	Concentration	Unit	Warnings
1	Metanil Yellow	0.25		

Buttons: Close, Copy, Print

RESULTS: NIR & Metanil Yellow

Samples	Samples with MET (n)	Concentration of MET (%)	Samples with MET detected (%)
Cameroon (n=100)	0	0	0
Tanzania (n=126)	10	0.07-0.237	7.9
Bangladesh (n=99)	8	0.007-0.463	8.1
Total (n=325)	18	0.007-0.463	5.5

RESULTS: NIR & Metanil Yellow

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All from **Dhaka**



Bia Analytical

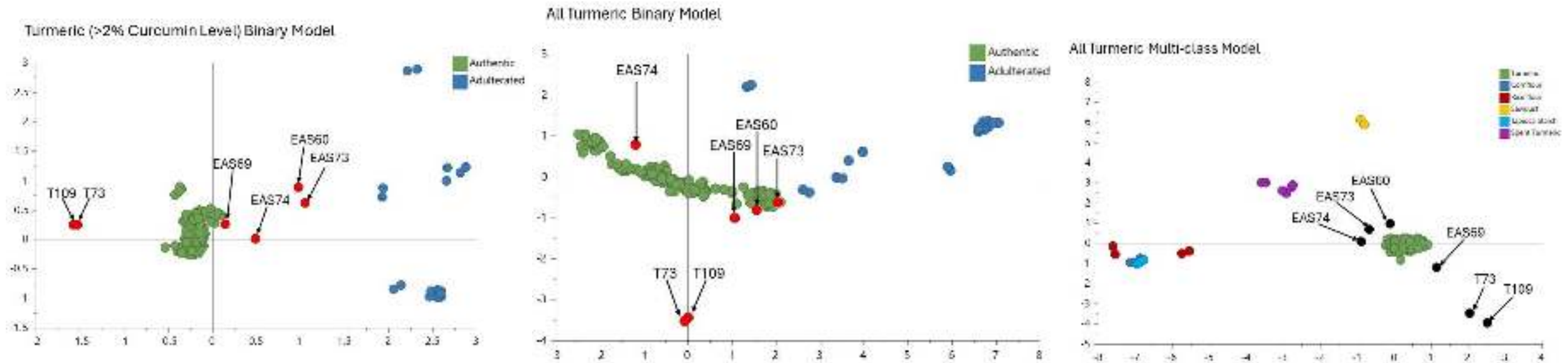
3 models were used:

- turmeric **>2% curcumin** level binary model
- **all turmeric** binary model
- all turmeric **multi class** model

FTIR Analysis

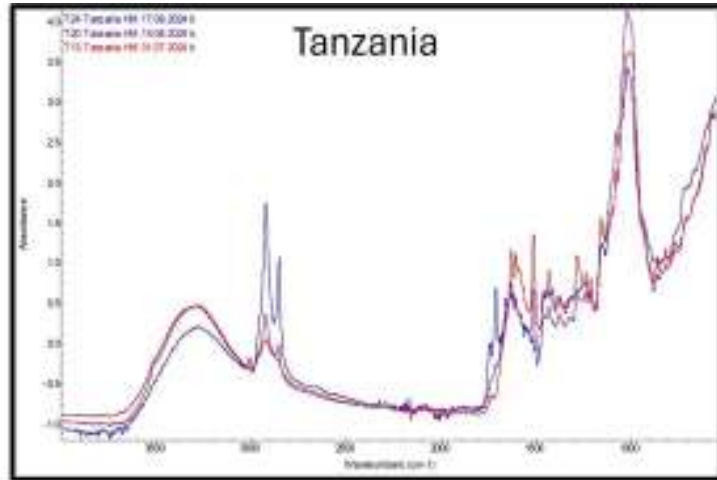
Aim: Authenticity testing of a sub-set from amongst the suspicious TP samples was taken to our collaborator, Bia Analytical, using ISO 17025 Accredited method FTIR/Chemometrics.

Observation:

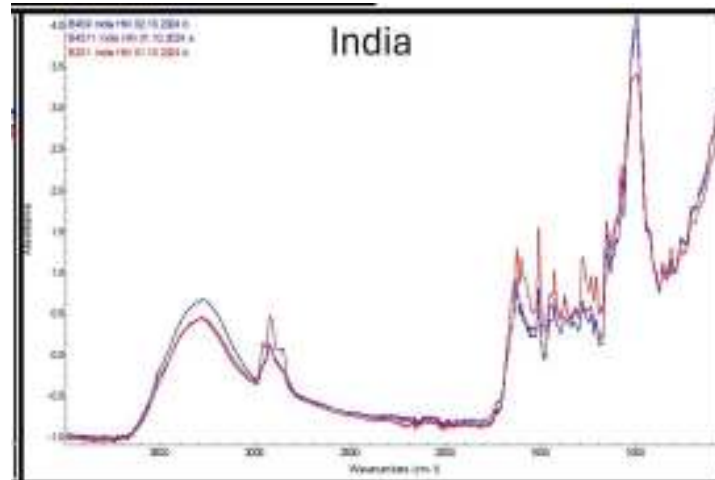


Conclusion: 6/10 TP samples were non-compliant. 2 suspicious – thought to be other spices but not turmeric. May contain unknown adulterants

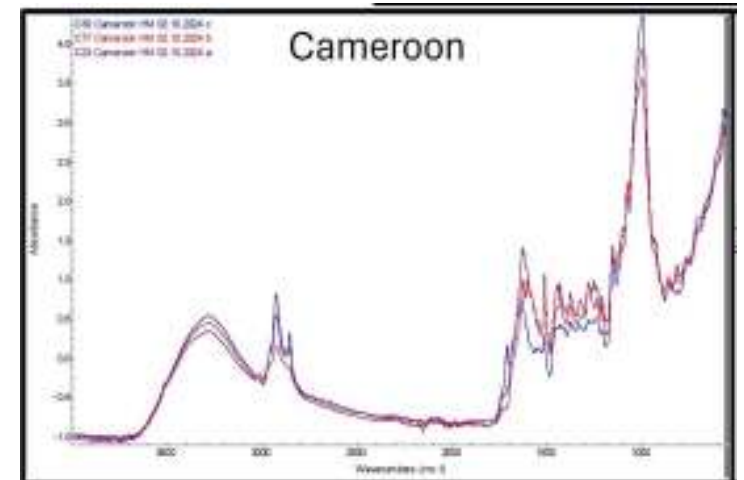
FTIR Analysis



N = 126



N = 20

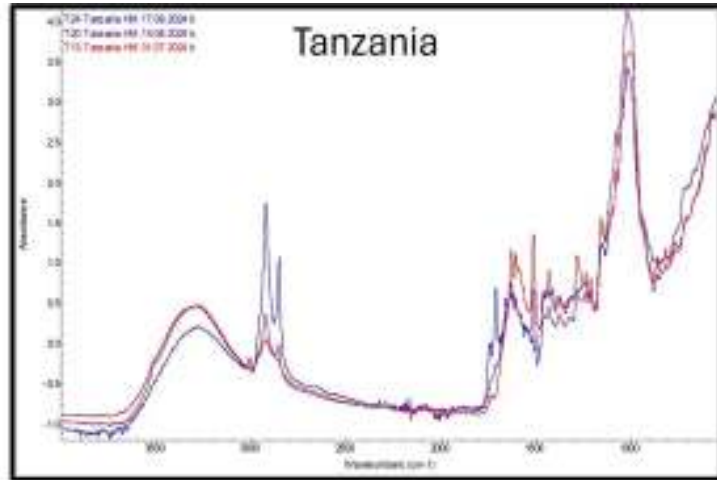


N = 20

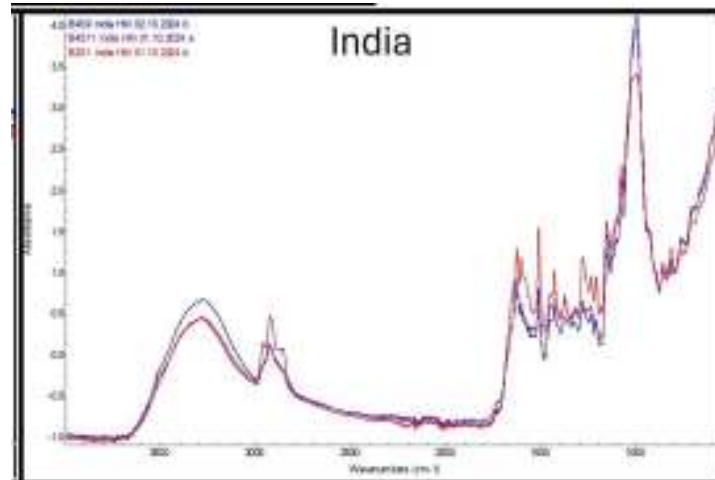
Visually there are obvious differences between spectra from the turmeric samples collected from Tanzania, Cameroon and India

Established chemometric models were used to test the samples to check if they were authentic or not

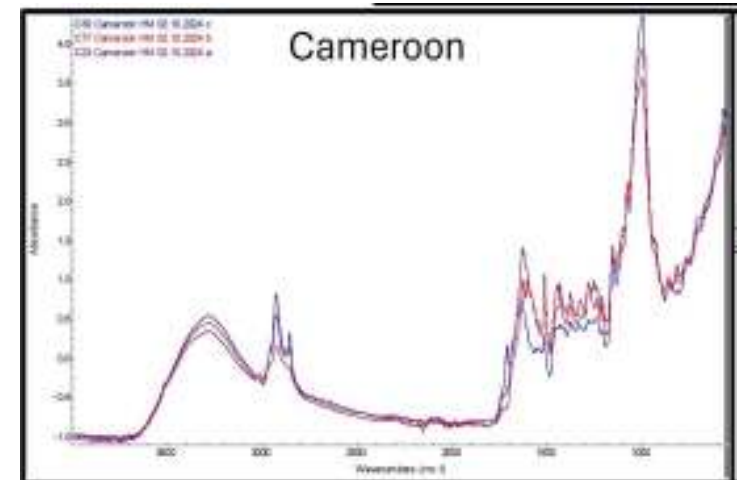
FTIR Analysis



N = 126



N = 20



N = 20

Overall, **77% of samples** tested for authenticity were non-compliant.

