UNIVERSITY OF LEEDS

Informal Circular Economy Systems for Plastic Waste

Conference on Biological Circular Economy 2023

Ed Cook
Research Fellow in Circular Economy Systems for Waste Plastics
e.r.cook@leeds.ac.uk

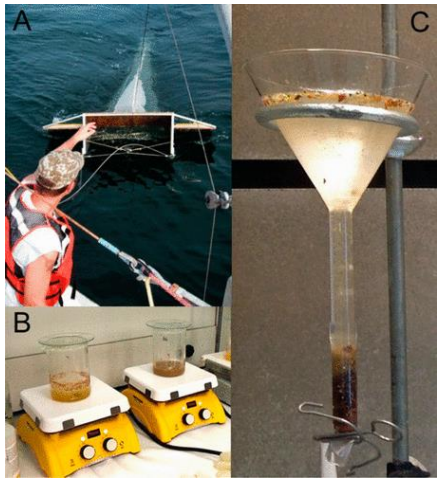
Costas Velis Research Group https://plasticpollution.leeds.ac.uk/

Part 1
Quantification of plastic pollution

How can we quantify plastic pollution?

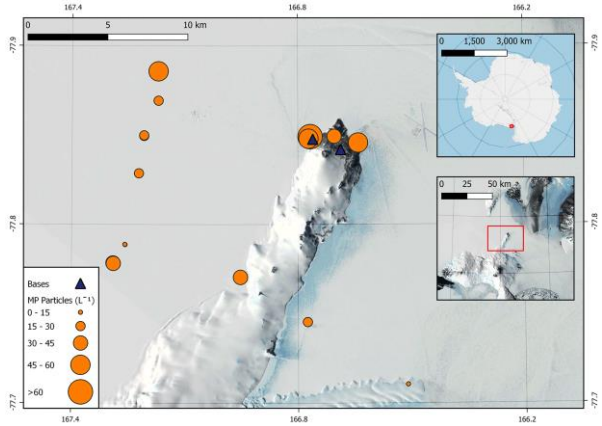
UNIVERSITY OF LEEDS

Marine Conservation Society survey of stranded debris Redcliffe Bay Sep 2014 (courtesy of Ed Cook)

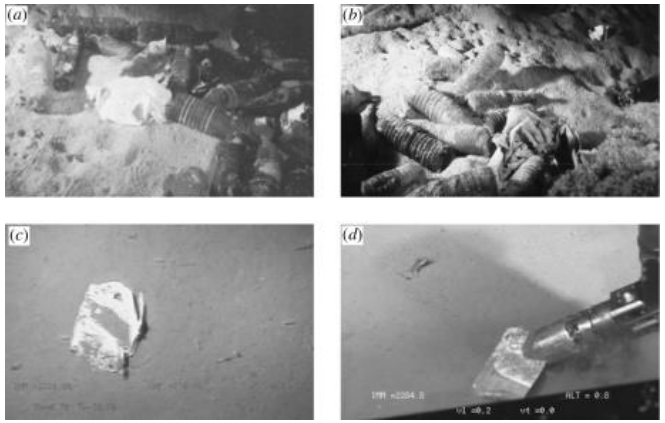


Monitoring of water column in Chesapeake Bay, U.S.A.: Yonkos et al. (2014) https://doi.org/10.1021/es5036317

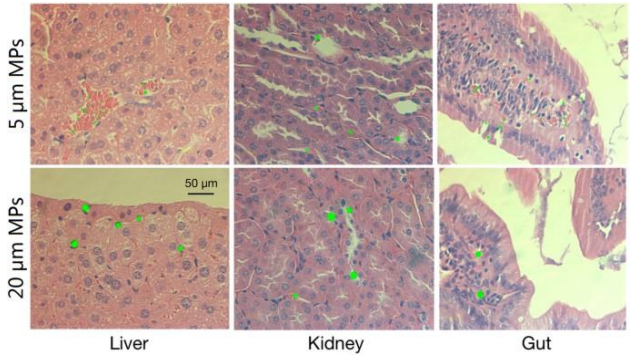
Dumpsite in Serrakunda, The Gambia: Copywrite 2021 CNES/Airbus / Maxar technologies



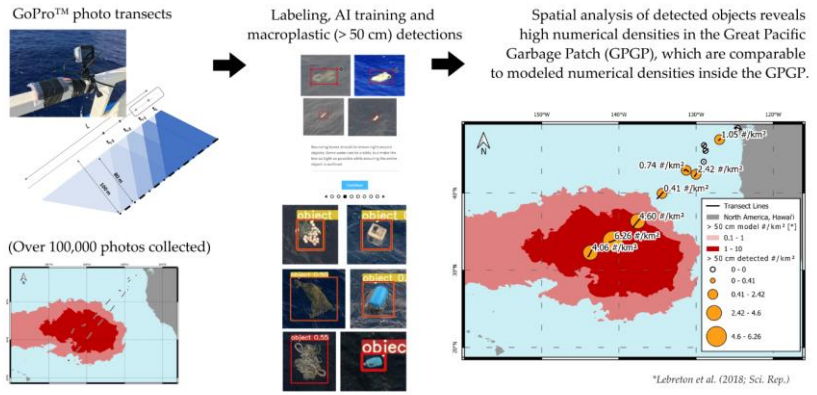
Microplastics found in Ross Island region of Antarctica: Aves et al. (2022) https://doi.org/10.5194/tc-16-2127-2022



Plastic debris detected in Marseille Canyon, Mediterranean: Barnes et al. (2009) https://doi.org/10.1098/rstb.2008.0205



Microplastics in tissue of mice: Deng et al 2017 https://doi.org/10.1038/srep46687

