



AI for Sustainability

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University of Porto



The project has been selected for funding by the EC within the Horizon Europe programme, under the topic HORIZON-CL3-2021-FCT-01-09 - Fight against organised environmental crime



Outline

1. EMERITUS Project

Use Case 1: Artificial Intelligence in Soil Protection

- Detecting Landfills
- Detecting Illegal Constructions
 - Land Change Detection

2. EnSafe Project

Use Case 2: Network Science for Anomaly Detection in Waste Transportation

- Detecting Anomalies
- Fraudulent Patterns

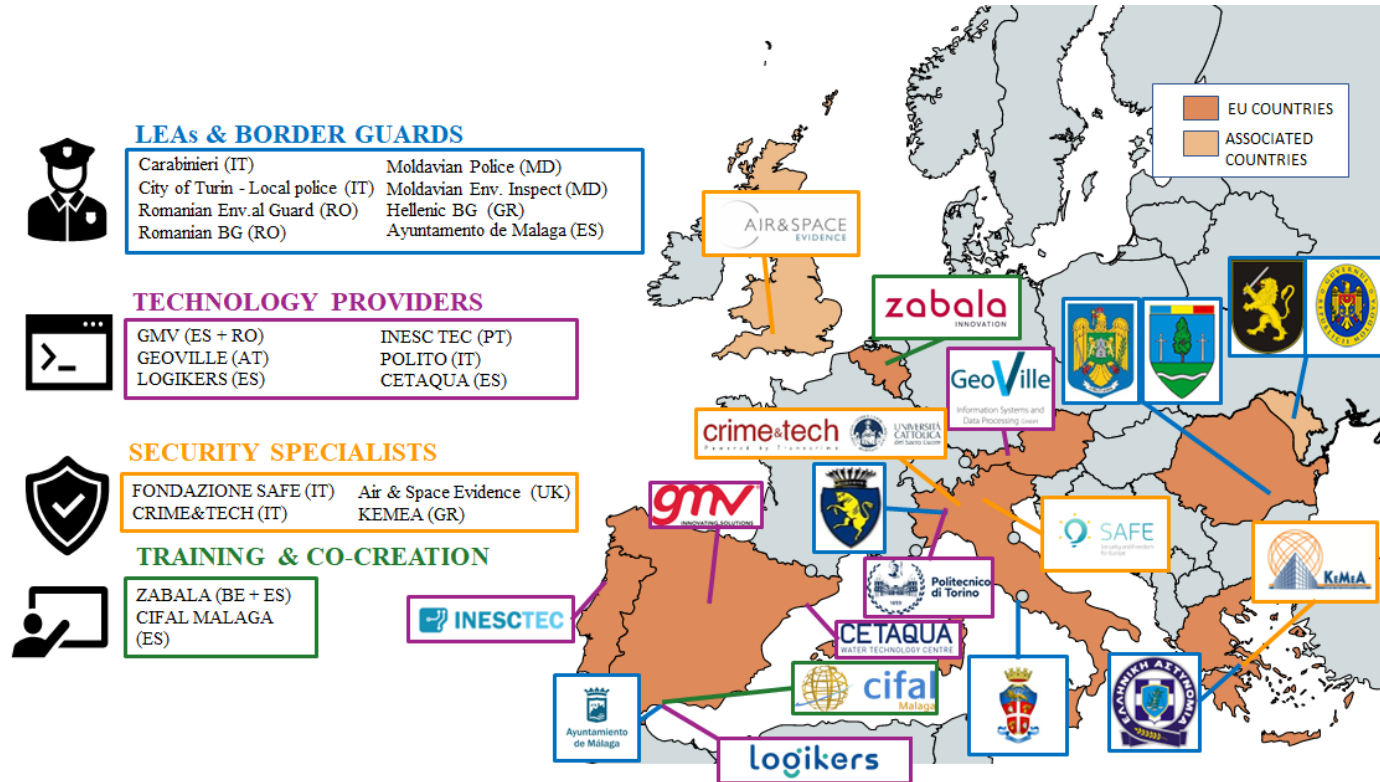
3. Conclusions

EMERITUS - Environmental crimes' intelligence and investigation protocol based on multiple data sources