Suggests **fraud** involving **mis-labelling** and **addition of spent material**



EMERGING MARKETS



All Together:

Turmeric Powder Sample Sources & Emerging Markets



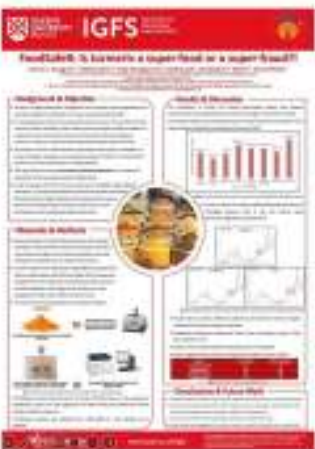
In Conclusion



Adulteration of turmeric powder is on the increase ?

XRF has a role in front line protection of our food – but correct QC is critical

Need to also integrate XRF with other measurements – data fusion approaches



Is turmeric a super-food or a super-fraud?

Is turmeric a super-food or a super-fraud?

Multi-instrumental calibration

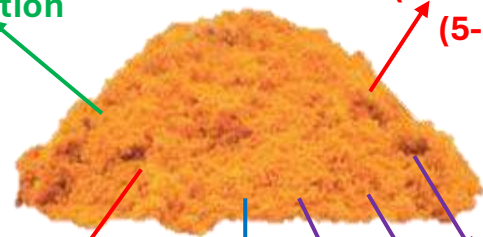
Mean (max) Pb levels: 1.89 – 3.62 (10.90) mg/kg (5-30 %)

Metanil yellow levels: 0.007 – 0.463 in 5.5 % of total samples

Stable C and N Pb Isotope Ratio

Pb & Cr distribution map

Non-compliant samples - Suspicious: Not turmeric powder



Thanks to ...

Paul Williams Chris Elliott
 Holly Montgomery
 Simon Haughey Heidi Russell
 Wilfred Abia Rudi Kraska
 Yicong Li Britt Maestroni



holi
food

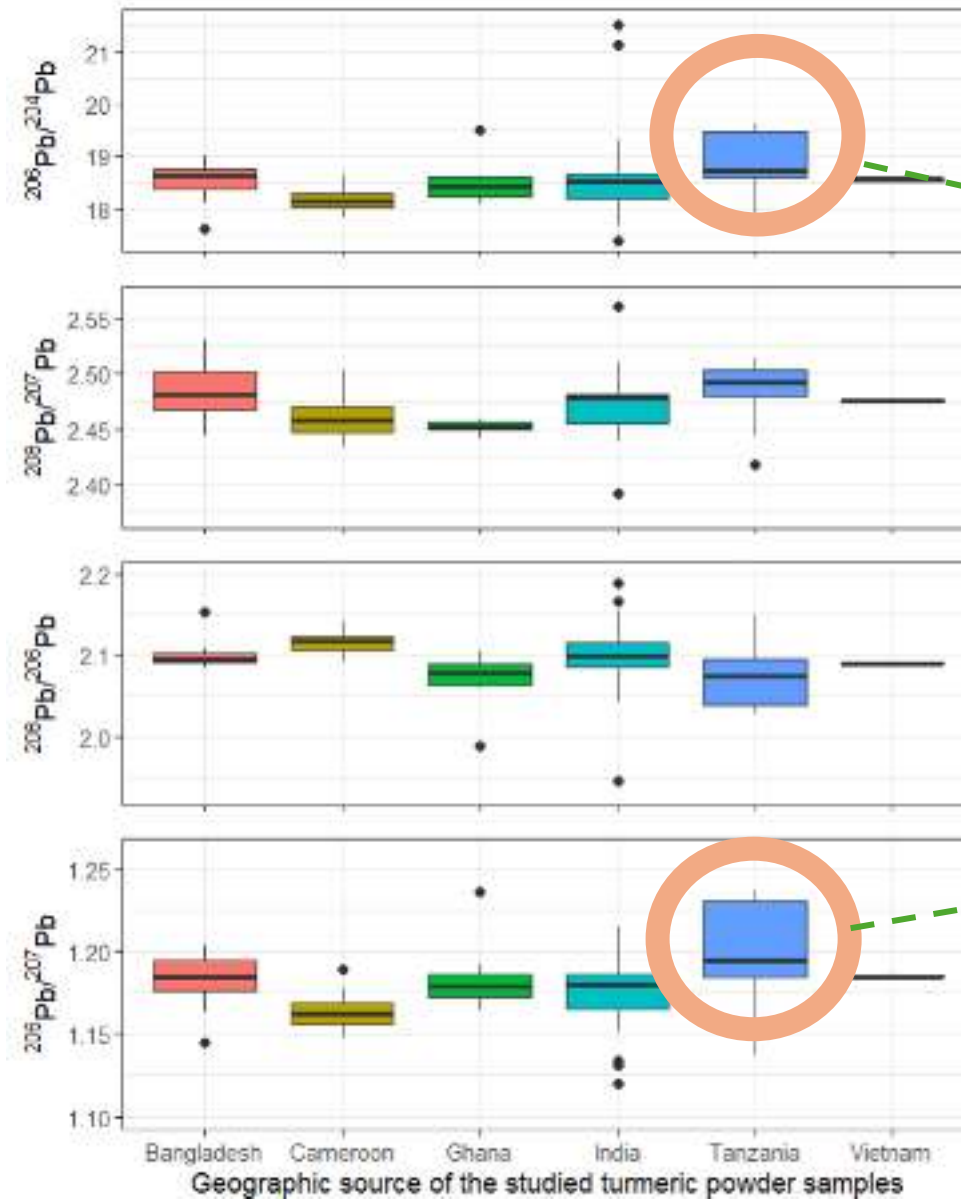


FOODSAFER
"EVERYBODY'S BUSINESS"