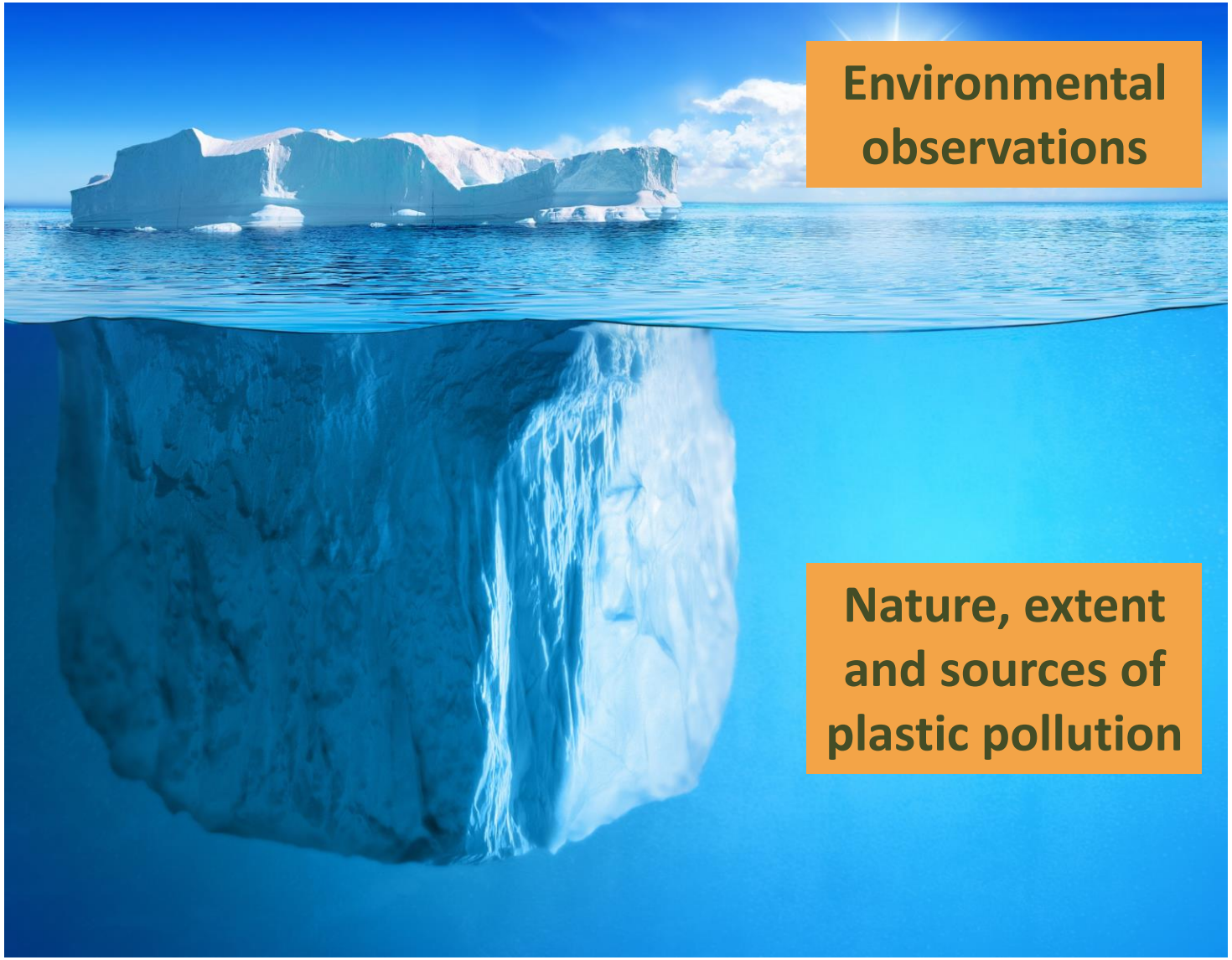


Marine transect analysis using GoPro and machine learning: de Vries et al. 2021 https://doi.org/10.3390/rs13173401

Observable and measurable concentrations only show us part of the picture

UNIVERSITY OF LEEDS

Emission sources are challenging to determine from environmental observations



There are many land-based sources of plastic pollution?

UNIVERSITY OF LEEDS

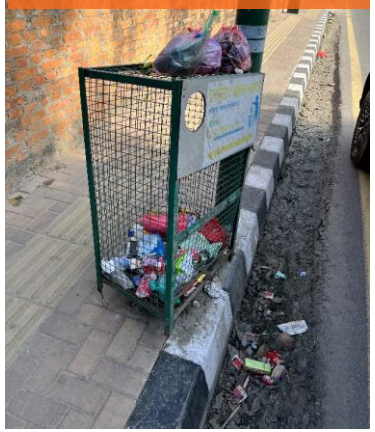
Waste sorting and reprocessing

Uncollected waste

Uncollected waste

Littering

Collection system



Collection system

Uncontrolled disposal

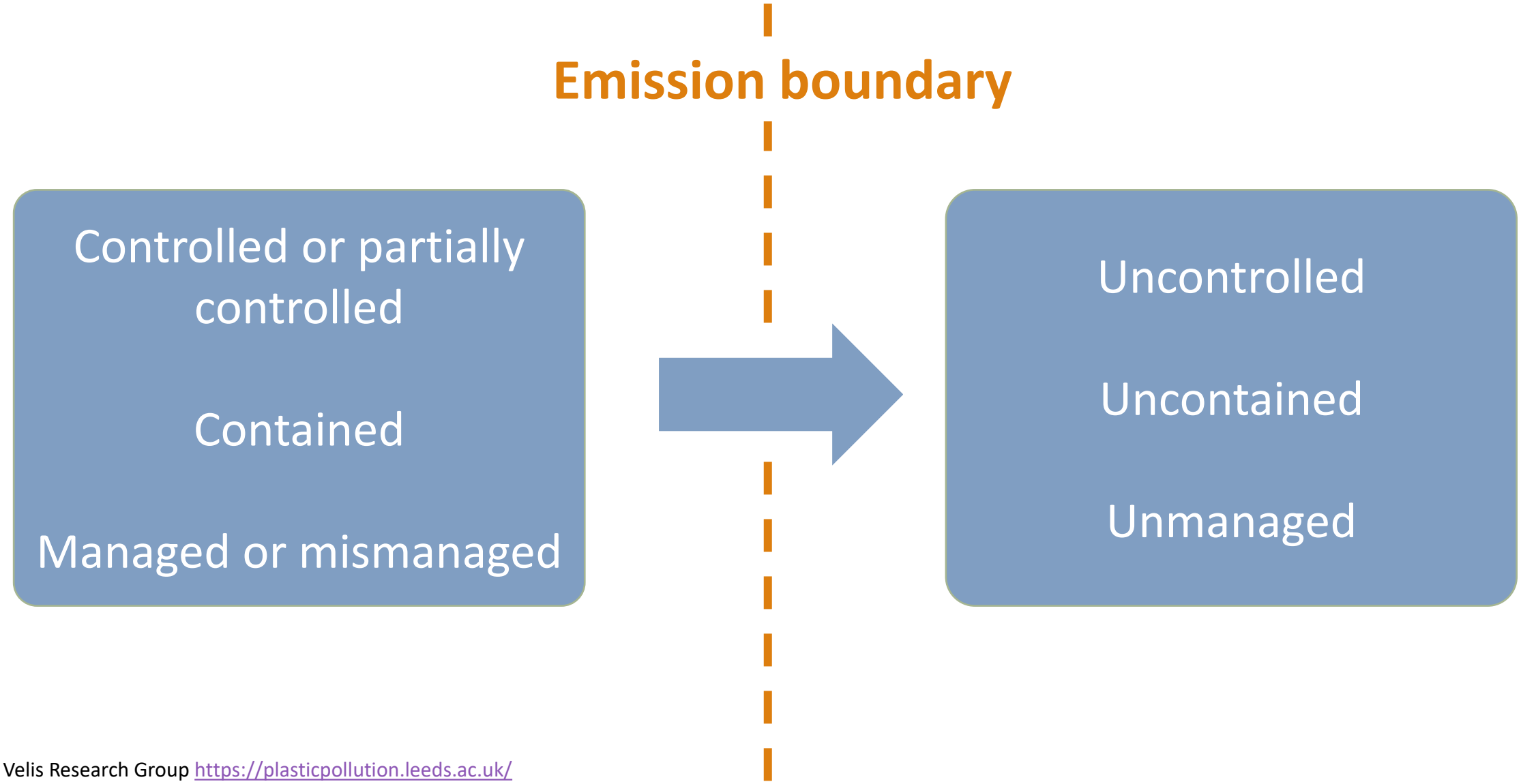
Costas Velis Research Group https://plasticpollution.leeds.ac.uk/

Open burning of waste is sometimes overlooked as a form of plastic pollution

UNIVERSITY OF LEEDS

What do we mean by emissions?

UNIVERSITY OF LEEDS



Part 2
Modelling plastic pollution

Plastic pollution research

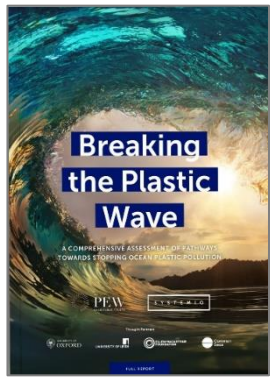
UNIVERSITY OF LEEDS

Our research group (Dr Costas Velis) is developing models to simulate flow of plastic through the global system

Focus on waste management phase

and

Global South (Developing countries) where challenges are most acute

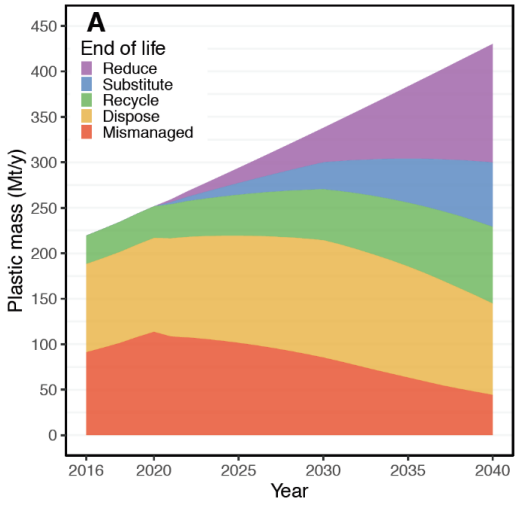


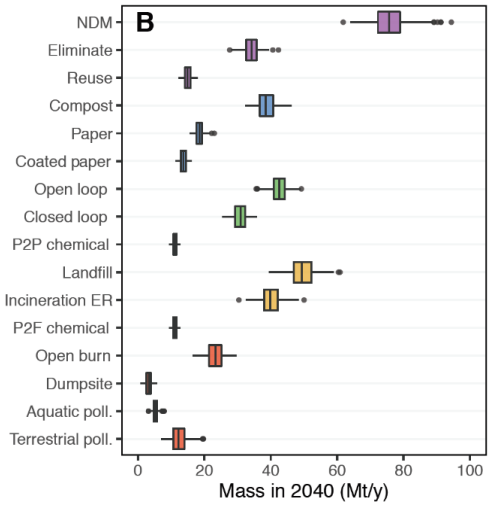
SYSTEMIQ, and The Pew Charitable Trust (2020). *Breaking the Plastic Wave.* UK: The Pew Charitable Trust. https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf

Lau, W.W.Y., Shiran, Y., Bailey, R.M., Cook, E., Stuchtey, M.R., Koskella, J., et al. (2020). Evaluating scenarios toward zero plastic pollution. *Science* (369), 1455–1461. https://doi.org/10.1126/science.aba9475.