20 PARTNERS

8 COUNTRIES

Austria
Belgium
Greece
Italy
Moldova
Portugal
Spain
United Kingdom

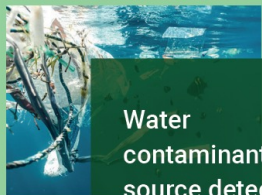


OBJECTIVES

- *Laying the foundations for a new generation of **technological tools at support of Law Enforcement Agencies and Border Guards investigation of environmental crimes integrating satellites, drones, AI and others***
- *To realize and implement a **protocol** for effective environmental crime investigation, leveraging on the integration of innovative monitoring and analysis **technologies**, and on a complementary **training programme***

Use cases

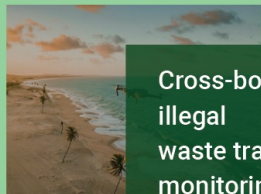
Four relevant **use cases** have been identified to ensure that the project results can translate into technologies and operative support fitting in real-world scenarios and needs, as well as to test the EMERITUS results with actual data and operators.



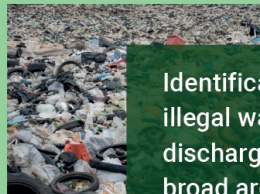
Water
contaminant
source detection



Waste storage
centres
monitoring



Cross-border
illegal
waste trafficking
monitoring



Identification of
illegal waste
discharge sites in
broad areas



UC1 - Water contamination detection

Water contamination detection and prediction, discharge point location for crime analysis

Location: Guadalhorce river, natural protected area in Malaga, Spain

Technology sources: sensors, AI, multispectral cameras

Context: water quality

Involved partners: **CETAQUA**
WATER TECHNOLOGY CENTRE



POLICÍA
LOCAL
MÁLAGA



UC2 - Industrial Storage Centres Monitoring

Waste storage centres monitoring, including hazardous materials (i.e., radiological and chemical)

Location: industrial site on river in Piedmont, Italy

Technology sources: drones, satellites, sensors, AI, blockchain

Context: land, air, water

Involved partners:



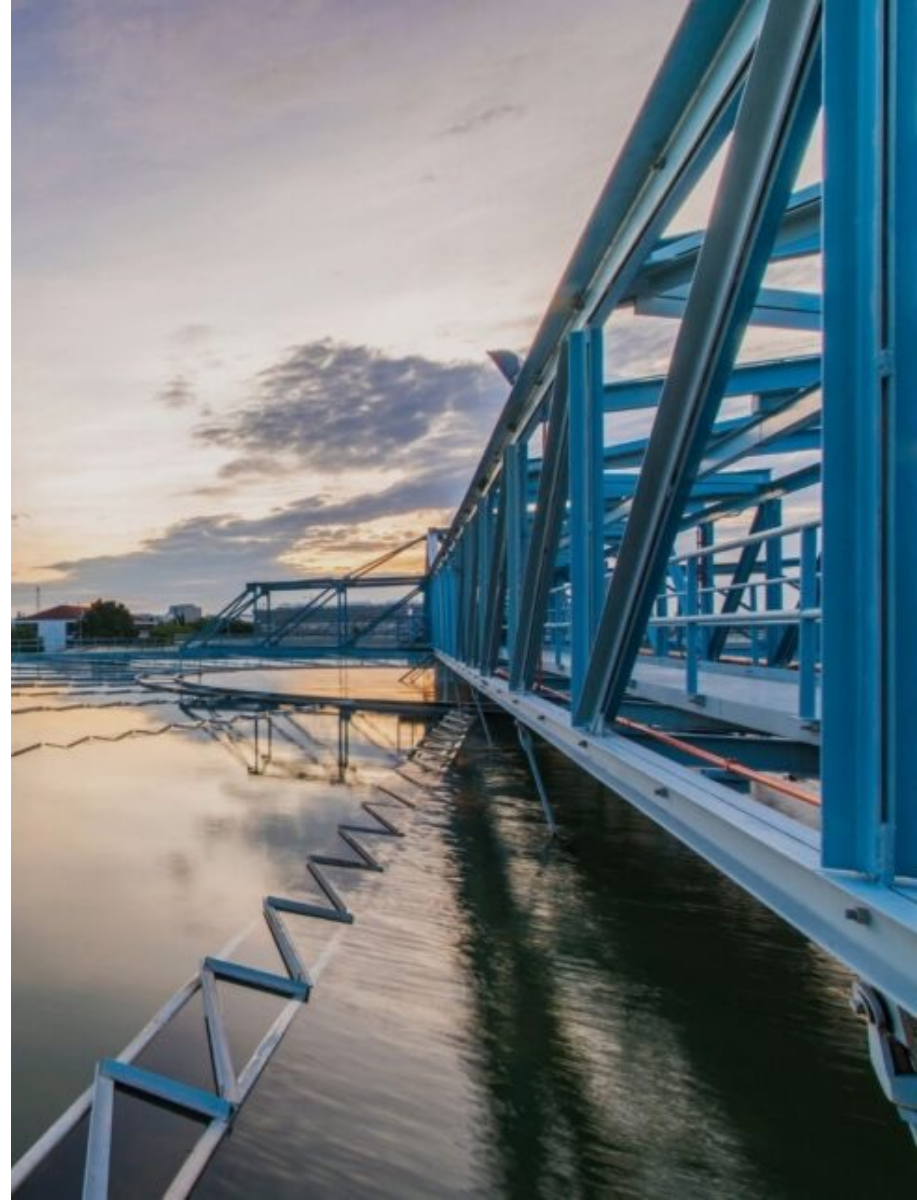
LOCAL POLICE OF TURIN



logikers



Politecnico
di Torino



UC3 - Cross-border illegal trafficking via land

Cross-border illegal waste trafficking, illegal waste storage and dumping detection

Location: cross border monitoring across Romania and Moldova

Technology sources: satellites, drones, AI/ML

Context: land, air

Involved partners:



Romanian Border
Police



GARDA NAȚIONALĂ
DE MEDIU
Romanian National
Environmental Guard



Moldovian
Police



Moldovian Inspectorate for
Environmental Protection



UC4 - Identification of illegal waste sites and link with trafficking

Identification of illegal waste sites + thermal sites (fires), and intelligence tool to identify/monitor exports

Location: Greece

Technology sources: satellites, AI

Context: land, exports

Involved partners:



Hellenic police



INESC TEC
ASSOCIATE LABORATORY
PORTUGAL
LIAAD





Artificial Intelligence in Soil Protection



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101073874.

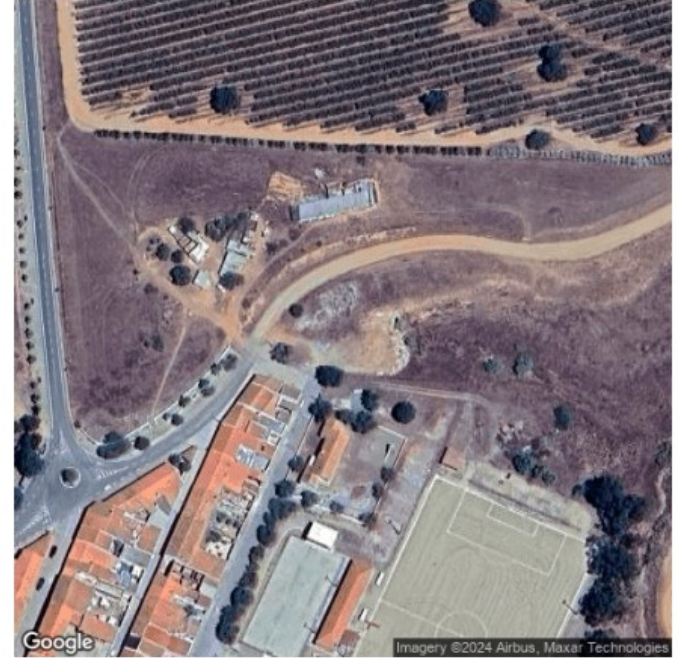


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Identification of illegal waste sites



(a) Legal landfill site.



