EPFL

- Laboratory on Human-Environment Relations in Urban Systems

Where does Plastic Waste go?

A Geo-Referenced and Bottom-Up Approach to Assess Plastic Waste Flows at the Neighbourhood Level in Indonesia

Giulia Frigo

PhD theme

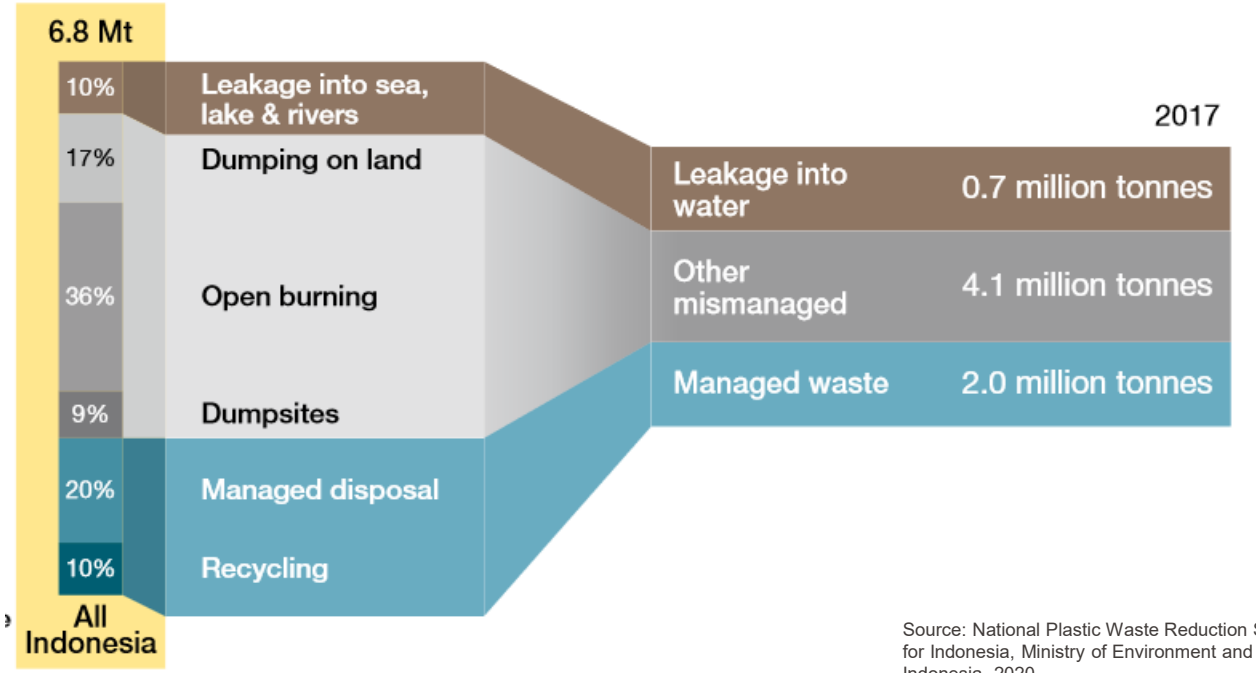
- With an ever-increasing population and growing consumption, plastic waste generation has become one of the most challenging problems
- Global South

Why Indonesia:

- Serious garbage problem
- Environmental and social impact
- → urban sprawl, informal settlements and unequal access to facilities

- **Comprehensive data on plastic waste flow is missing**

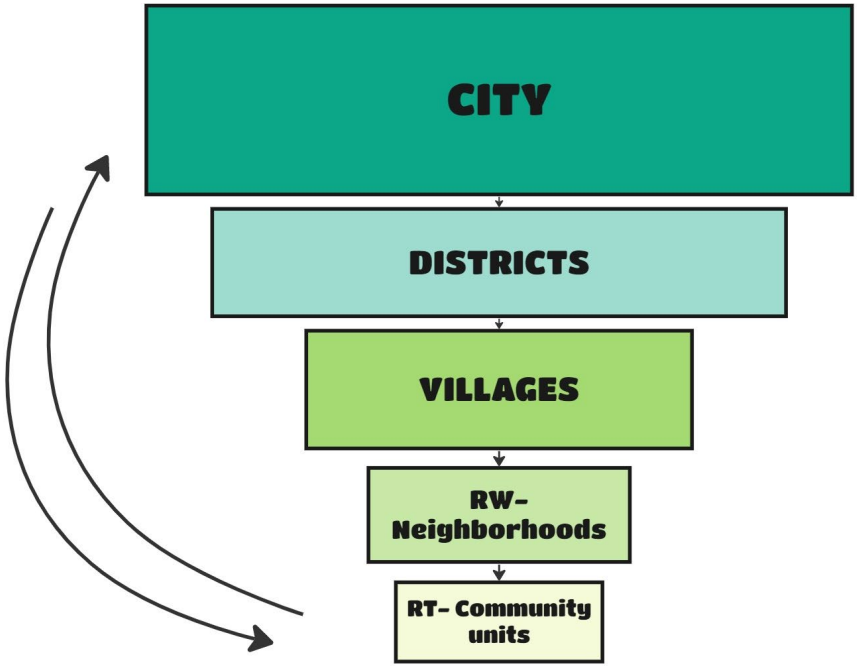
At the national scale..