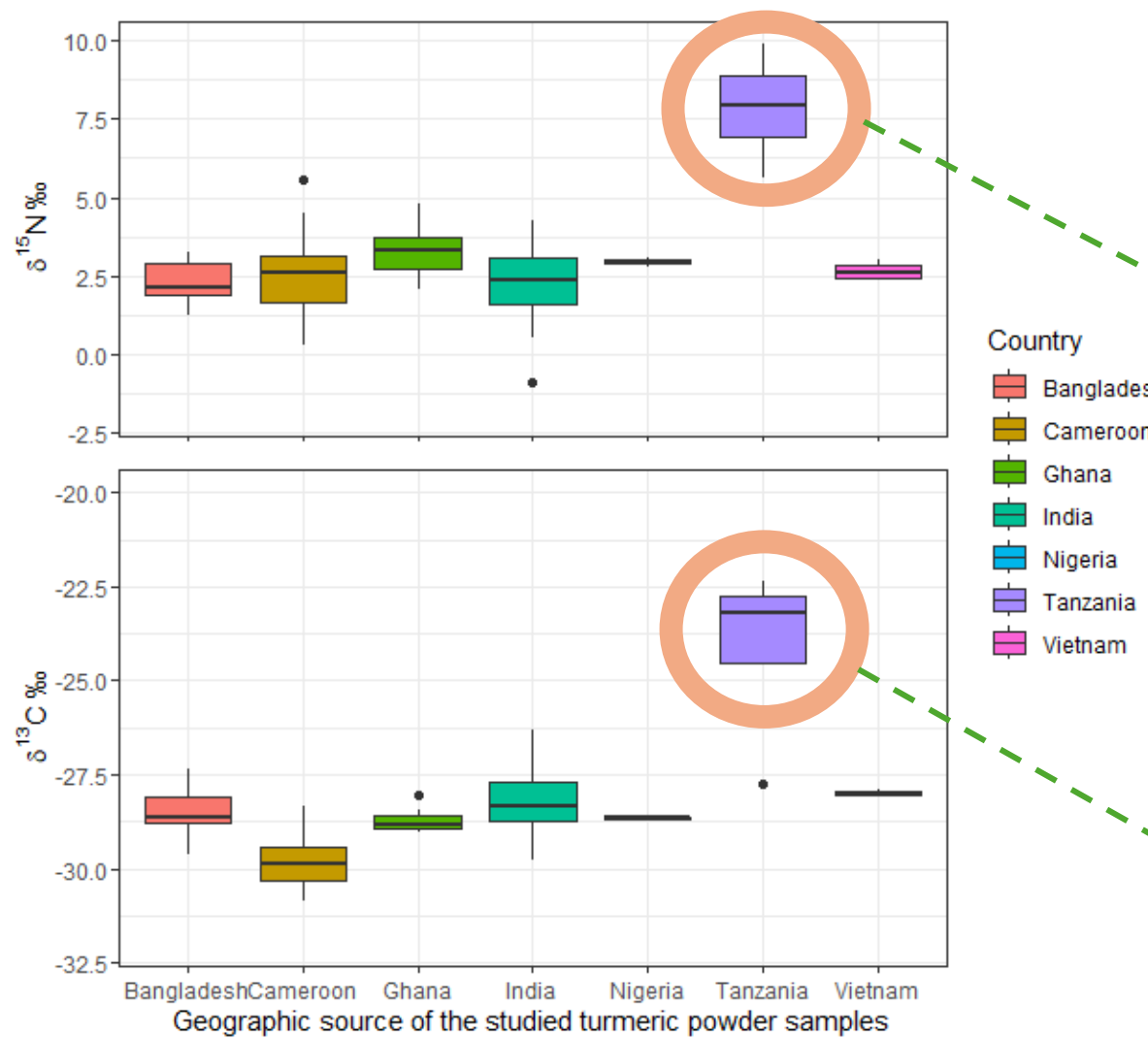
QUEEN'S
UNIVERSITY
BELFAST

IGFS THE INSTITUTE
FOR GLOBAL
FOOD SECURITY



Tanzania
ratio





Tanzania
ratio



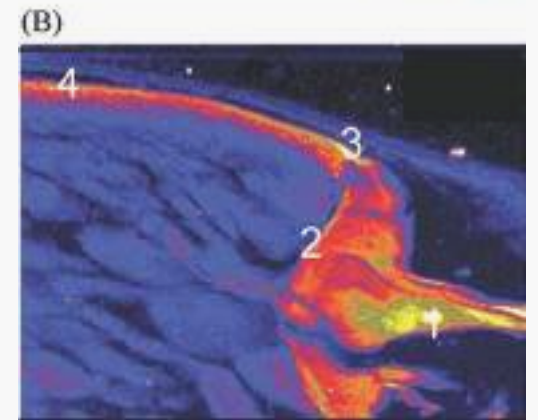
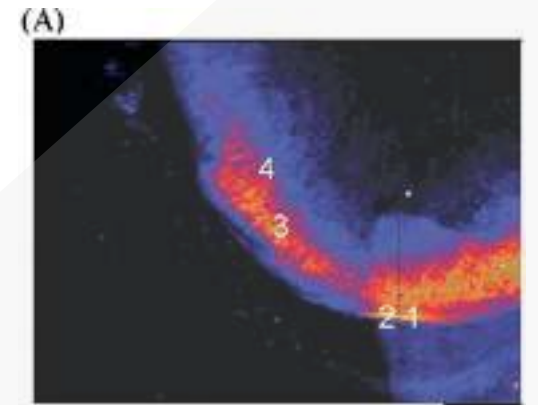
High
Low



LA-ICP-QQQ-MS

Rice Grains

μ -XRF

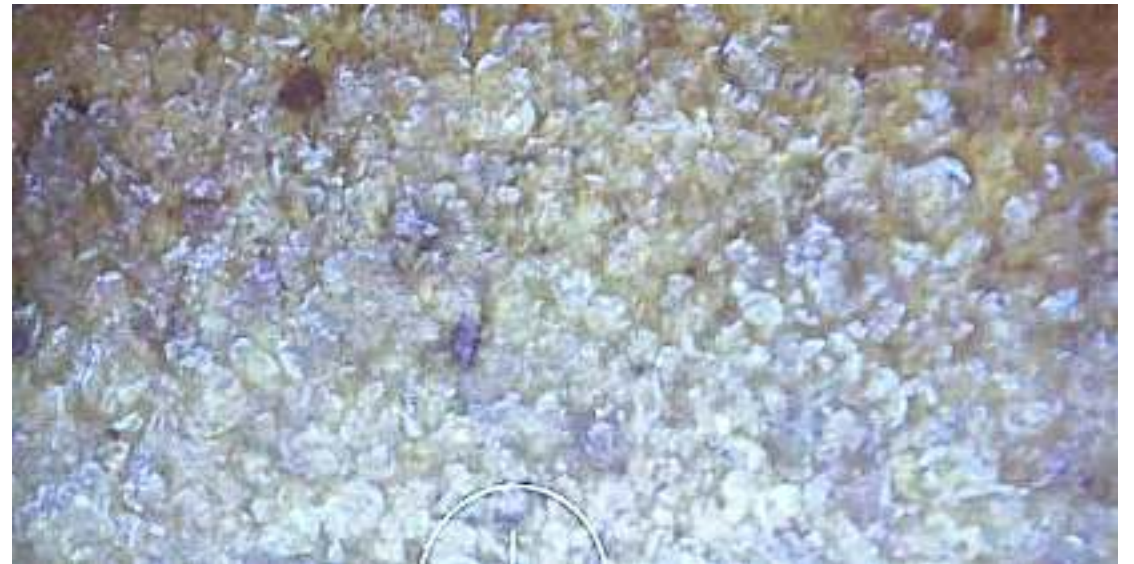


Williams et al. 2009



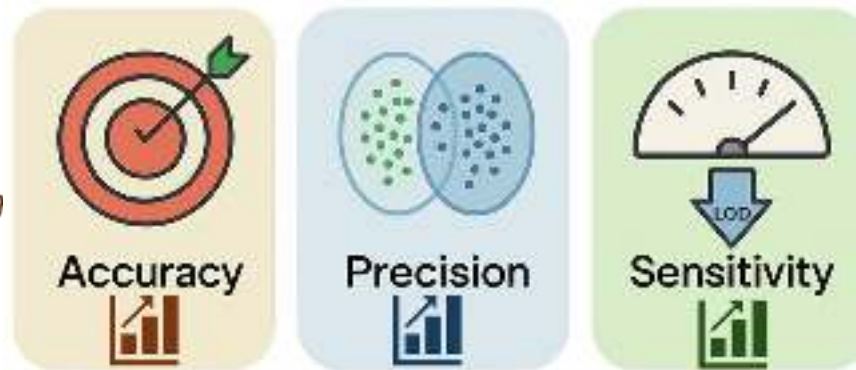
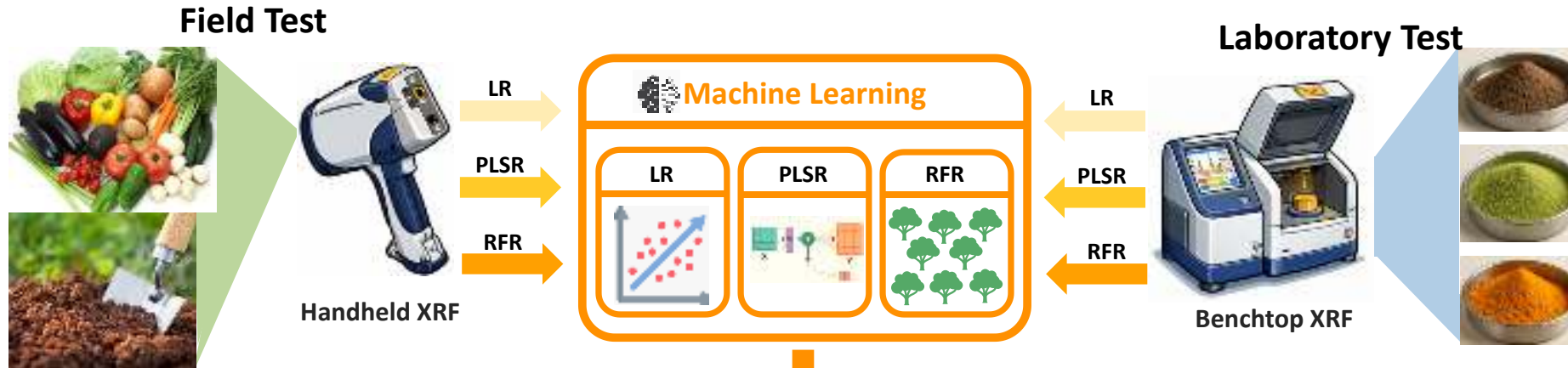
LA

QQQ-ICPMS



Enhance the accuracy and precision of XRF detection

Multi-elemental Measurement

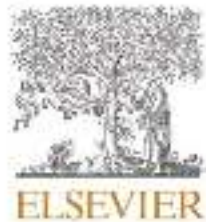


Certified Reference Materials (CRMs):