(b) Illegal landfill site.

Model for Waste Classification and Detection

DATA SOURCE

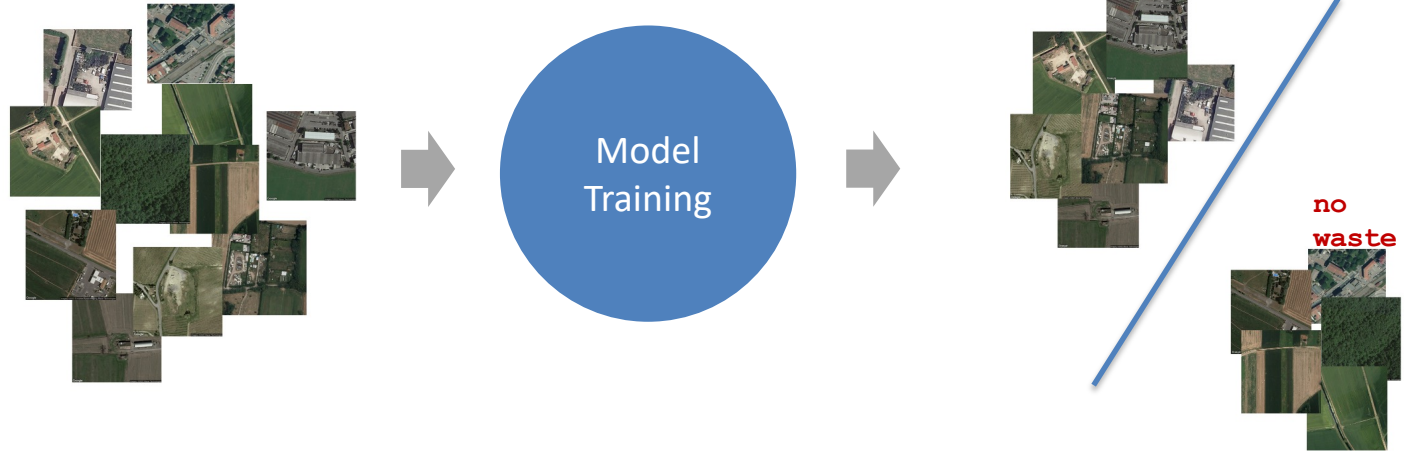
Public dataset:

-> Aerial Waste dataset.

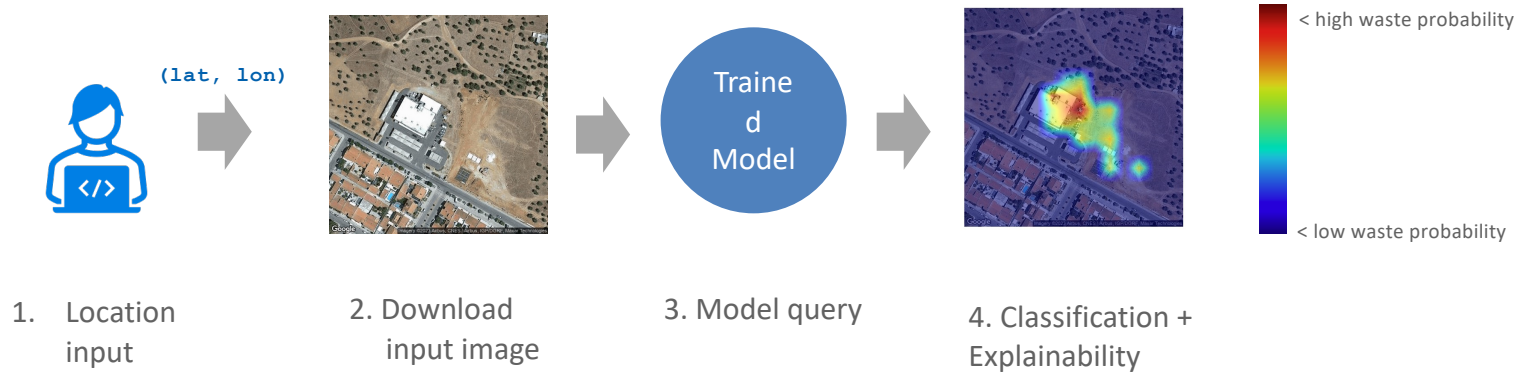
Data Collected:

-> Partnership with Portuguese territory observation entity.