Source: National Plastic Waste Reduction Strategic Actions for Indonesia, Ministry of Environment and Forestry Indonesia, 2020

Why it is difficult to understand the flow of plastic waste

1. City structure



- RW: *Rukun Warga* RT: *Rukun Tetangga*

2. Informal sector

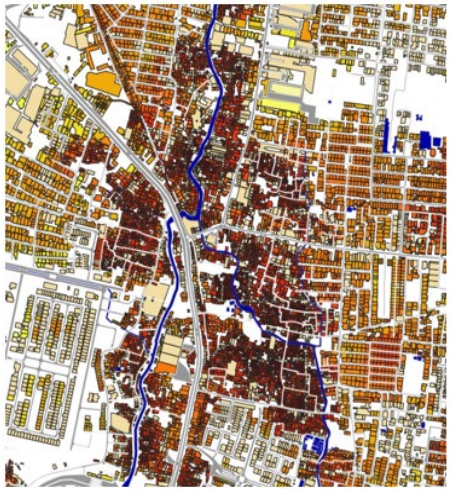
Economic activities that are invisible to official statistics and research (Hart 1973)

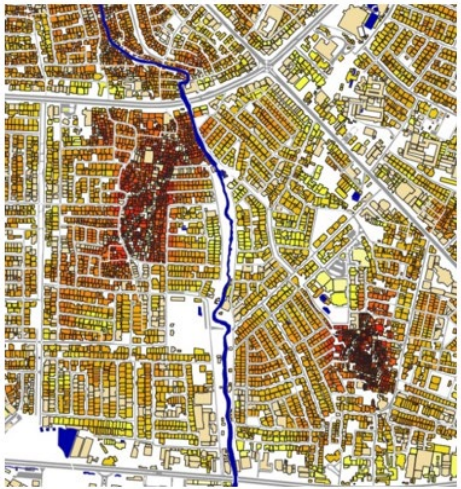
Source: The Jakarta Post 2021

3. Different urban landscapes

- Growing population in cities → urban sprawl, informal settlements and unequal access to facilities (recycling, waste banks, TPS)

(Jones 2017)





Neighborhoods in Bandung (ID). Red represents slums, while yellow planned RTs

Source: Author

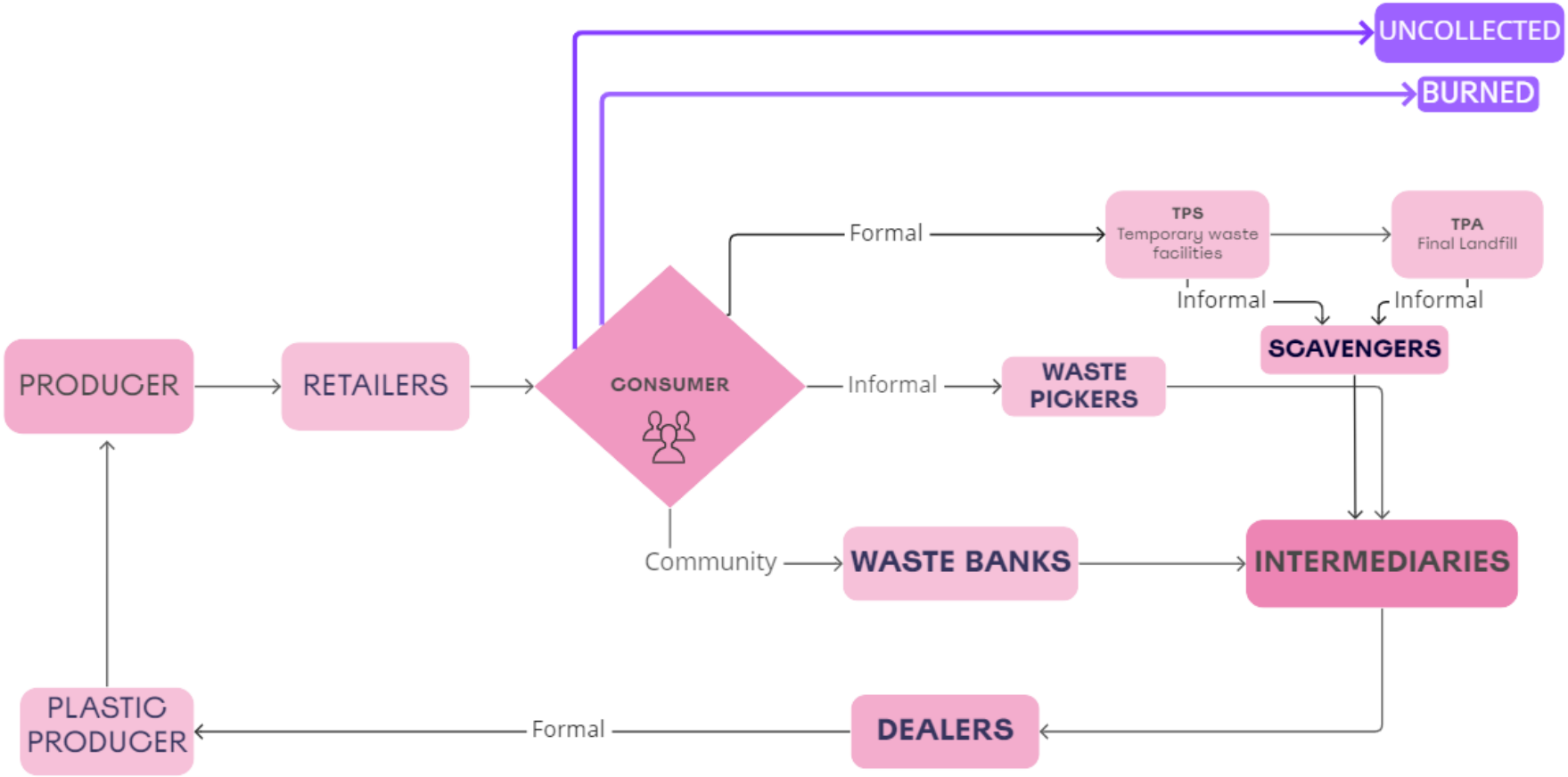
Disposal choices, consumption and collection systems:

1. Spatial features
reflect power dynamics and inequalities (Onu, Surendran, and Price 2014)

2. Socioeconomic factors
influence consumption patterns and behaviour (Bandara et al 2007)

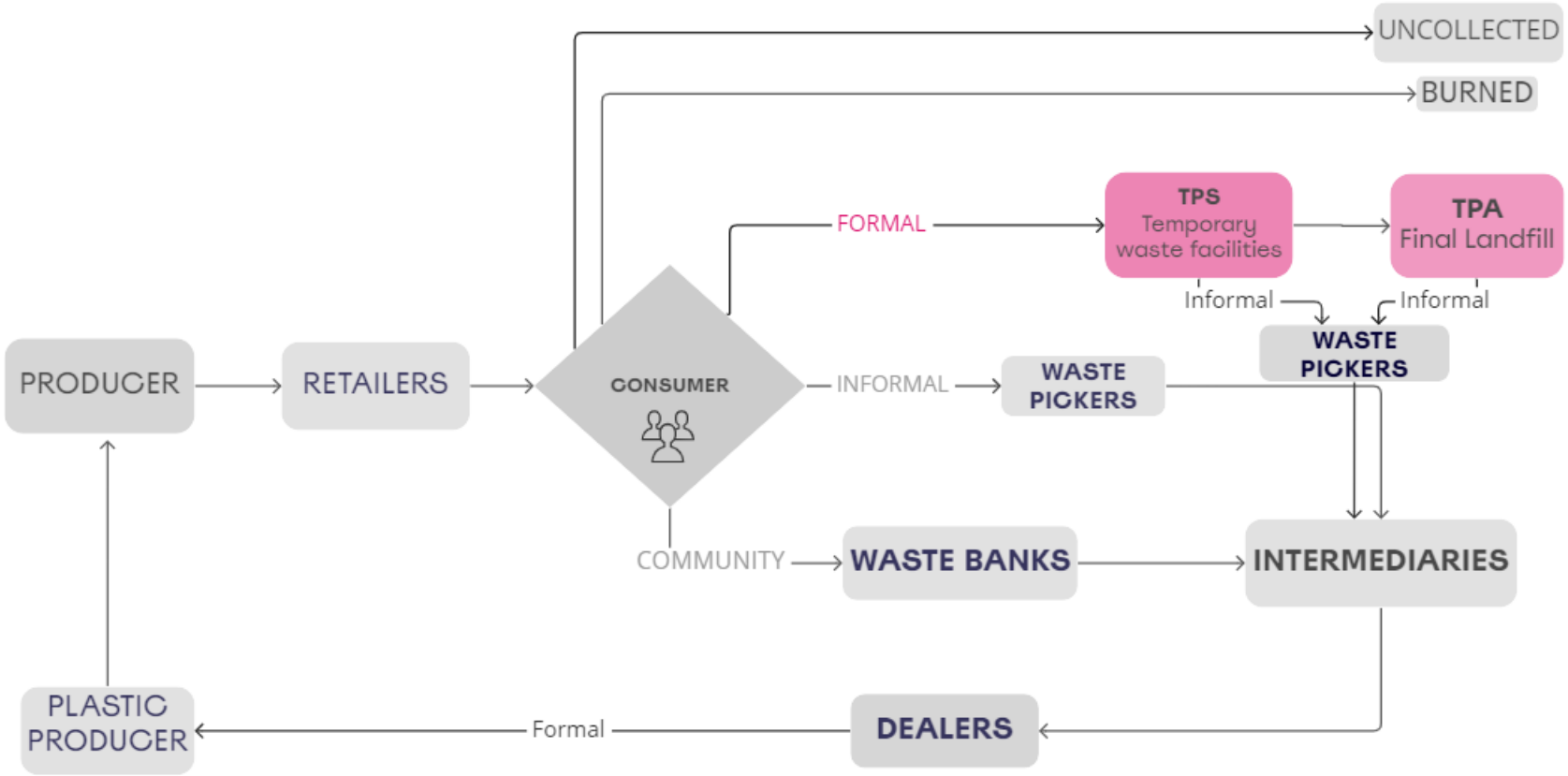
Unequal access:

Stakeholders and formal-informal interaction



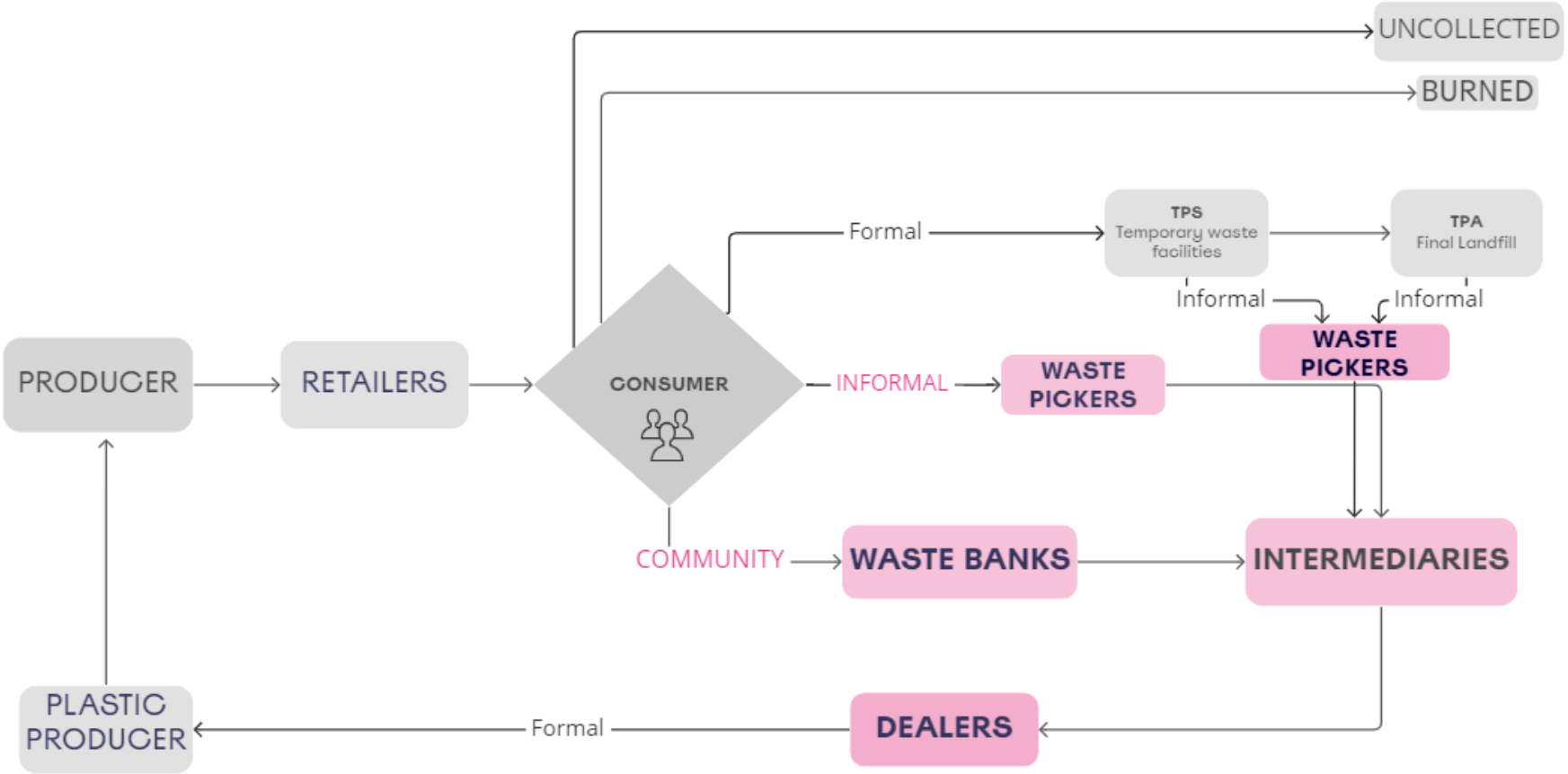
Source: Author

Stakeholders and formal-informal interaction



Source: Author

Stakeholders and formal-informal interaction



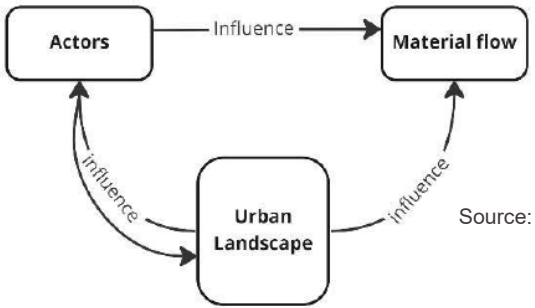
Source: Author

..How would you build an MFA in the absence of data?

..How does plastic waste flow in different neighbourhoods?

Overcoming the “black box” approach of urban metabolism

Cities are complex systems, in which social, economic, environmental, infrastructural and material processes are **intertwined and coexist** in a **particular space**.