- 21 soil CRMs
- 65 food and biological material (FBM) CRMs

Enhance the accuracy and precision of XRF detection

Environment International 212 (2026) 110294



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Environment International

journal homepage: www.elsevier.com/locate/envint



Full length article

Advancing environmental and food system monitoring with machine-learning-enhanced X-ray fluorescence analytics

Yicong Li^a, Wanqi Jia^a, Wilfred Angie Abia^{a,b}, Simon A. Haughey^{a,c}, Manus Carey^{a,c},
Coalain McCreanor^{a,b}, Mark Mooney^{a,c}, Maame Croffie^d, Karen Daly^d,
Britt Marianna Maestroni^e, Caroline Meharg^a, Andrew A. Meharg^a, Christopher T. Elliott^{a,f},
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^d Environment Soils and Land Use Department, Teagasc Johnstown Castle Research Centre, Wexford Y35 TC97, Ireland

^e Food Safety and Control Laboratory, Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture, Department of Nuclear Sciences and Applications, International Atomic Energy Agency, Wagramerstrasse 5, A-1400 Vienna, Austria

^f Thammasat University Center of Excellence in Global Food Security, Mhu 18, Khong Luang, Pathum Thani 12120, Thailand

Sample Diversity (soil matrices)



Sample Diversity (FBM matrices)



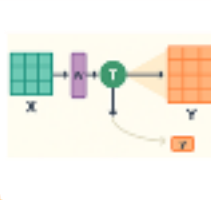
FP-ML Calibrations & Comprehensive Assessment