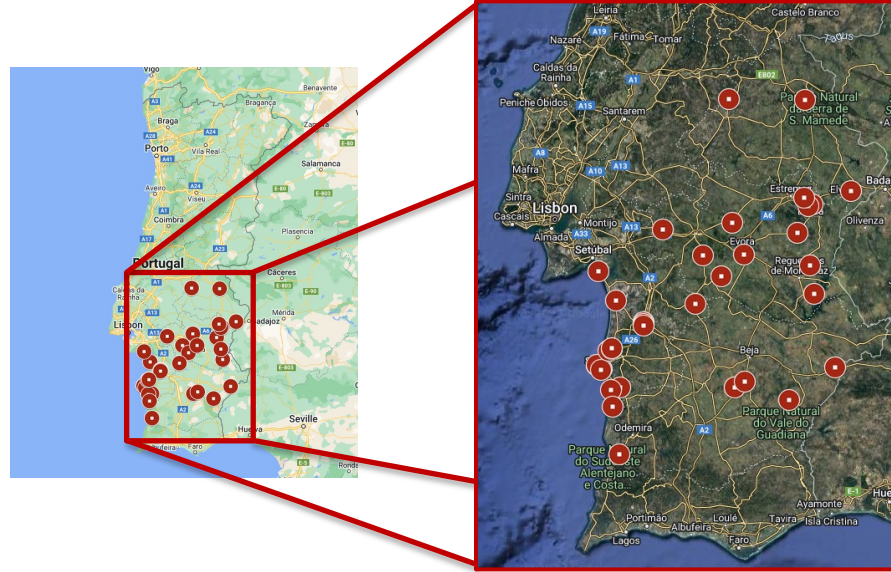
Very High-Resolution Images



Model for Waste Classification and Detection: approach



Waste Detection: *Case study*



Locations of interest

Same location with different zoom

prefix - image identifier - source - details level

PT_id01_google_zoom18.png



zoom: 16



zoom: 18



zoom: 19

Locations of interest

Query sample: classification and location.

*We are querying images
of zoom 18.*

Why?
Similar than training resolution!



zoom: 18

Locations of interest

Query sample: classification and location.

*We are querying images
of zoom 18.*

Why?

Similar than training resolution!



✓ Waste detected!

Locations of interest

Query sample: classification and location.

*We are querying images
of zoom 18.*

Why?

Similar than training resolution!