OECD (2022). *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options.* Paris, France: OECD Publishing. https://www.oecd-ilibrary.org/environment/global-plastics-outlook_aa1edf33-en

OECD (2022). *Global Plastics Outlook: Policy Scenarios to 2060.* Paris, France: OECD Publishing. https://www.oecd-ilibrary.org/environment/global-plastics-outlook_aa1edf33-en





Costas Velis Research Group https://plasticpollution.leeds.ac.uk/

Spatio temporal Plastic pollution Origins and Transport (SPOT) model

UNIVERSITY OF LEEDS

A plastic pollution emissions inventory model and predictor of SDG11.6.1 linking local to global scales

It has 2 main components:

A: Probabilistic MFA for plastic emissions

Use local (municipal) MSW management data to perform probabilistic material flow analysis and calculate plastic emissions into the environment.

Municipalities with missing data are estimated using random forest machine learning.

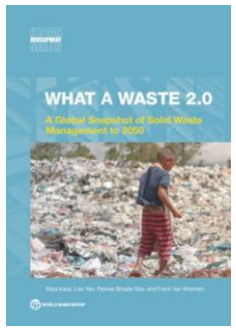
B: Temporal geo-spatial modelling for plastic movement

Evaluate the likely movement of plastic debris in the environment using a dynamic geospatial model.

Interlinks item properties with topographical and meteorological conditions across series of time steps.

PART A: Data collection, harmonization and cleaning

UNIVERSITY OF LEEDS

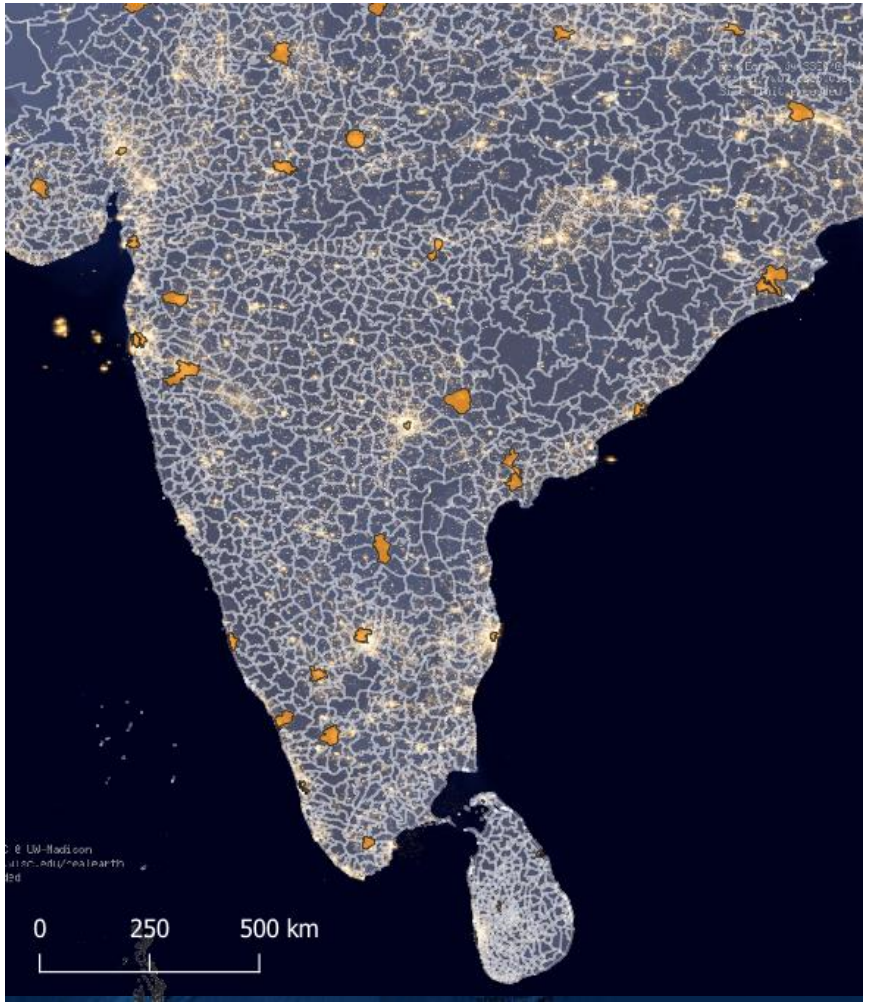


- Solid waste management data collected from global and national databases **at municipal level**
- Data **harmonized** and undergone rigorous **cleaning** exercises (~20% removal rate)
- **Data corrected** when necessary, based on understanding underlying methodology
- Further collection of reliable municipal level data (e.g. UN-Habitat **Waste Wise Cities Tool**) ongoing – can be fed into SPOT

PART A: Spatial allocation of data, prediction, and material flow analysis

UNIVERSITY OF LEEDS

- Municipal data **allocated spatially** to an administrative boundary
- National and sub-national **explanatory variables** assigned to each municipality
- **Machine learning** (quantile regression random forest) **fills data gaps** whilst providing uncertainty estimates
- Machine learning **predictions increase in accuracy as more data is added** to the model
- **Probabilistic material flow analysis (MFA)** (Monte Carlo) used calculate SDG11.6.1 and plastic emissions

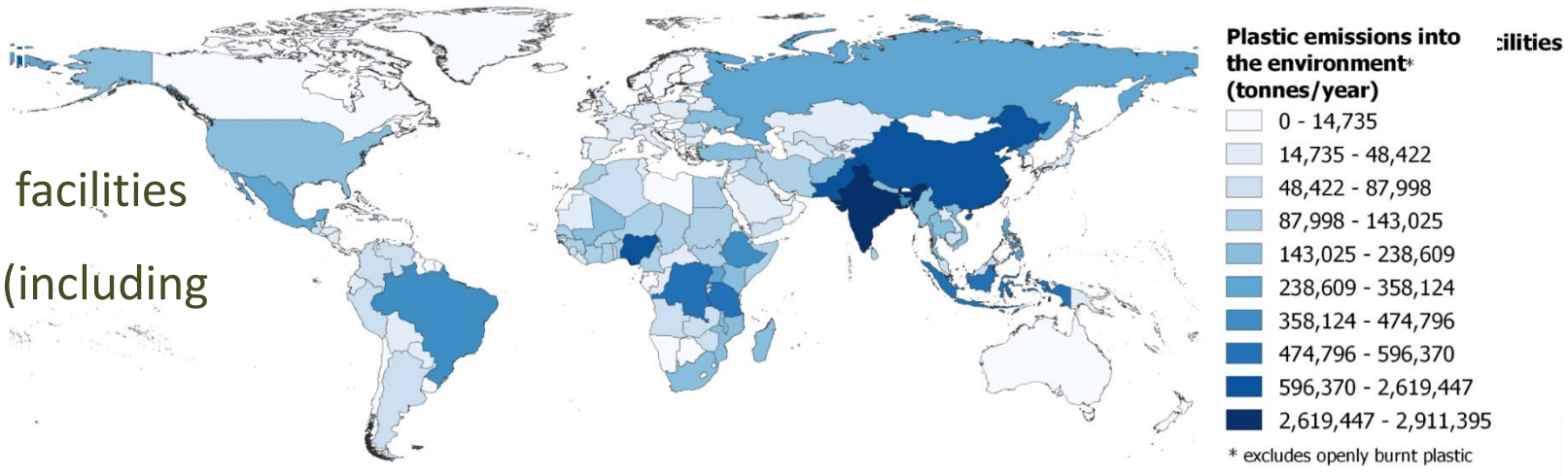


Incomplete results shown to indicate model capability

PART A: Results

UNIVERSITY OF LEEDS

- Waste generation
- Collection coverage
- SDG11.6.1 – Managed in controlled facilities
- Plastic emissions into environment (including by source)
- And much more…
  - Open burning
  - Formal & informal recycling
  - Controlled disposal
  - Recovery
  - Incineration
  - Population without waste collection services
  - and so on…