Machine Learning

LR



PLSR



RFR



Multiple XRF Platforms & Elemental Diversity

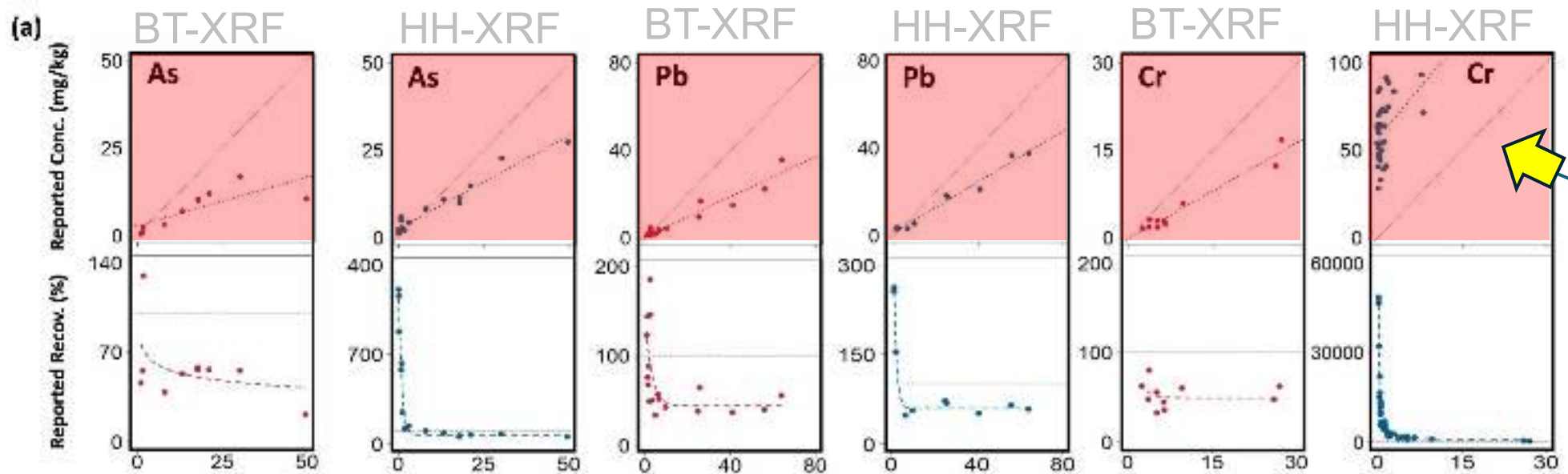


Benchtop XRF

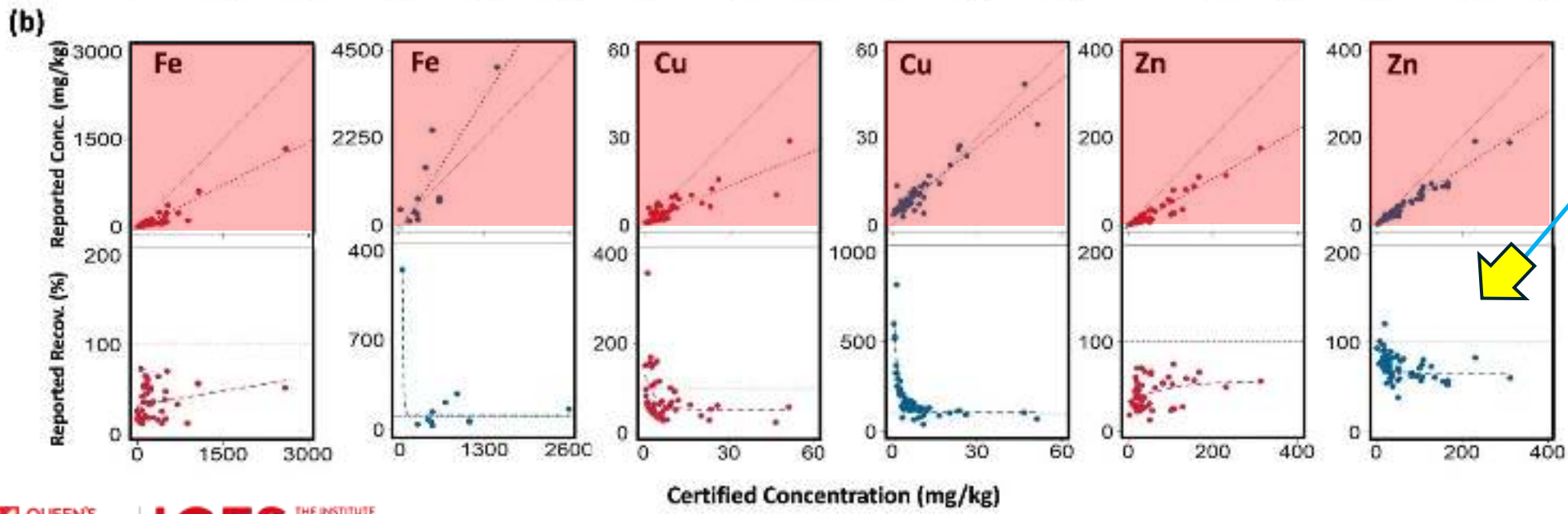


Handheld XRF

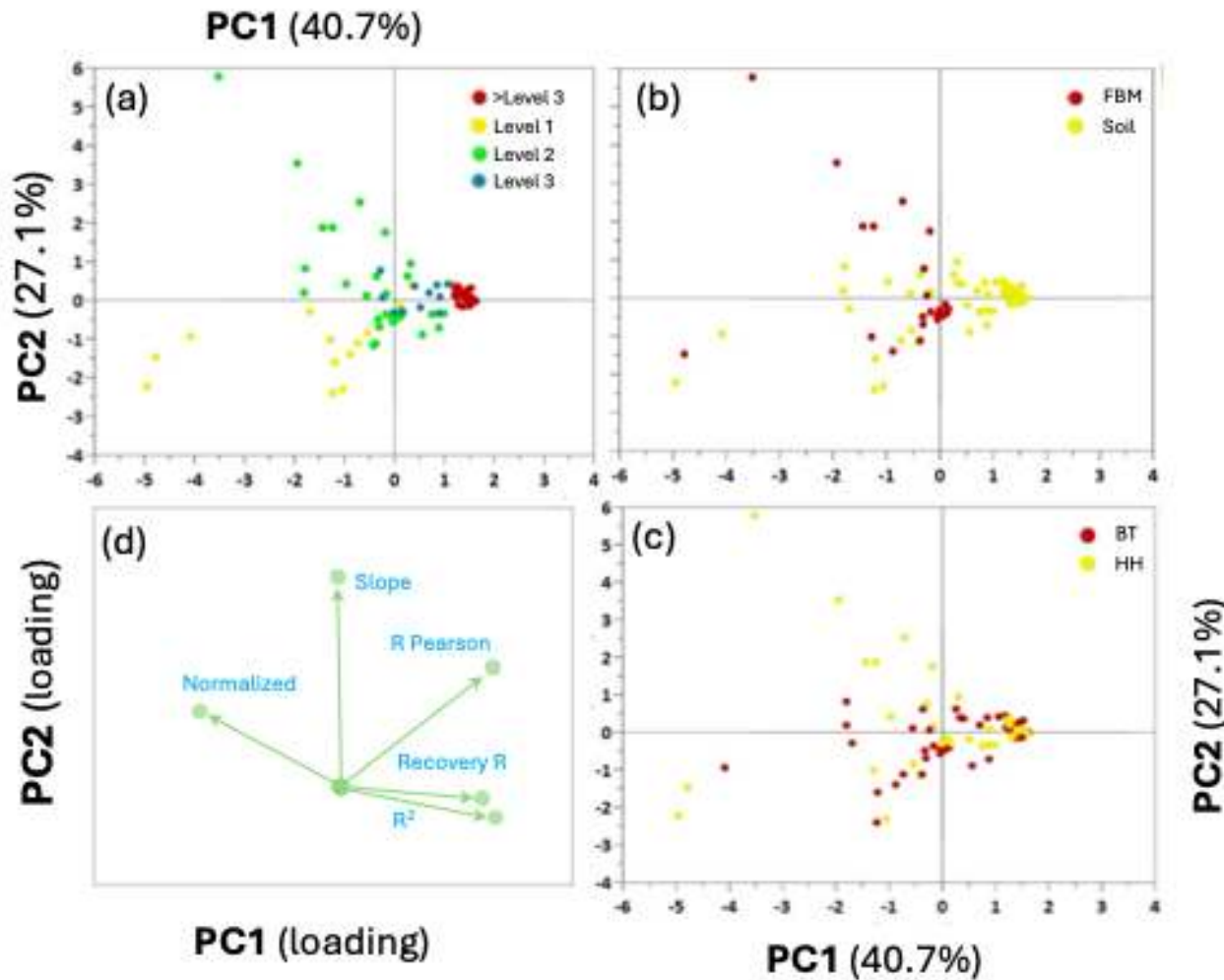




Cert. []
vs.
XRF []



Cert. []
vs.
XRF
Recovery



Level 1 screening focused on elemental detectability and the performance criteria



Level 2 performance evaluation assessed the linear association between measured and certified concentrations using Pearson's correlation coefficient (R_{Pearson})



Level 3 evaluation employed the coefficient of determination (R^2), calculated from measurement residuals



Level 4 performance evaluation assessed analytical accuracy using recovery analysis

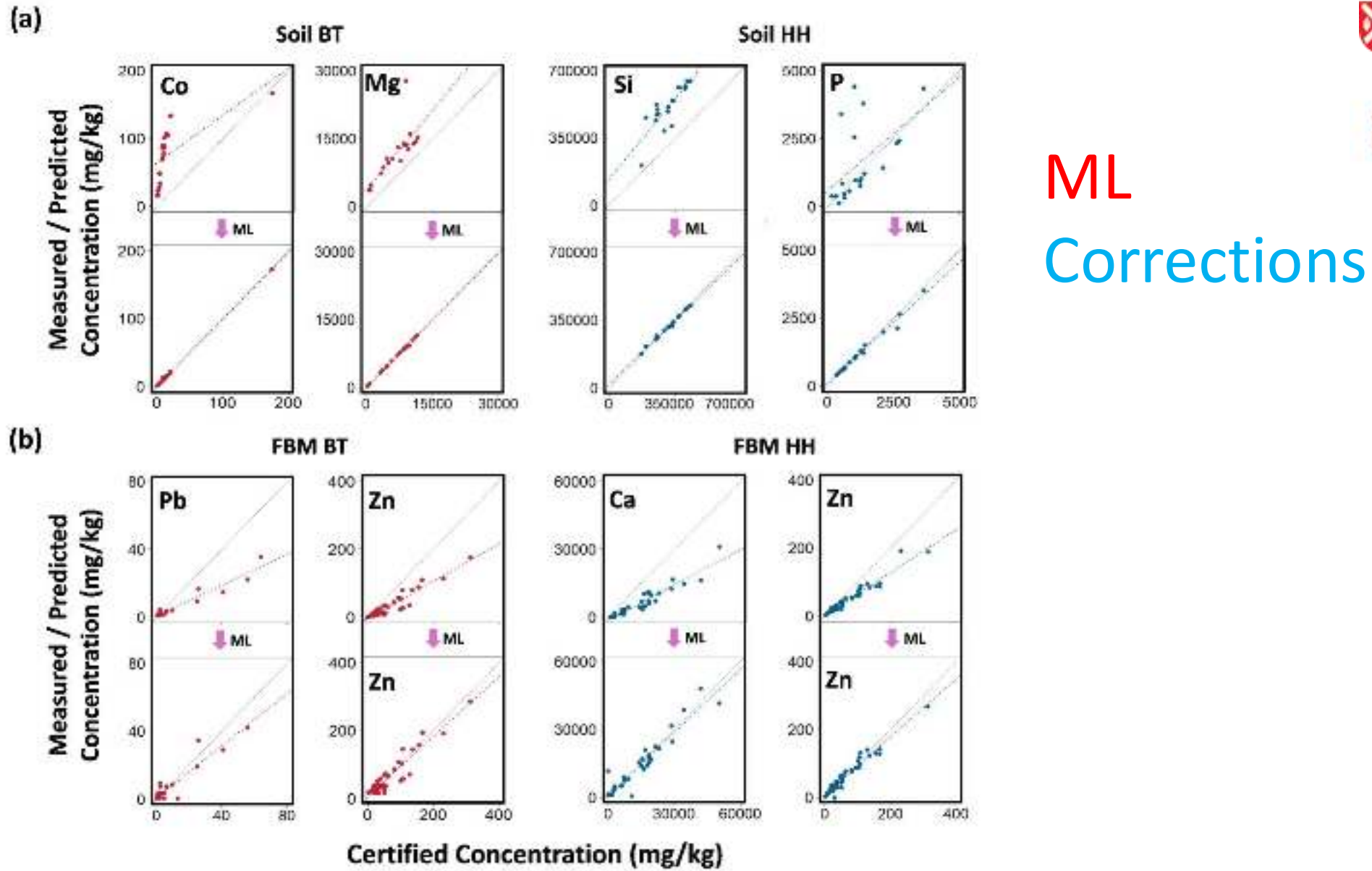


Level 5 represented the strictest performance tier, focusing on analytical precision and repeatability of the XRF measurements as assessed by averaged relative standard deviation (RSD)

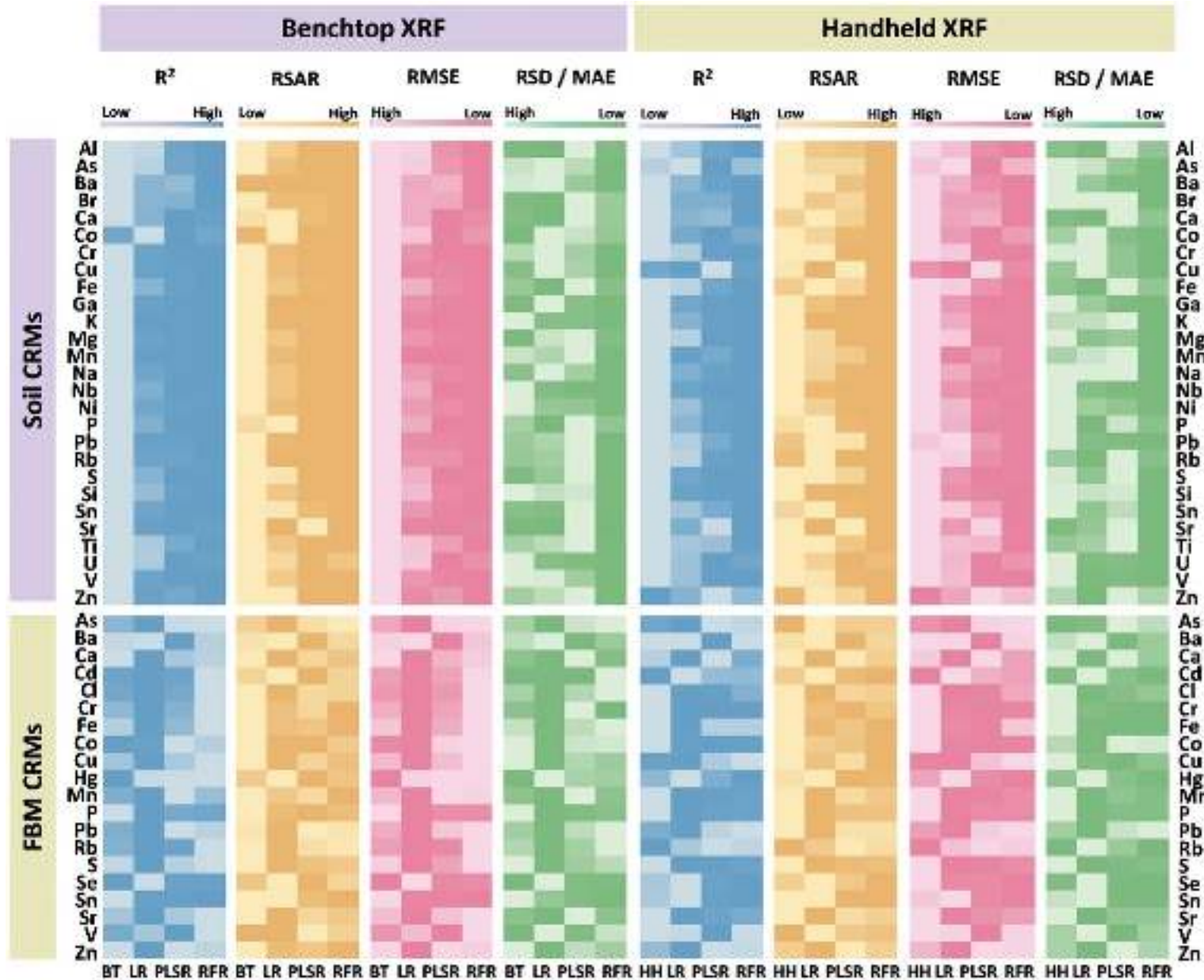
Table 1. Summary of XRF instruments and analytical performance for elemental analysis.