Source: Author

Overcoming the “black box” approach of urban metabolism

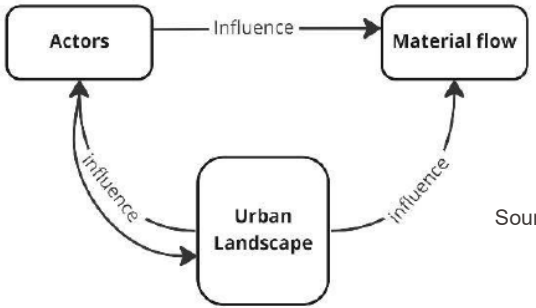
Landscape Ecology

- ***spatial heterogeneity***
- Cities as “patchy” ecosystems

(Turner and Gardner 2015)

Industrial Ecology and Urban Metabolism

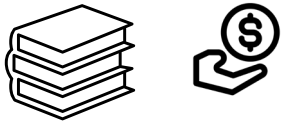
- Quantification of **flows** within a system



Source: Author

Aim

- Develop a **bottom-up, geo-referenced Material Flow Analysis (MFA)** to determine **plastic waste flow** at the neighbourhood level



How do sociodemographic factors influence the flow of plastic waste?

How do local governance affect plastic waste flow?

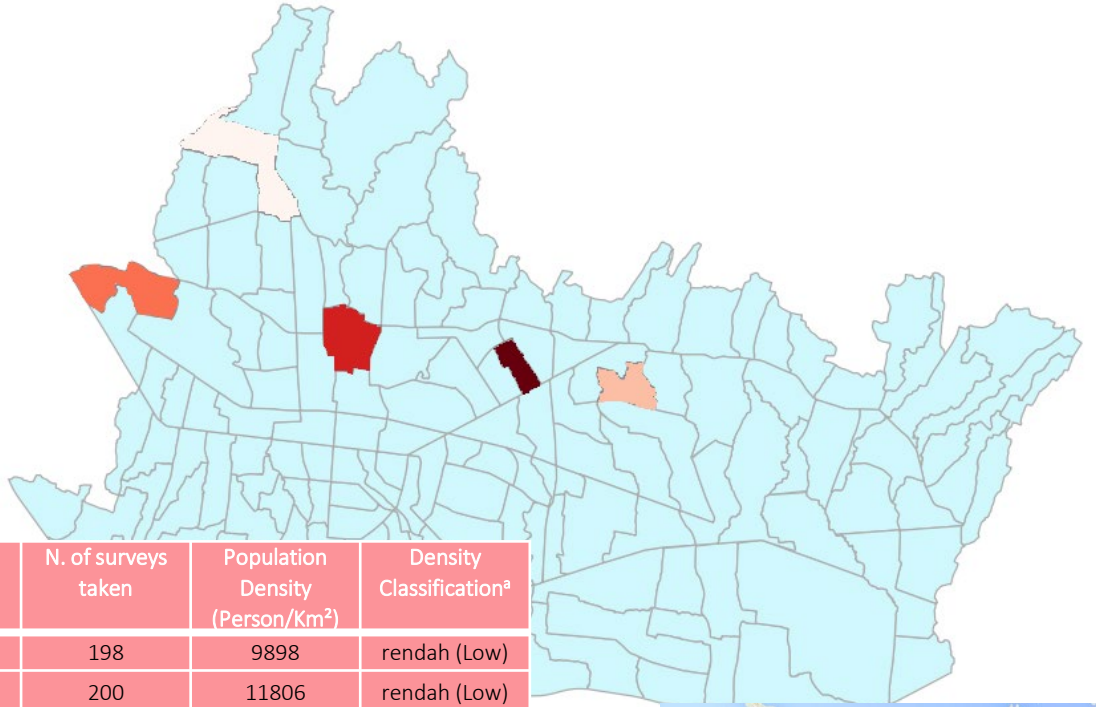
Where are the hotspots of uncollected waste?

Research question

Is there a significant difference in how plastic waste flows in different urban neighbourhoods?

Case study

Bandung City, East Java Island, Indonesia



Sub-District	Neighborhood	Total villages	Population	N. of surveys taken	Population Density (Person/Km²)	Density Classification[a]
Sukasari	**Gegerkalong**	8	16629	198	9898	rendah (Low)
Antapani	**Antapani Kulon**	8	11216	200	11806	rendah (Low)
Cicendo	**Sukaraja**	10	20326	289	15398	sedang (Medium)
Cibeunying Kidul	**Cicadas**	15	16452	427	29912	tinggi (High)
Bandung Wetan	**Tamansari**	20	25713	425	25208	tinggi (High)