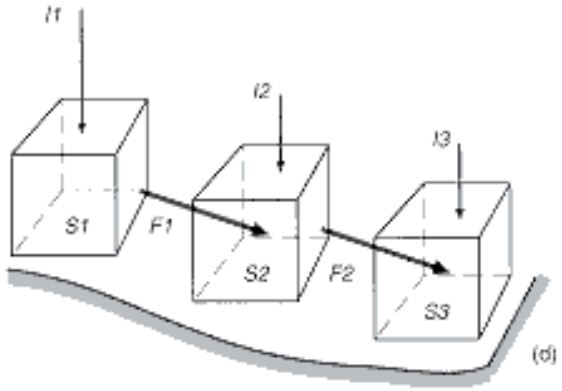
Our models convert bottom-up data on waste and resources management to give macroplastic emission inventories

Results useful for baselining, monitoring, hot-spotting and development of local to national action planning

Incomplete results shown to indicate model capability

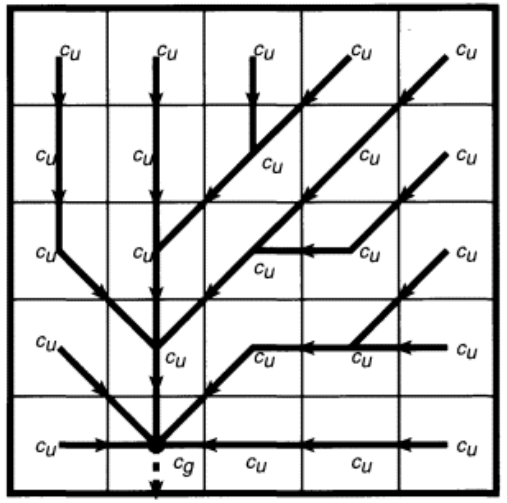
PART B: Temporal geo-spatial modelling of plastic movement

UNIVERSITY OF LEEDS



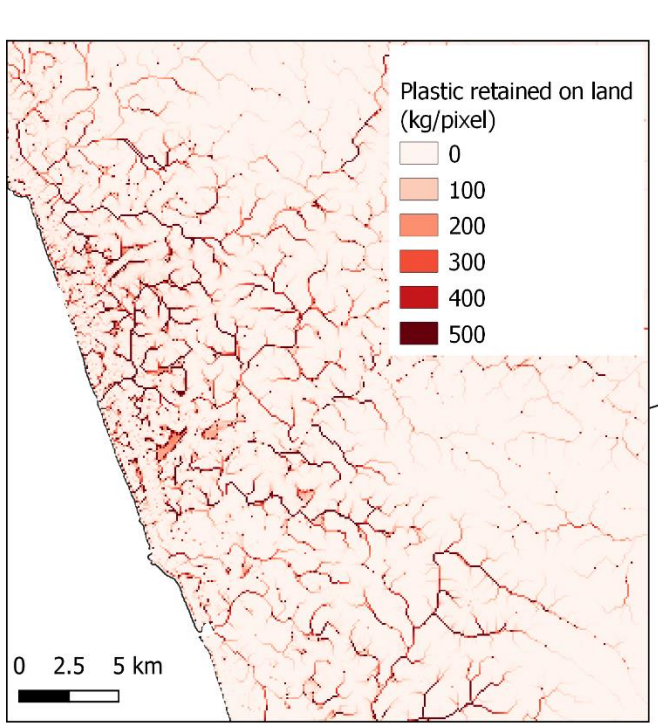
- **Movement of plastic items with time** is determined using an R - GIS based dynamic geospatial model.
- Determines plastic movement across **monthly time steps, accounting for source, sinks and flows**.

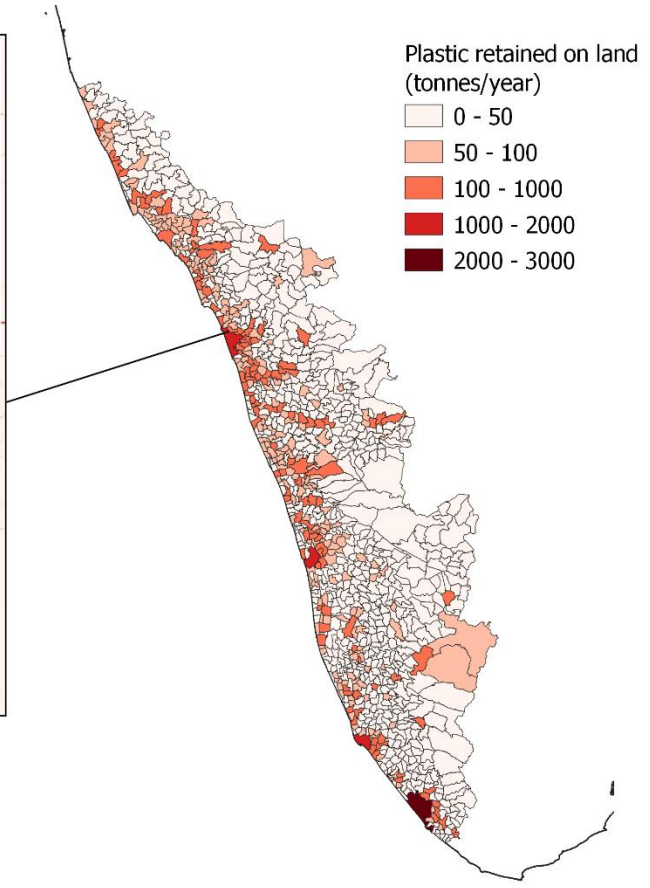
- Calculates movement for both **rigid and flexible plastic items** to allow for variation in conditions under which they move.
- Uses digital elevation maps (DEM) to understand direction of movement and **release points to ocean**.