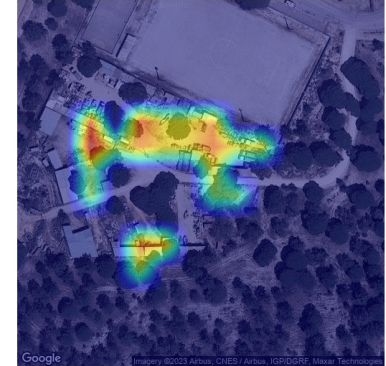
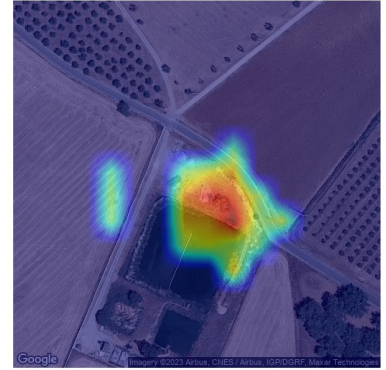
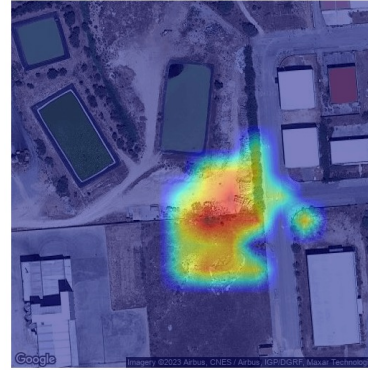
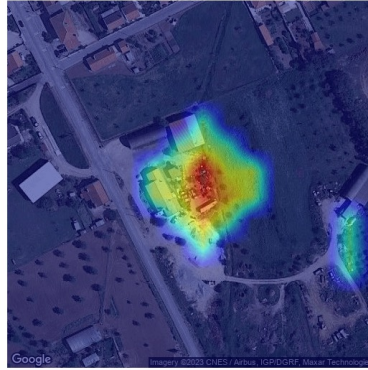
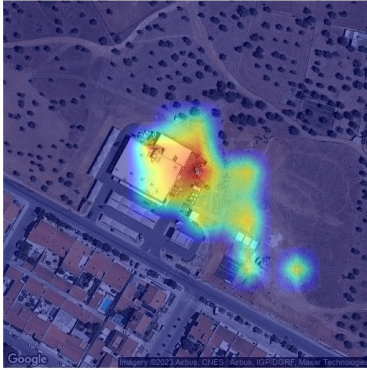


✓ Waste detected!

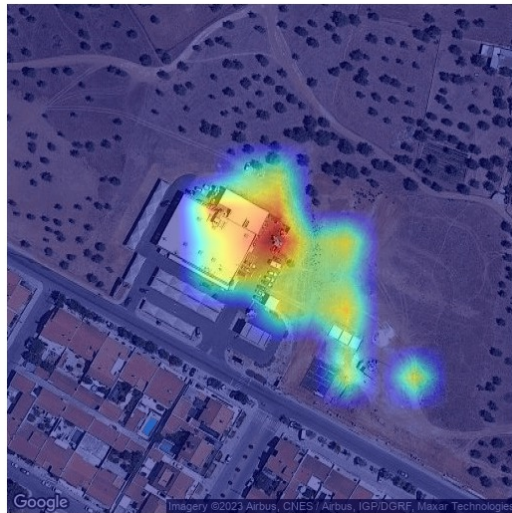
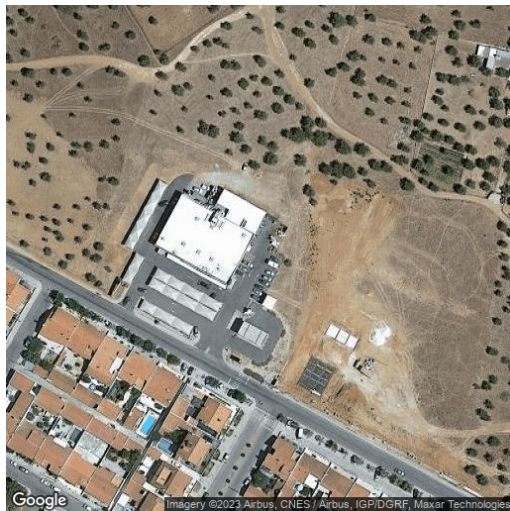
Highlighted pixels indicate the regions
that contributed most to the prediction.

Waste location!

Waste Detection: *Case study*



Waste Detection: *Case Study*



2023: positive detection



2024: negative detection

Zenodo is currently experiencing slowness and intermittent outages due to heavy automated traffic from bots and AI crawlers. We are aware of the problem, and our team is focused on stabilizing the service. Thank you for your patience. [More info here](#).

Preview

You are previewing a new record that has not yet been published.