Methods

- **Geo-survey**

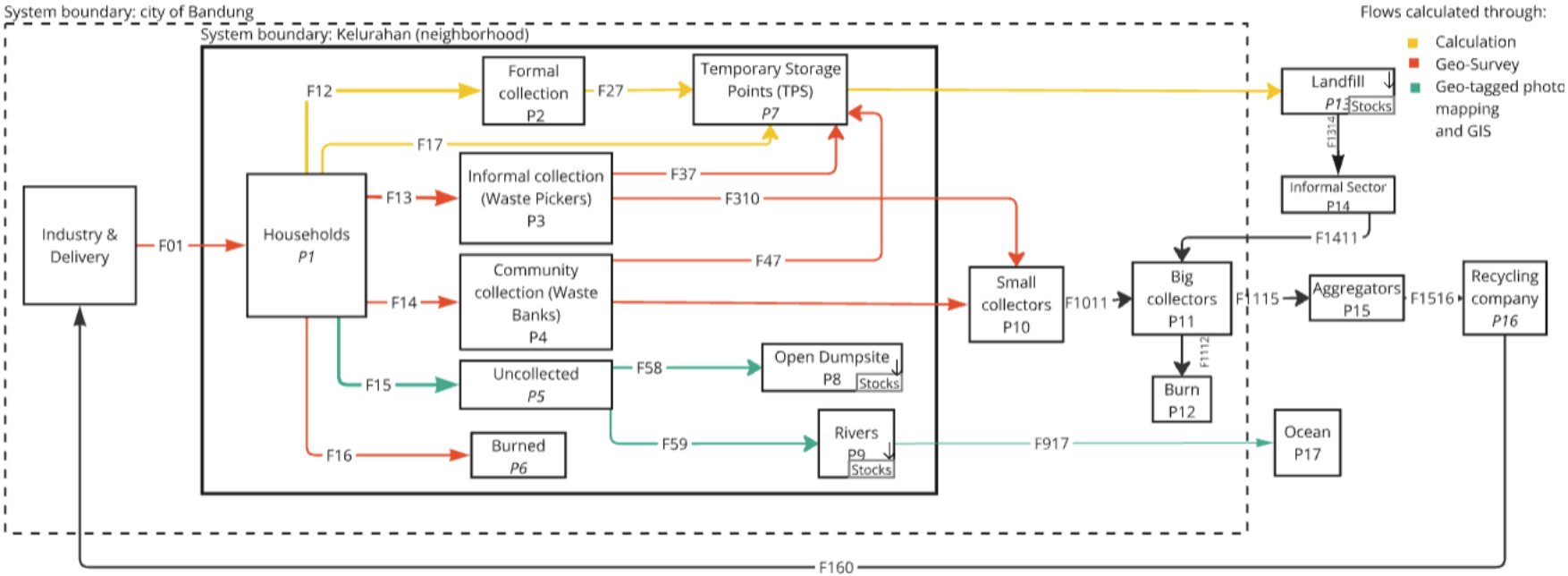
(1) socioeconomic characteristics (household type and size, income, education level)
(2) plastic consumption (e.g., quantity, frequency and type)
(3) segregation (category and frequency)
(4) disposal choices (e.g., burning, dumping, segregation)
(5) uncollected wastes observed
(6) psychological aspects related to consumption and disposal choices

- **Geotagged photo mapping**

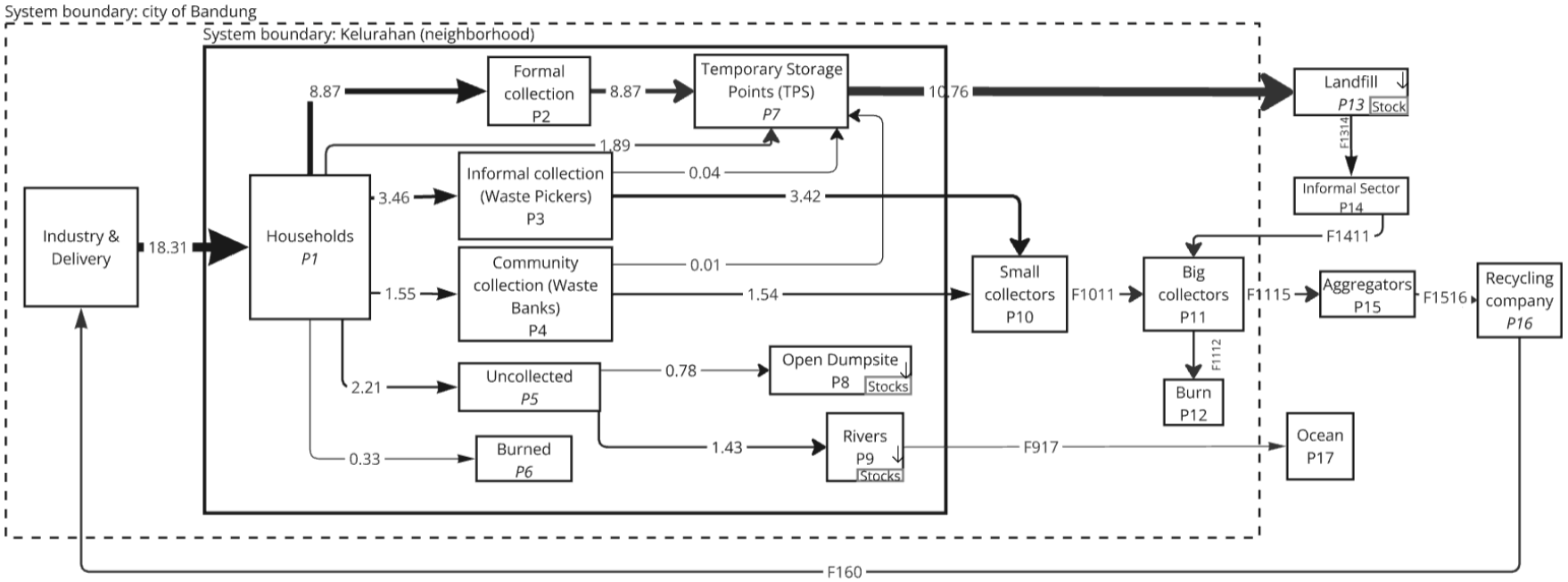
(1) Quantify the amount of uncollected waste and identify its locations
(2) Mobile app to geotag and photograph observed uncollected waste