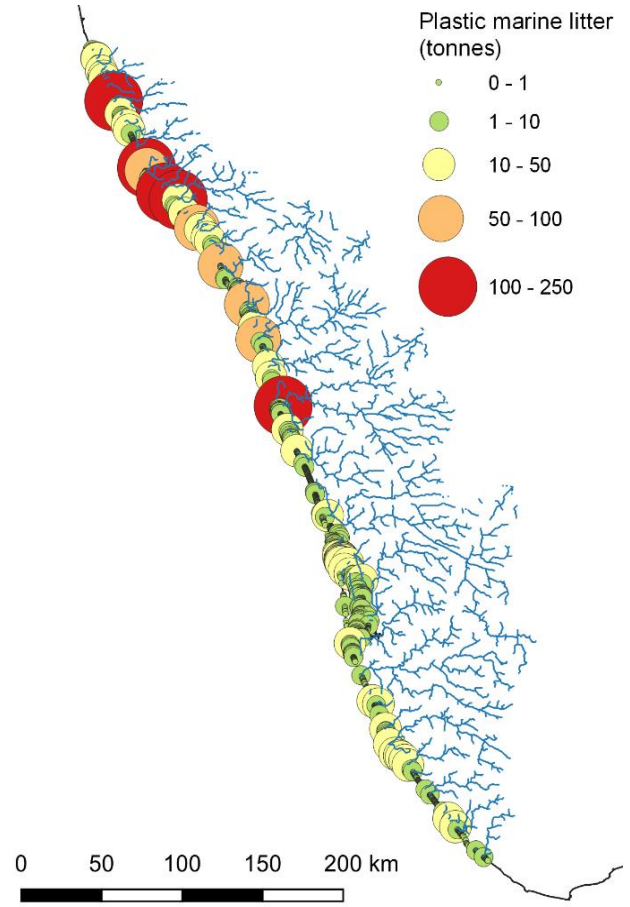


PART B: Results - Spatial identification of hotspots

UNIVERSITY OF LEEDS





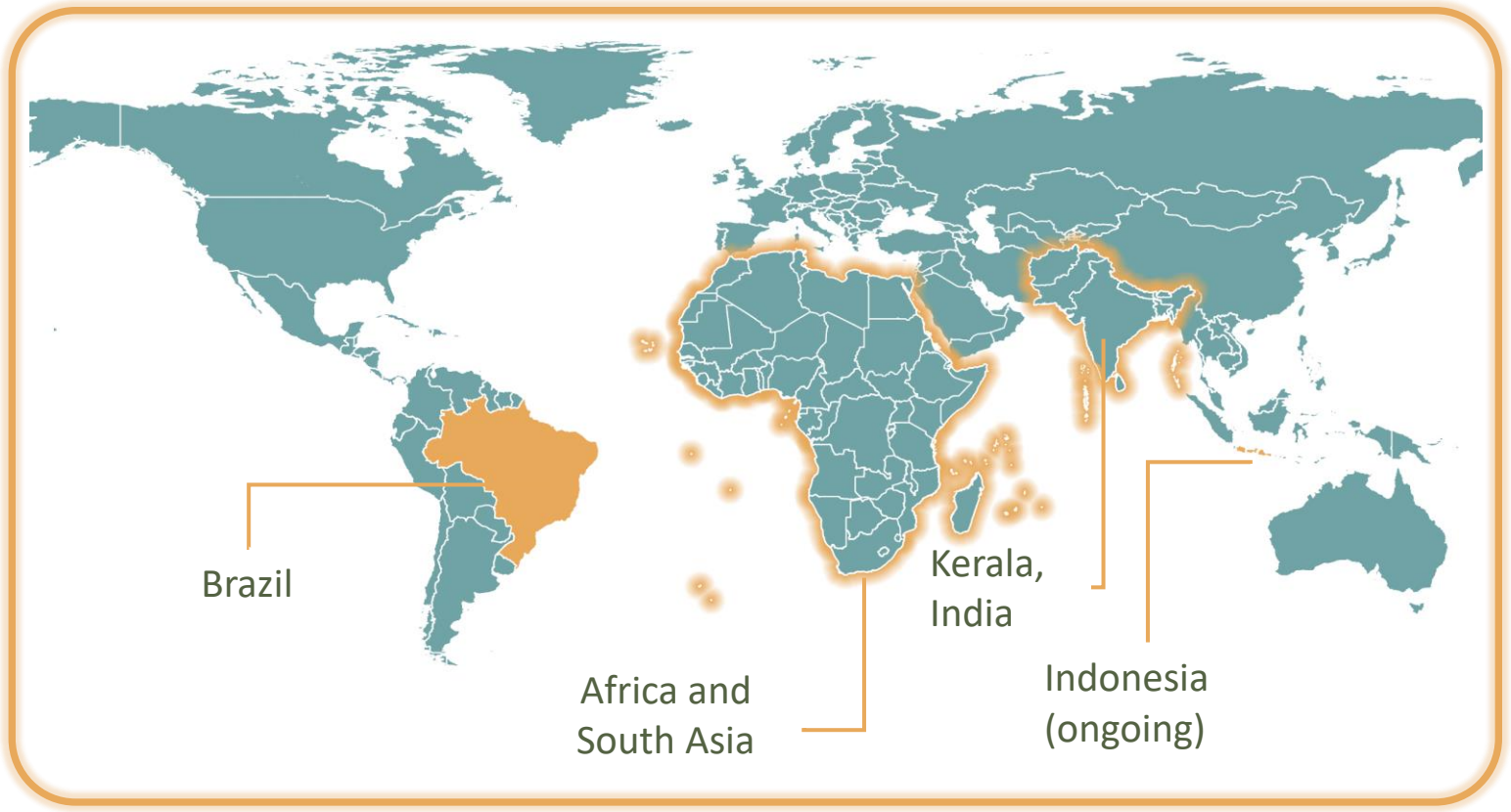


Key outputs:

- Maps plastic movement with time
- Maps plastic discharge to oceans
- Maps plastic sinks / accumulation sites