Published January 2, 2026 | Version 1

Dataset

 Open

Landfills of Portugal: Dataset of Legal and Illegal Waste Sites

Molina, Matias (Researcher)^{1,2} ; Ribeiro, Rita (Researcher)^{3,1} 

Gama, Joao (Researcher)^{3,1} 

Characterizing Legal and Illegal Waste Sites: A Dataset of Landfills in Portugal

Matías Molina¹, Rita P. Ribeiro^{1,2}, João Gama^{1,3}

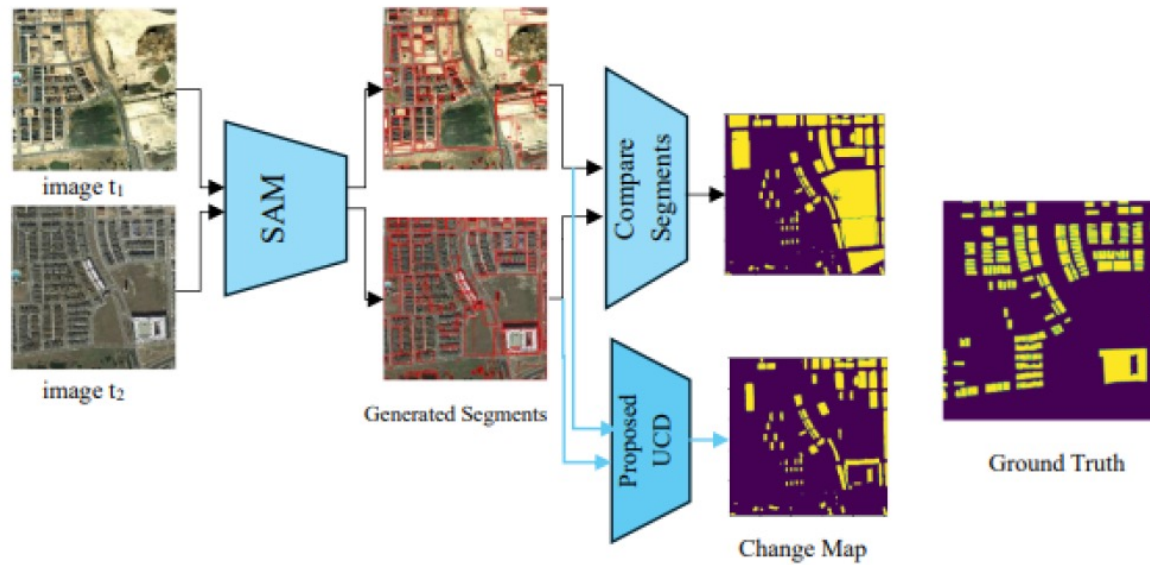
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³Faculty of Economics, University of Porto, 4200-464 Porto, Portugal

matias.d.molina@inesctec.pt

Land Change Detection



Model for Land Change Detection: case study II



Model for Land Change Detection: case study II

Image Jun2019



Image Jun2023



Image Jun2023with unmatched segments

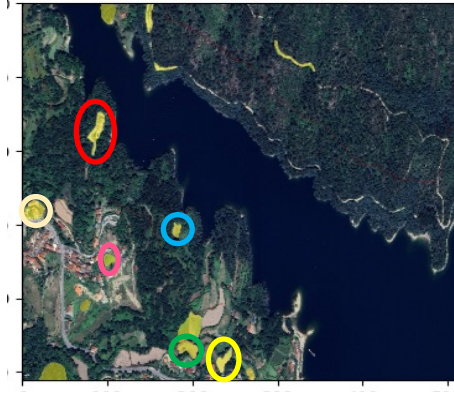


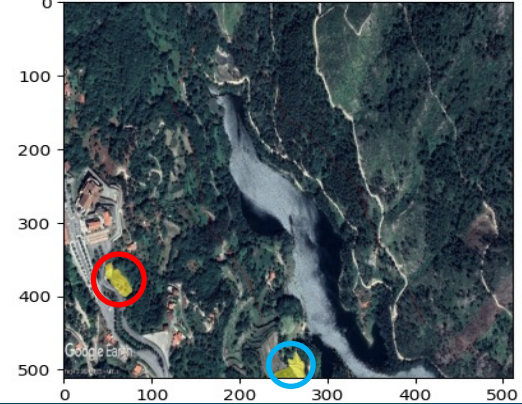
Image Jan2019



Image Jun2020



Image Jun2020with unmatched segments



Lessons from earth observation

- Satellite imagery and AI can identify potential illegal waste sites and detect relevant land-use changes.
- **Explainable predictions** help investigators understand why a location has been flagged.
- **The principal limitation is the scarcity and cost of labelled, high-resolution multispectral images.**
- Progress requires shared datasets and continuous validation by environmental and earth-observation experts.