- **GIS analysis** for uncollected waste
- **Material Flow Analysis**
- **Statistical analysis**

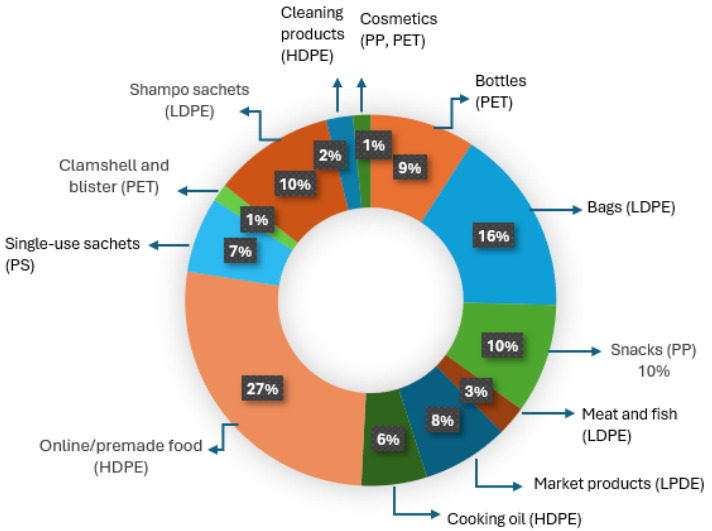
Results


System boundary: city of Bandung
System boundary: Kelurahan (neighborhood)
Flows calculated through:
Calculation
Geo-Survey
Geo-tagged photo mapping and GIS
Industry & Delivery
F01
Households P1
F12
Formal collection P2
F27
Temporary Storage Points (TPS) P7
F17
F13
Informal collection (Waste Pickers) P3
F37
F310
F14
Community collection (Waste Banks) P4
F47
F15
Uncollected P5
F58
Open Dumpsite P8
Stocks
F16
Burned P6
F59
Rivers P9
Stocks
F917
Ocean P17
Small collectors P10
F1011
Big collectors P11
F1115
Aggregators P15
F1516
Recycling company P16
F1112
Burn P12
Landfill P13
Stocks
F1314
Informal Sector P14
F1411
F160

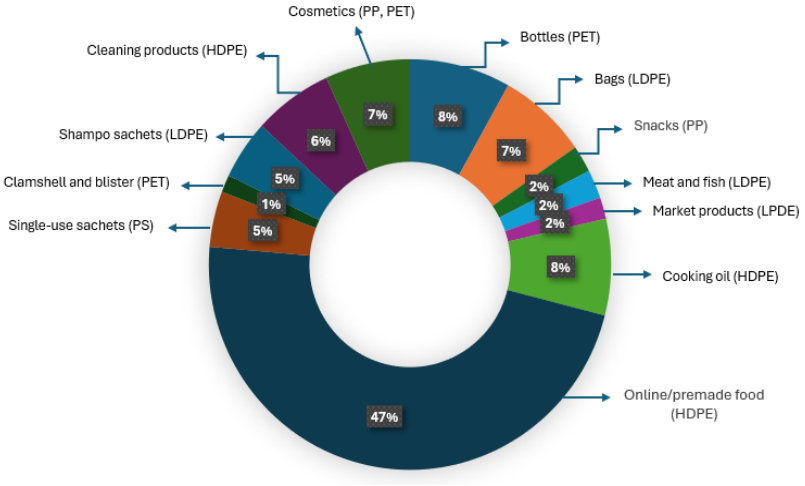
Plastic flow analysis in kg per capita per year (2023)