Track record & users

UNIVERSITY OF LEEDS



UN environment programme 50 1972-2022

UN HABITAT FOR A BETTER URBAN FUTURE

WORLD BANK GROUP

COBSEA COORDINATING BODY ON THE SEAS OF EAST ASIA

SEA circular solving plastic pollution at source

NATURVÅRDSVERKET SWEDISH ENVIRONMENTAL PROTECTION AGENCY

UKRI UK Research and Innovation

GCRF Global Challenges Research Fund

PISCES

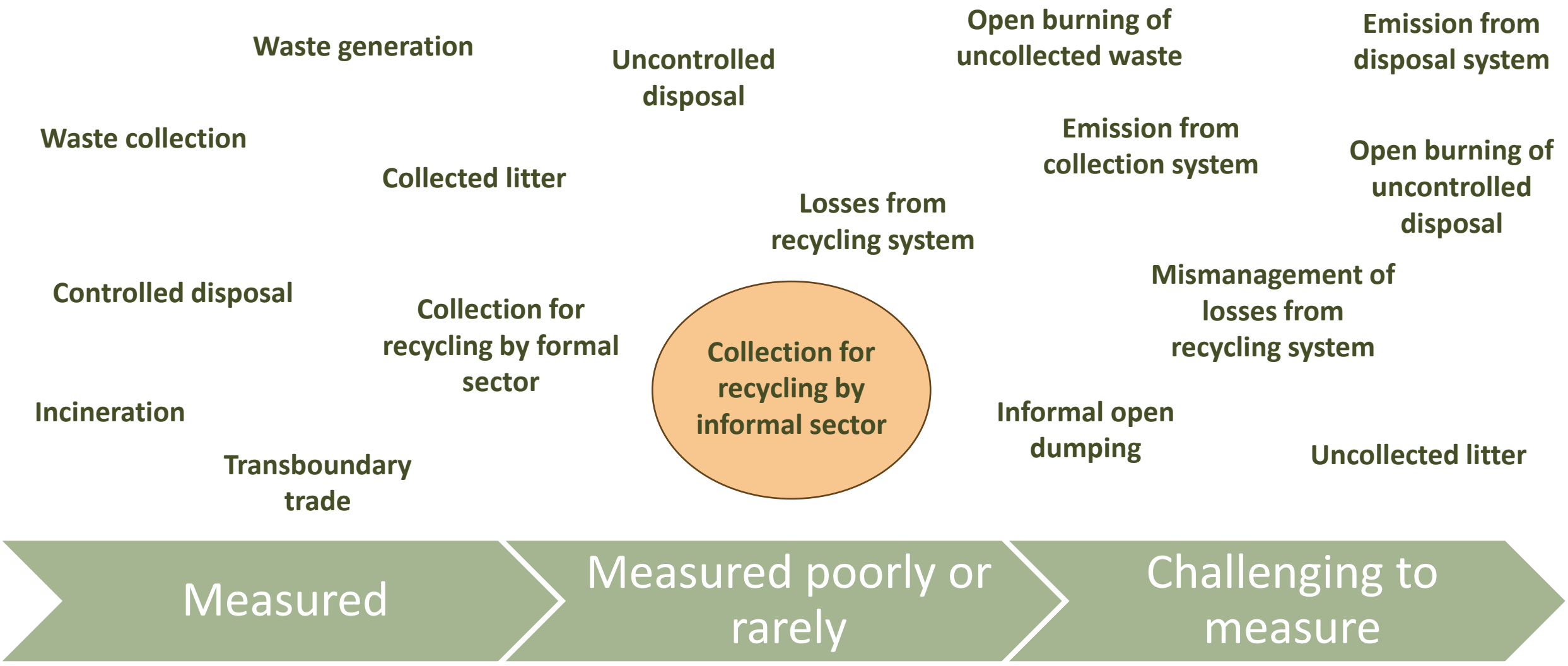
wasteaware

resourcefutures

Costas Velis Research Group https://plasticpollution.leeds.ac.uk/

Unmeasured - poorly measured - challenging to measure

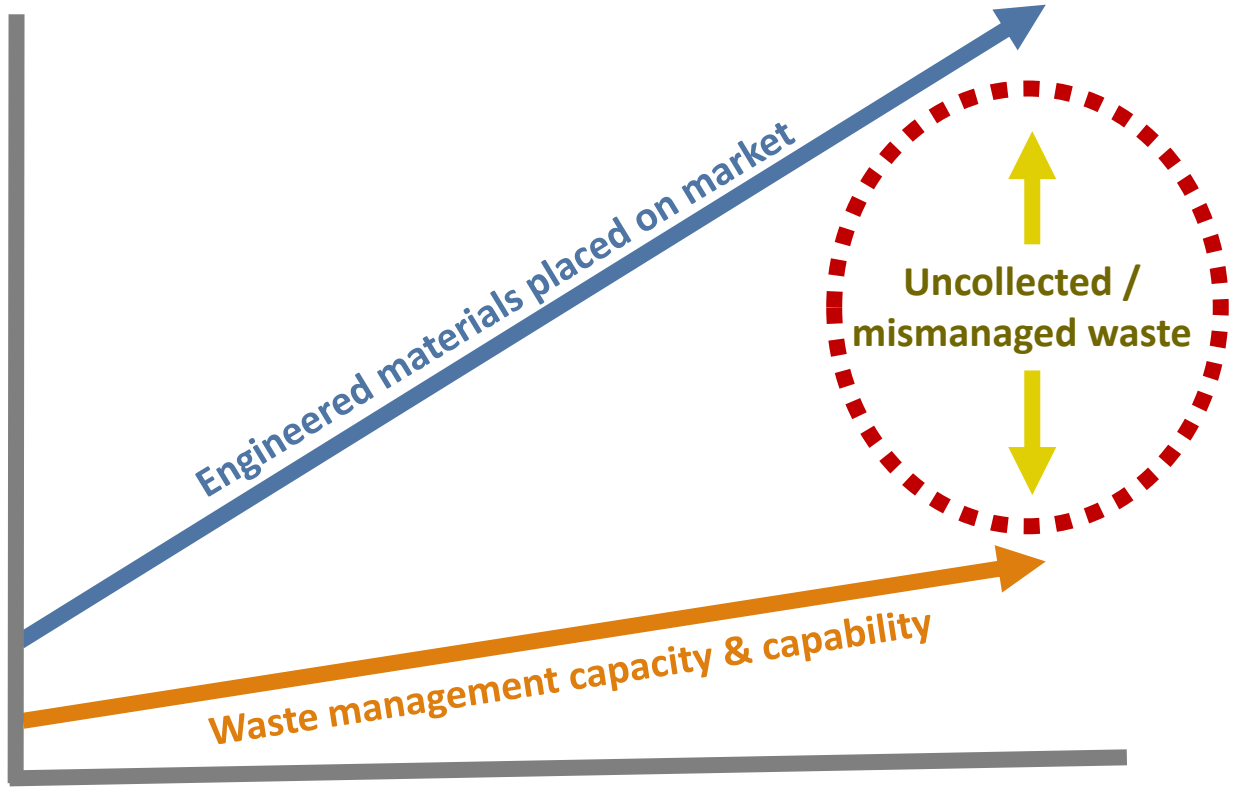
UNIVERSITY OF LEEDS



Costas Velis Research Group https://plasticpollution.leeds.ac.uk/

Part 3
Informal sector

The Informal Recycling Sector (IRS) dominates the global circular economy



Opportunity for ‘urban poor’ who now number

10-20 million individuals worldwide

Costas Velis Research Group https://plasticpollution.leeds.ac.uk/

Informal recycling sector business models

UNIVERSITY OF LEEDS

Type 1a: Informal itinerant buyer

Type 1b: Informal door-to-door collector (selective)

Type 1c: Informal door-to-door collector (non-selective)

Type 2a: Informal collection from formal vehicles

Type 2b: Informal collection from built environment

Type 3a: Informal collection from transfer / sorting facilities

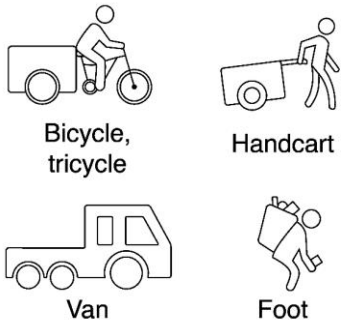
Type 3b: Informal collection from land disposal sites

Informal recycling sector – modelling productivity

UNIVERSITY OF LEEDS

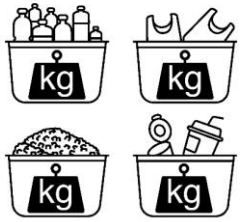
Number of waste pickers

X

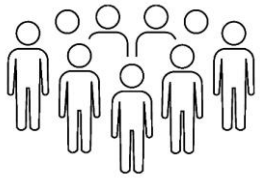


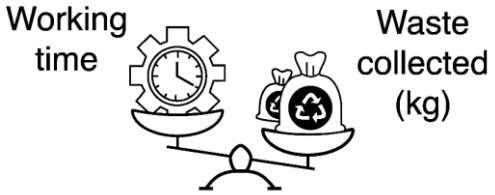
Individual productivity

=



Amount collected for recycling

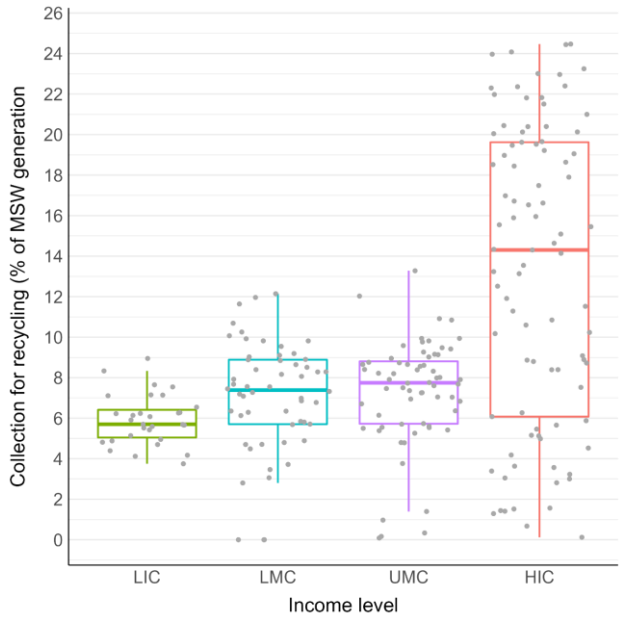




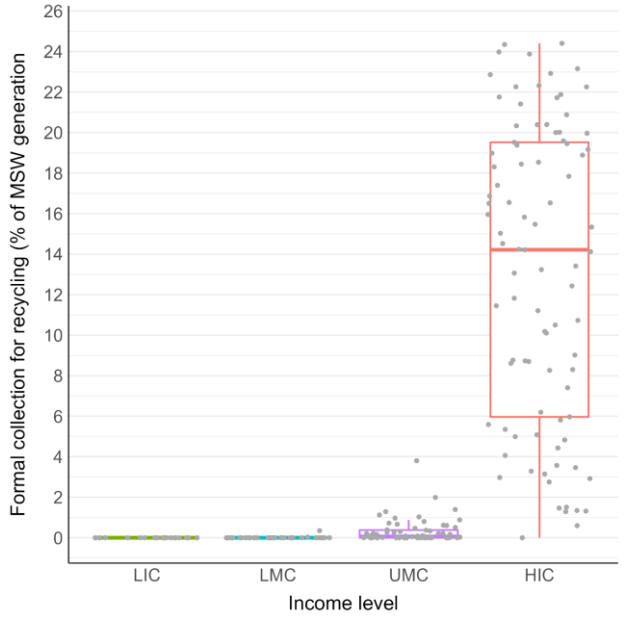
Informal recycling sector & plastic pollution: Modelling outputs from random probabilistic material flow analysis