Element	CRMs	XRF	$R_{Pearson}$	Slope	R^2	nRMSE	Min - Max (mg/kg)	LOD1 (mg/kg)	LOD2 (mg/kg)	N
Mg	Soil	HH ^{L2}	0.92	0.84	0.73	0.39	509 - 28827	407	6028 ^a	18
Cl	FBM	BT ^{L2}	1	0.62	0.82	4.92	178 - 57000	1.65	--- ^a	34
K	Soil	BT ^{L3}	0.98	0.87	0.94	0.08	5988 - 21865	44.0	2480 ^b	20
		III ^{L5}	0.97	1.03	0.83	0.14	5988 - 21865	44.0	5810 ^b	20
Ca	Soil	BT ^{L3}	0.98	1.22	0.89	0.57	2062 - 221000	52.9	4899 ^c	20
		III ^{L5}	0.98	1.17	0.92	0.47	2062 - 221000	52.9	4497 ^c	20
Ti	Soil	BT ^{L3}	0.98	0.83	0.94	0.09	563 - 4914	19.2	1197 ^c	20
		III ^{L5}	0.96	0.88	0.87	0.13	563 - 4914	19.2	1437 ^c	20
Cr	Soil	HH ^{L3}	0.9	0.78	0.71	0.41	19 - 259	10.6	86.1 ^c	20
Mn	Soil	BT ^{L4}	0.99	1.02	0.92	0.2	75 - 1331	17.4	324 ^a	20
		III ^{L5}	0.99	1.05	0.88	0.25	75 - 1331	17.4	412 ^c	20
Fe	Soil	BT ^{L5}	0.95	1.07	0.85	0.18	3851 - 40100	17.7	--- ^a	20
		III ^{L5}	0.99	1.01	0.96	0.1	2620 - 52800	17.7	--- ^a	20
Ni	Soil	BT ^{L3}	0.99	1.01	0.75	0.37	6.6 - 101	3.37	35.7 ^b	20
		HH ^{L4}	0.97	1.09	0.91	0.19	7.2 - 101	3.37	--- ^a	18
Cu	Soil	BT ^{L3}	1	1.08	0.87	0.97	5.1 - 263	3.07	--- ^b	20
		HH ^{L5}	0.99	0.94	0.96	0.51	5 - 263	3.07	17.8 ^c	20
	FBM	HH ^{L3}	0.94	0.77	0.82	0.76	0.6 - 51	0.57	5.37 ^c	56
Zn	Soil	BT ^{L5}	1	1.1	0.98	0.46	18 - 1054	2.68	20.8 ^c	20
		HH ^{L4}	1	0.91	0.99	0.4	18 - 1054	2.68	--- ^a	20
	FBM	III ^{L3}	0.97	0.63	0.74	0.87	2.5 - 313	0.42	--- ^a	58
As	Soil	BT ^{L4}	0.98	0.99	0.95	0.29	1.3 - 48	2.43	--- ^a	20
		HH ^{L4}	0.98	0.85	0.95	0.28	1.5 - 48	2.43	4.68 ^c	19
	FBM	III ^{L3}	0.97	0.53	0.73	2.32	0.1 - 50	0.21	2.56 ^c	15
Rb	Soil	BT ^{L3}	1	1.08	0.87	0.15	23 - 132	0.78	24.3 ^c	20
		III ^{L5}	0.99	0.92	0.98	0.05	23 - 124	0.78	--- ^a	12
Sr	Soil	BT ^{L5}	1	1.16	0.93	0.27	27 - 597	0.6	29.6 ^c	20
		HH ^{L5}	0.99	1	0.98	0.16	27 - 597	0.6	35.6 ^c	20
Ba	Soil	BT ^{L4}	1	0.92	0.99	0.12	145 - 1488	30.9	--- ^b	20
Pb	Soil	BT ^{L3}	1	1.14	0.95	0.6	6.2 - 309	2.33	28.4 ^c	20
		HH ^{L4}	0.98	1.16	0.91	0.75	6 - 309	2.33	--- ^a	19