Plastic polymers



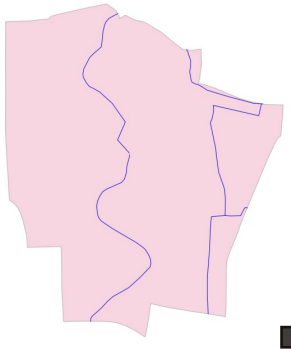
Number of products

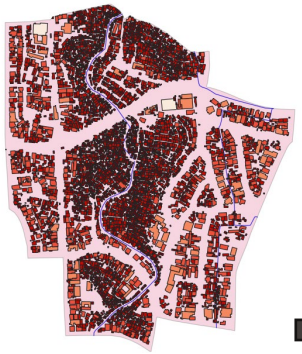


Weight of products

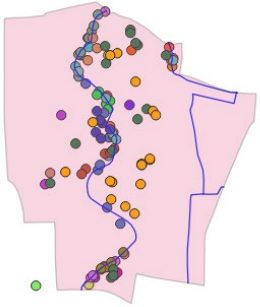
Uncollected waste

Layers

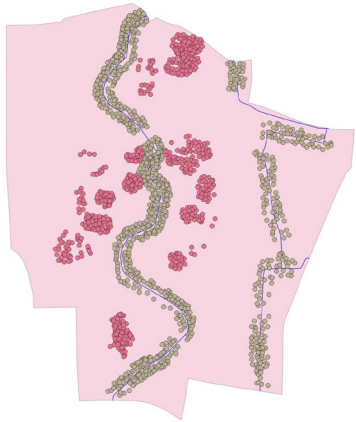




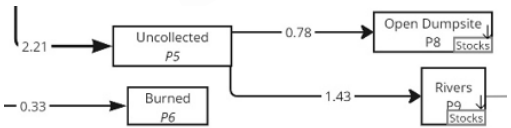
Uncollected waste points

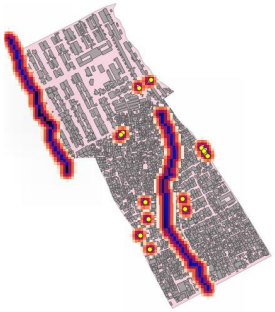


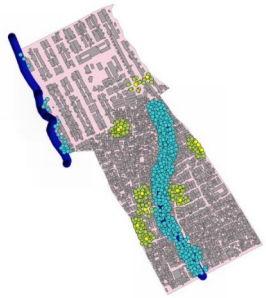
Buffer area (30m)



Neighbourhood	Buildings near the river	Buildings near dumpsites
1	513	229
2	1133	665
3	446	183
4	514	129
5	705	563
Total		
28519 (100%)	3311 (11%)	1769 (6%)







Differences across neighbourhoods

Dep. Variable	Nª.	Mean (SD)	Deviation Contrast (B)	P-value
Consumption	1	17,62 (13,52)	-,171	,753
	2	20,67 (10,22)	2,9	<.001
Flow: F01	3	13,98 (12,96)	-3,81	<.001
Mean: 18,31 (SD 11,92)	4	19,72 (10,25)	1,92	<.002
	5	16,95 (11,92)	-,84	,240
Segregated waste	1	6,04 (11,45)	1,293	**,004**
	2	4,65 (9,43)	-,092	,838
Flow: F13, F14	3	3,38 (8,35)	-1,365	,022
Mean: 4,96	4	5,37 (9,53)	,623	,226
(SD: 9,74)	5	4,29 (7,52)	-,459	,439
Burned waste	1	0,6 (,76)	-,29	,075
	2	,46 (4,2)	,113	,49
Flow: F16	3	,84 (4,28)	,487	**,026**
Mean: ,33	4	,35 (5,2)	,002	,990
(SD: 3,56)	5	,04 (,58)	-,310	,154

Dep. Variable	Nª.	Mean (SD)	Deviation Contrast (B)	P-value
Waste reaching TPS	1	9,5 (10,27)	-,982	,031
	2	12,8 (9,3)	2,392	<.001
Flow: F12, F17	3	8,0 (9,68)	-2,434	<.001
Mean:10,76	4	11,57 (9,68)	1,087	,037
(SD:9,97)	5	10,42 (9,97)	-,062	,918
Uncollected waste	1	1,9 (2,1)	-,201	,031
	2	2,6 (1,9)	,489	<.001
Flow: F15	3	1,6 (1,9)	-,498	<.001
Mean: 2,2	4	2,3 (1,9)	,223	,037
(SD: 2,04)	5	2,1 (2)	-,013	,917

Importance of Spatial MFA

Differences across neighborhoods

Dep. Variable	Education		Income		Local segregation programme	
Consumption	P-value	B	P-value	B	P-value	B
	,238	,535	<.001	$9{,}457 \times 10^{-7}$	,606	-,353
Segregation	P-value	B	P-value	B	P-value	B
	,002	1,171	,034	$2{,}569 \times 10^{-7}$	<.001	3,731
Burning	p-value	B	P-value	B	P-value	B
	,408	,114	,015	$1{,}079 \times 10^{-7}$	,243	,241
Waste reaching TPS	P-value	B:	P-value	B	P-value	B
	,104	-,618	<.001	$4{,}847 \times 10^{-7}$	<.001	-3,615

Conclusion: Neighbourhood difference matter

This research demonstrates the **feasibility of constructing an MFA in data-limited environments**, offering quantitative and qualitative insights into waste consumption and disposal patterns

This **bottom-up, geo-referenced methodology** provides **insights** that are not captured by conventional statistical offices or top-down material flow analyses

Next week → sociodemographic and governance in urban metabolism

EPFL

Laboratory on Human-Environment Relations in Urban Systems

Thank you!

giulia.frigo@epfl.ch

Supervisor:
Dr Claudia Binder (HERUS, EPFL)
Co-supervisor:
Dr Christian Zurbrügg (EAWAG, ETH Zurich)

Funded by

This project has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No 945363.

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

itenas
Institut Teknologi Nasional

eawag
aquatic research