UNIVERSITY OF LEEDS

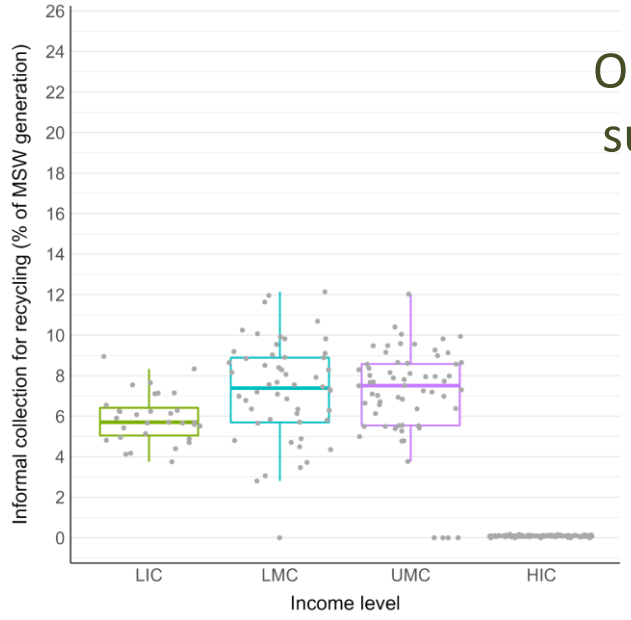
Collection for recycling formal & informal



Collection for recycling formal



Collection for recycling informal



Our previous research suggest that informal recycling sector collects **~88 Mt** of waste for recycling each year (Cook & Velis 2020)

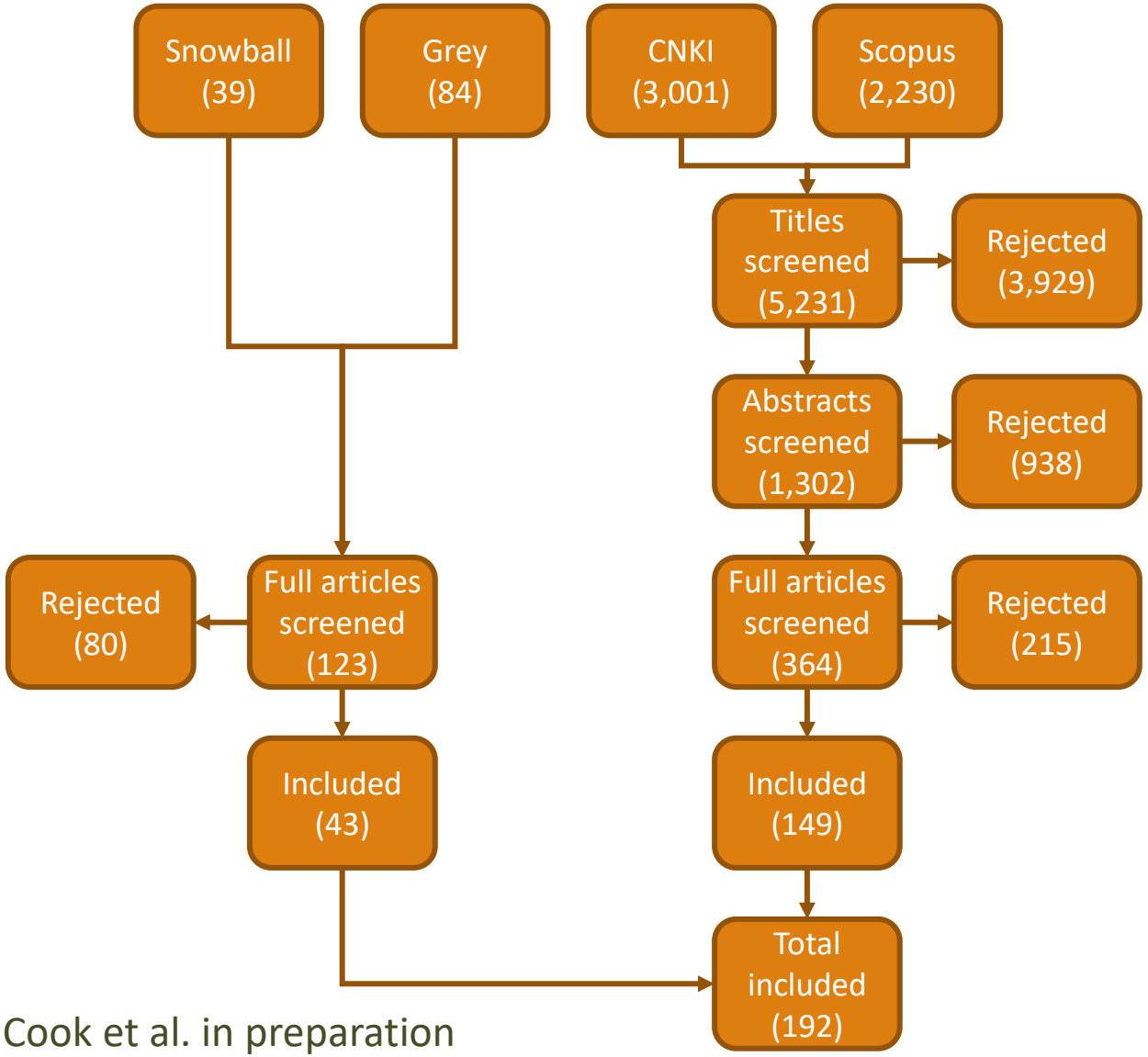
Incomplete results of random probabilistic material flow analysis from Cook et al. in preparation.
Data points represent countries in each income category

Systematic scoping review of informal sector productivity and prevalence (PRISMA-Scr)

UNIVERSITY OF LEEDS

A few used stratified sampling approach

Even fewer use repeatable method which is representative



Cook et al. in preparation

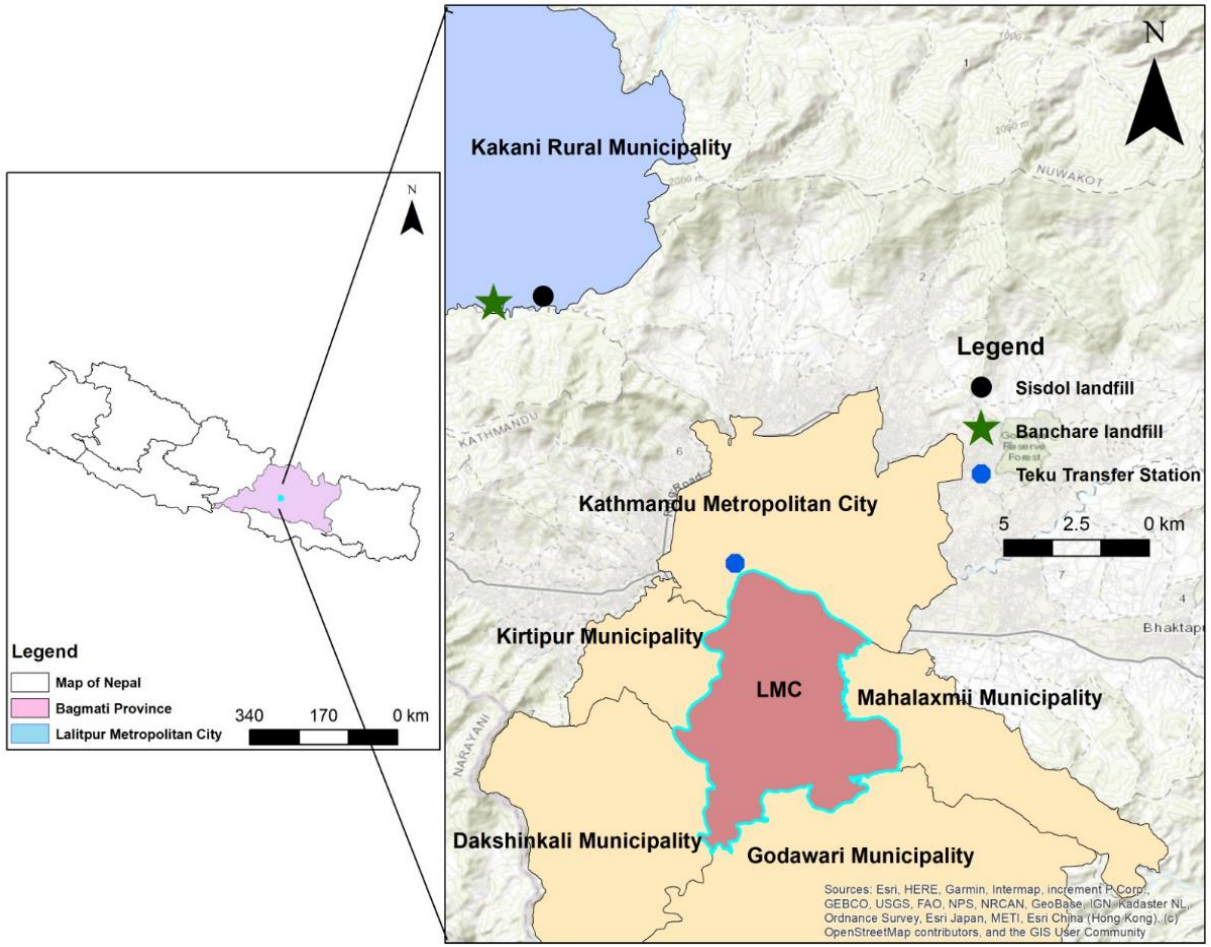
Informal recycling sector and plastic pollution mitigation – NEW METHOD