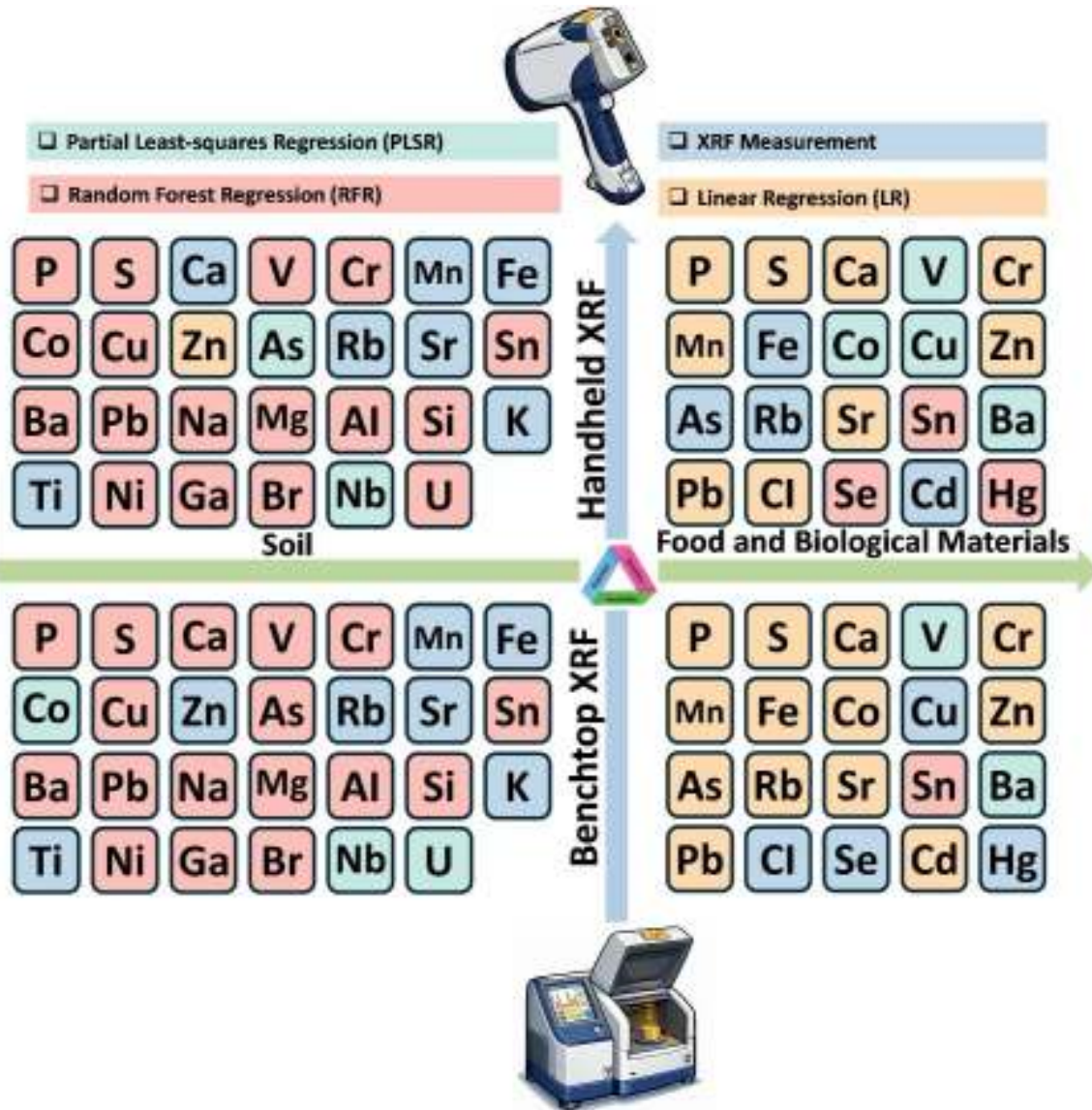
Performance
Criteria



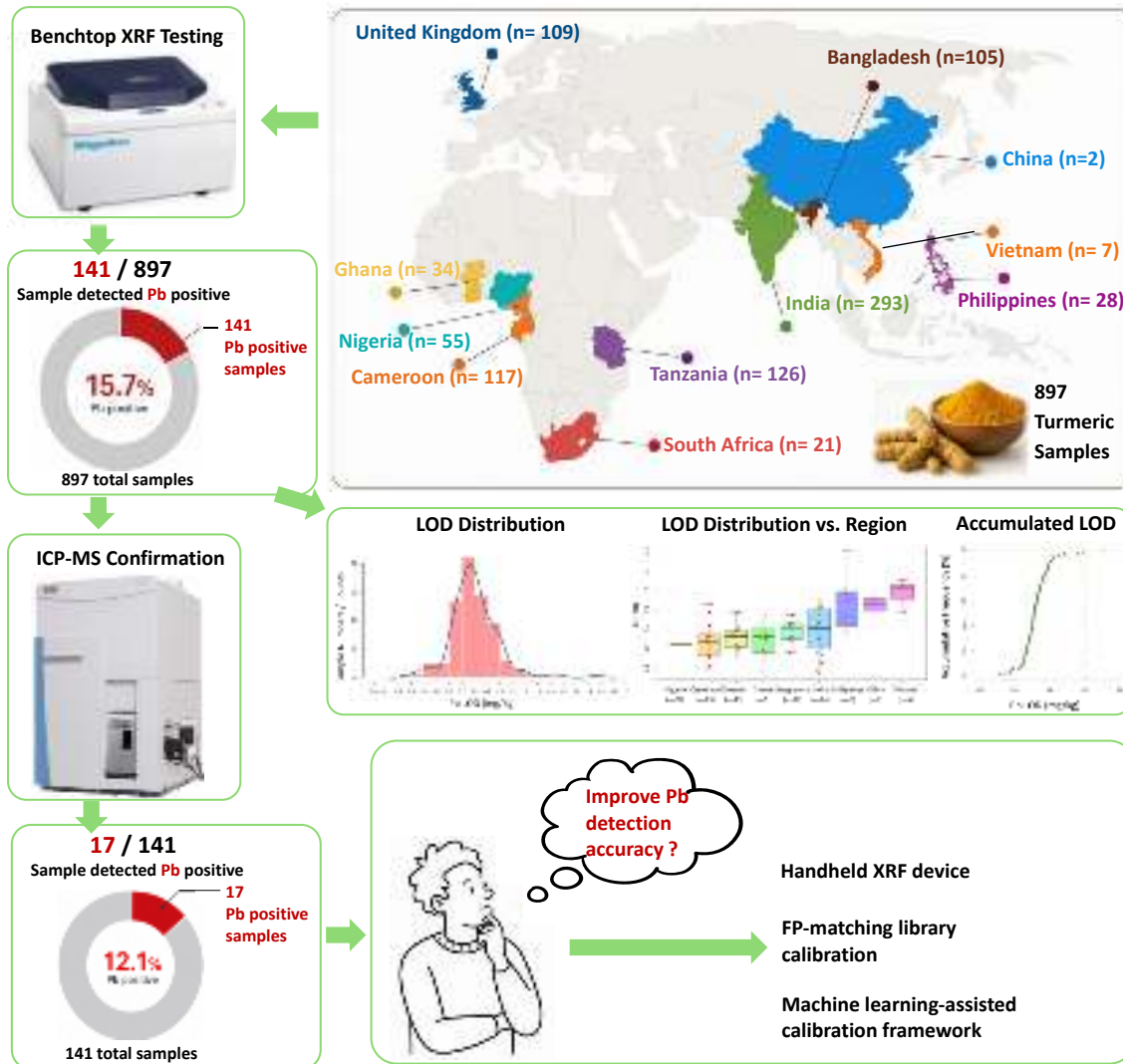
ML Corrections



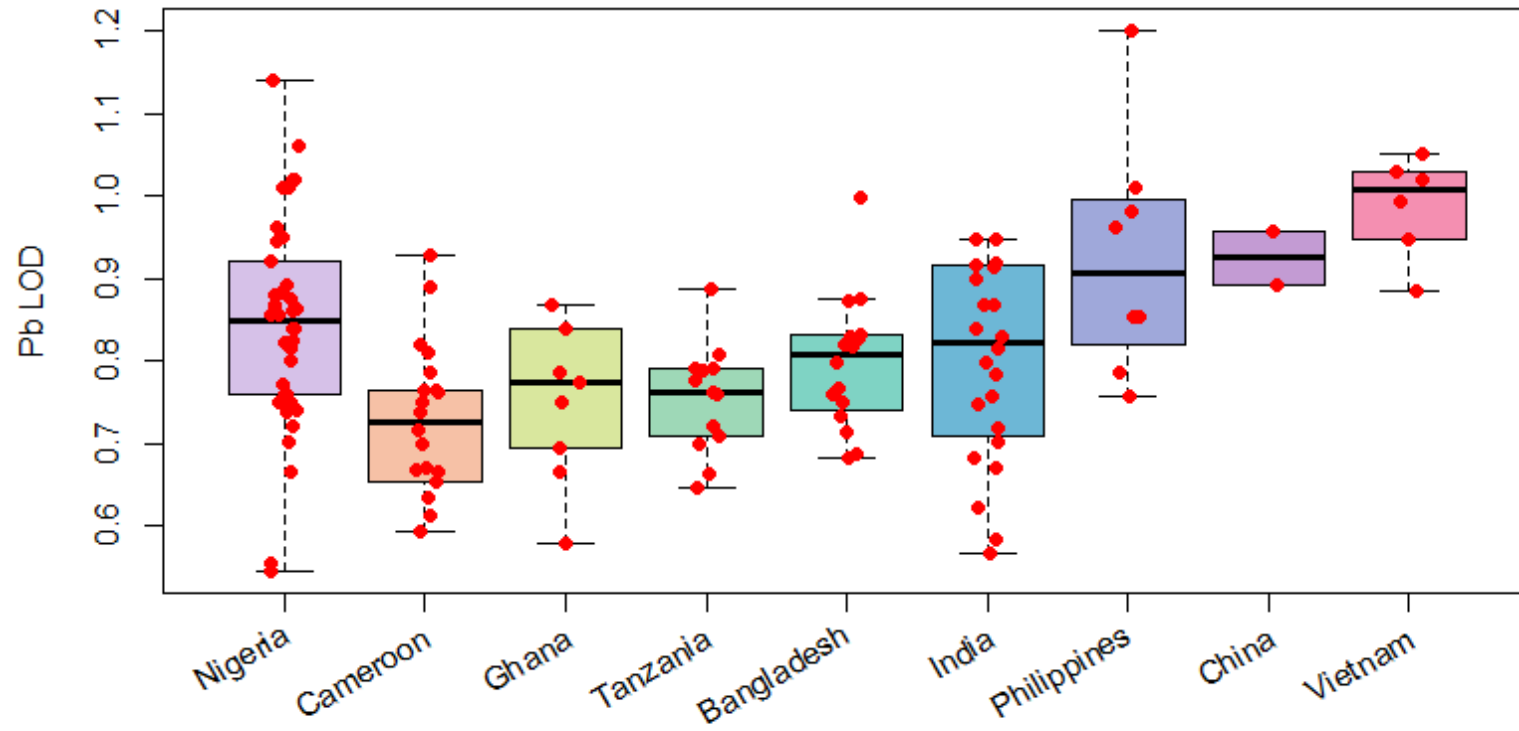
ML
Model
Performance



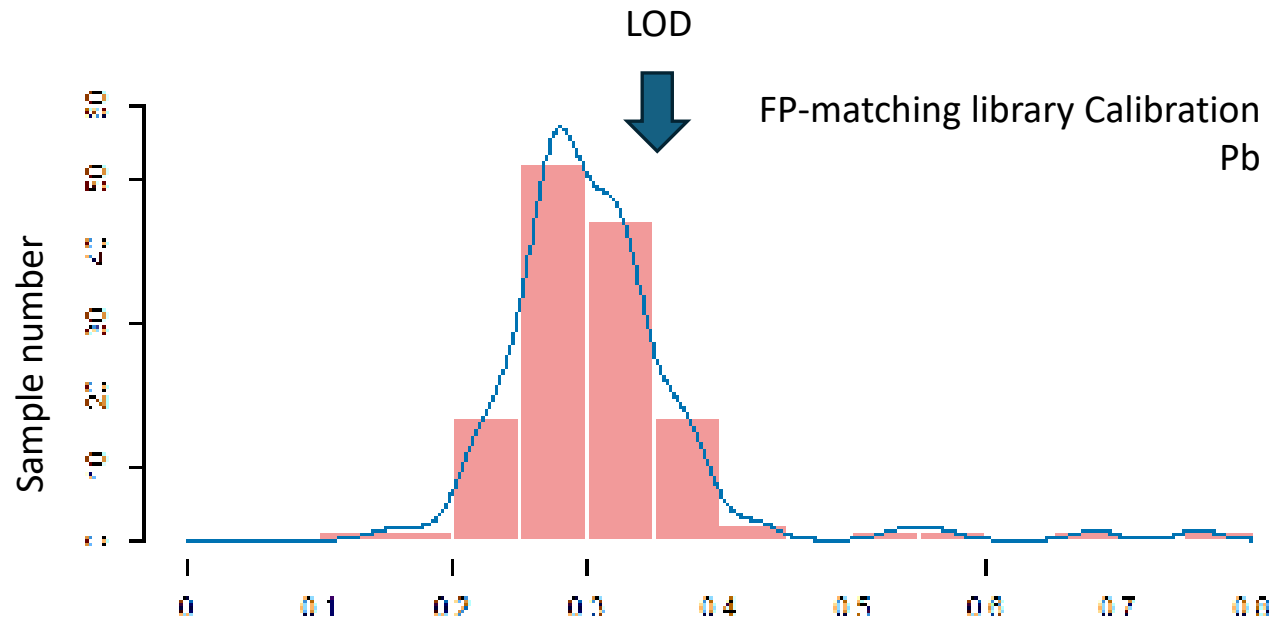
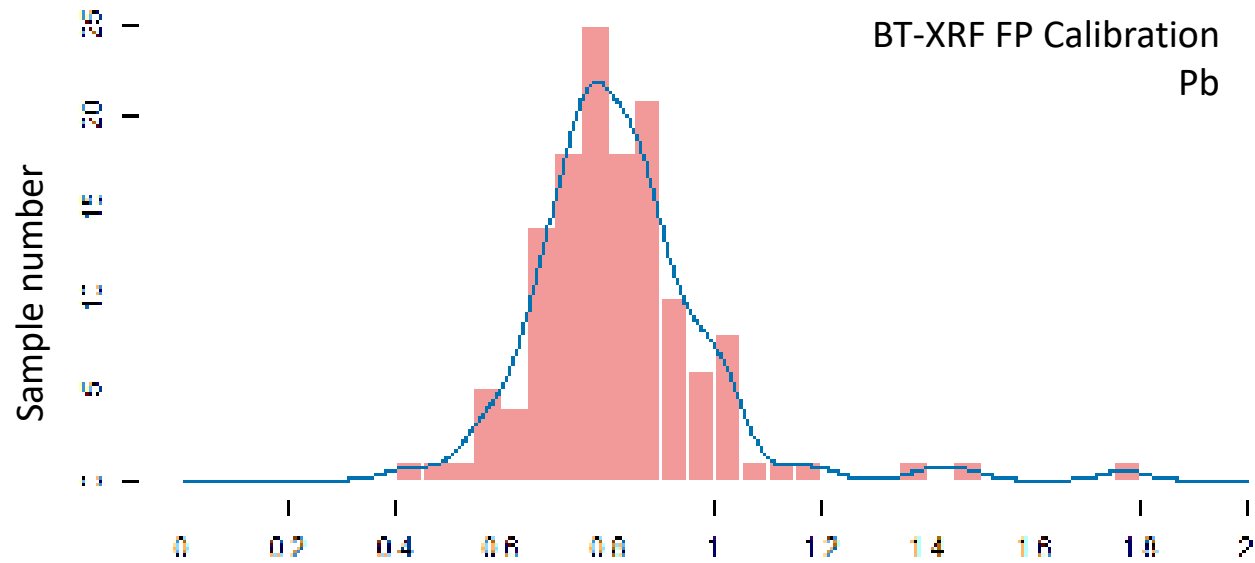
No One Size Fits ALL



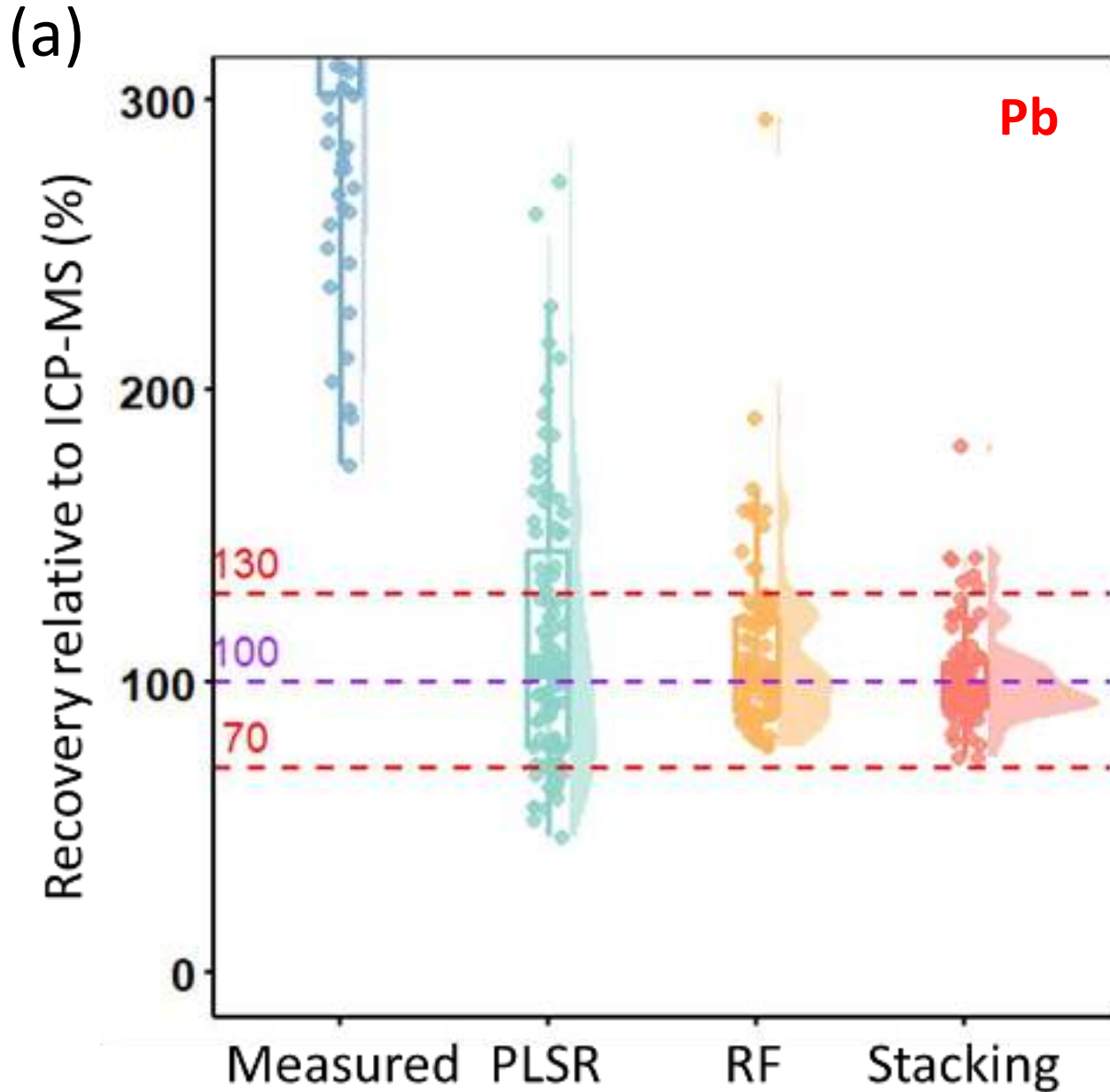
Turmeric specific Models



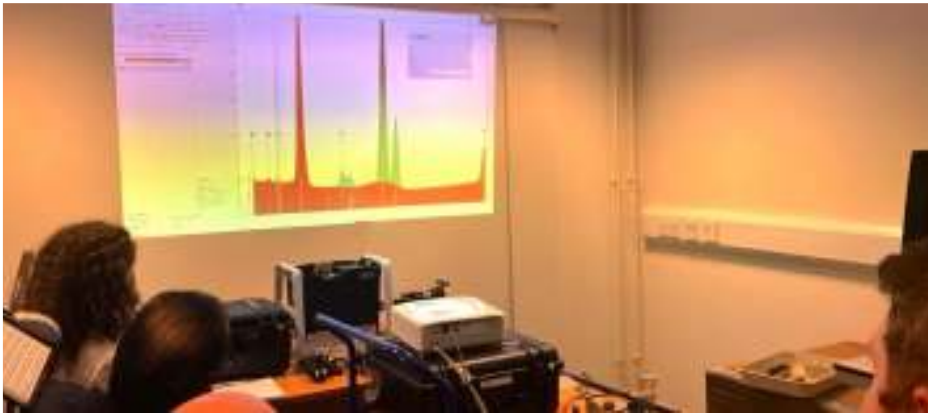
LOD variation
BT



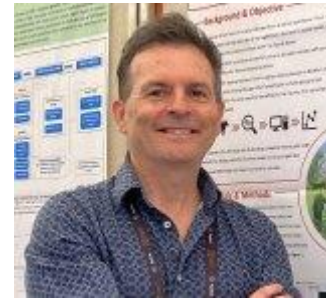
LOD variation
BT with FP-ML



Relative recovery of machine learning corrected **BT-XRF** measurements against ICP-MS reference values for multi-element analysis in **turmeric** training samples



**QUEEN'S
UNIVERSITY
BELFAST**



**Thank u
Any Q?**