Scientifically defensible quantification of informal sector activities

Achievable on low budget

Implementable across Global South

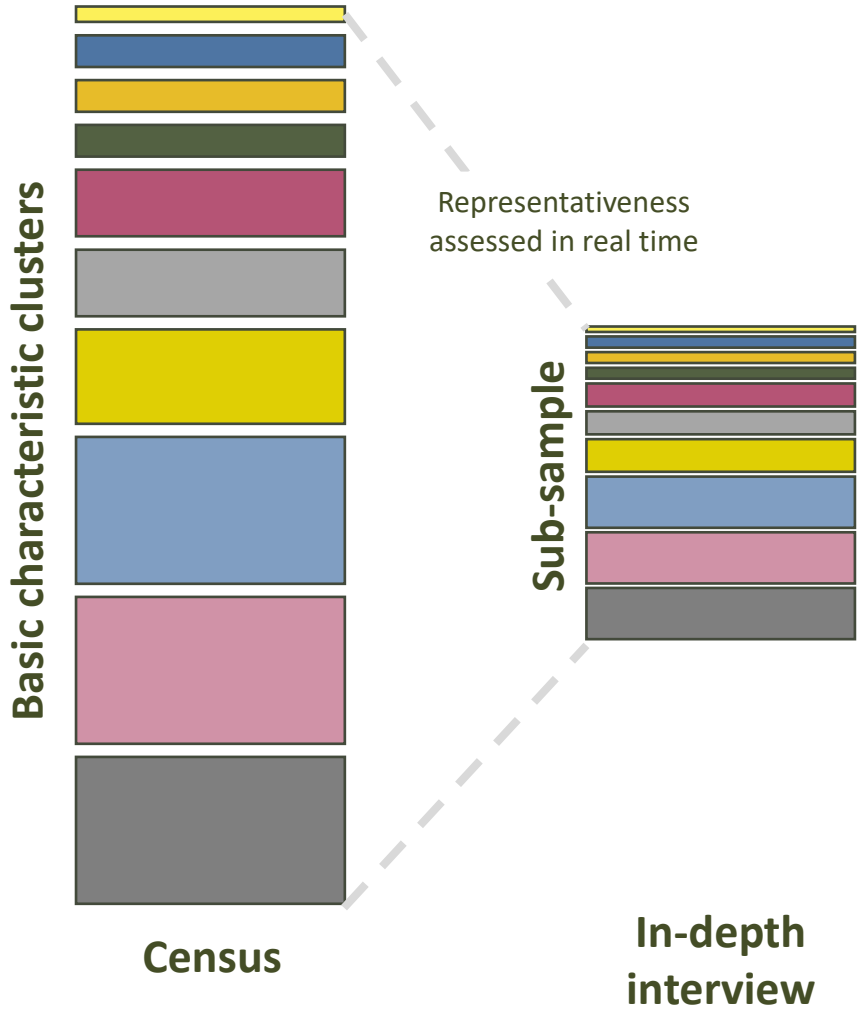
Pilot project underway in Lalitpur Nepal



Cook et al. in preparation.

Costas Velis Research Group https://plasticpollution.leeds.ac.uk/

Pilot project in Lalitpur



Cook et al. in preparation.

Costas Velis Research Group https://plasticpollution.leeds.ac.uk/

What can we apply to a new global model of informal sector productivity

UNIVERSITY OF LEEDS

Waste picker working patterns vary a lot

Many workers are seasonal

10-20 million individuals

~88 Mt·y^{-1}

Collected for recycling

Some evidence of over & underestimation of sector size

Productivity not always predictable

Sometimes people just want to finish work!

Materials basket influenced by changing market

UNIVERSITY OF LEEDS

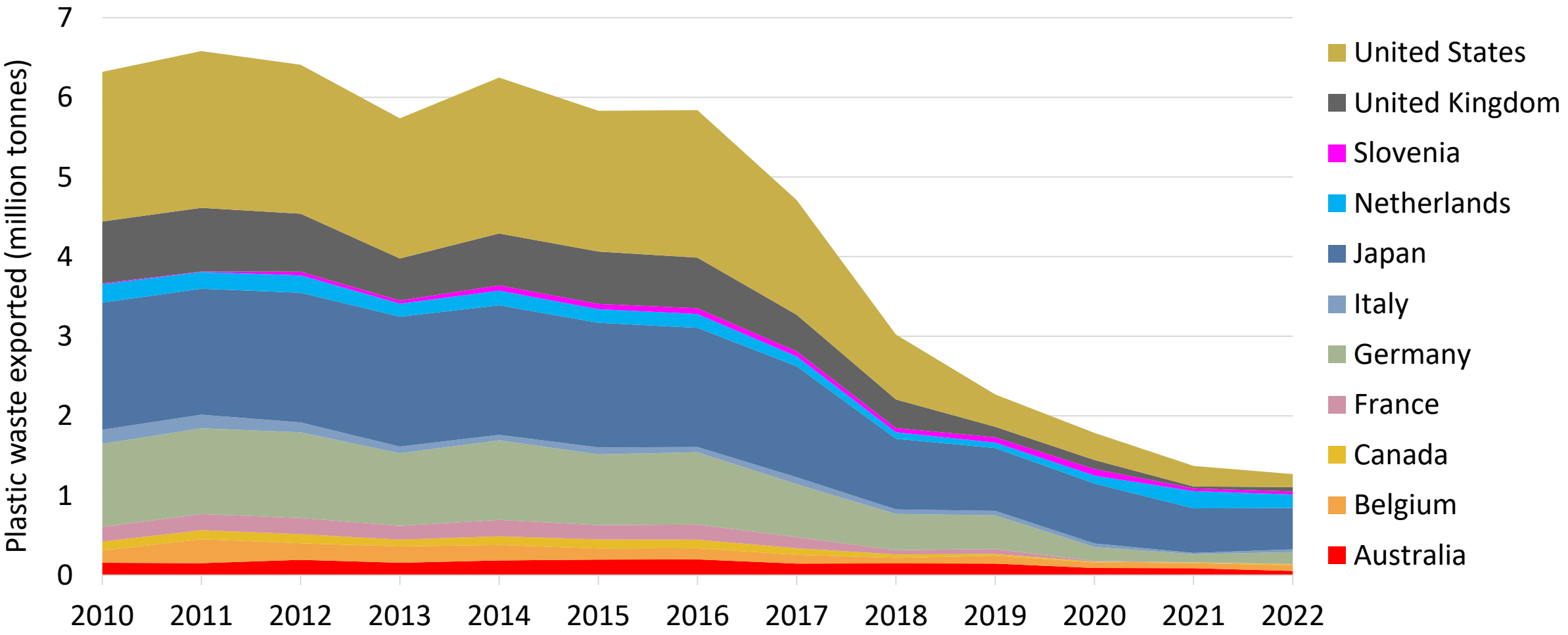
Thanks for listening

Ed Cook
e.r.cook@leeds.ac.uk

Costas Velis Research Group https://plasticpollution.leeds.ac.uk/

Transboundary trade

UNIVERSITY OF LEEDS



Plastic waste exported **from top 10 OECD exporters** (plus Slovenia) **to non-OECD countries** since 2010:
Iliff, C. (2023). *Plastic Waste and the Basel Convention: Investigation into the Impact of the January 2021 Amendments to Annexes II, VIII and IX.* University of Leeds.