Network Science Anomaly Detection in Waste Transportation



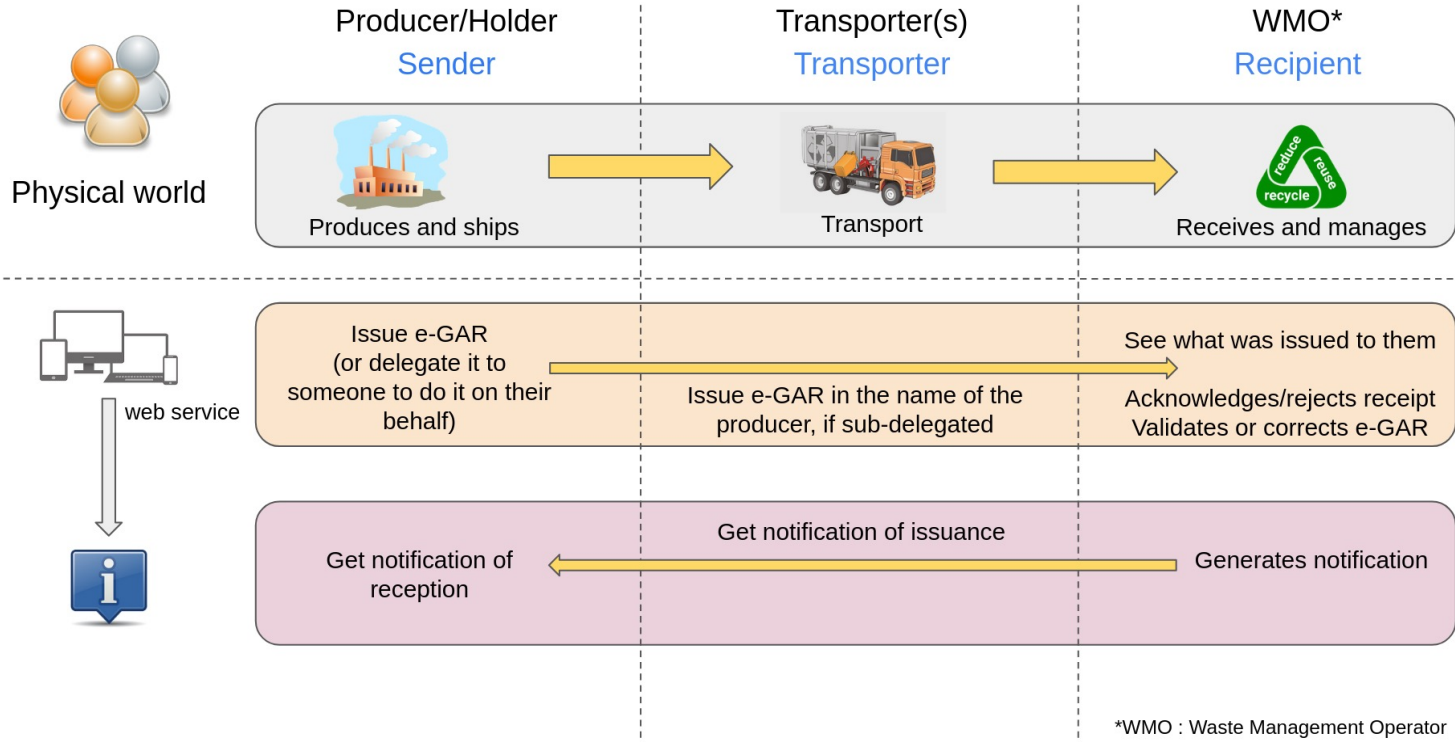
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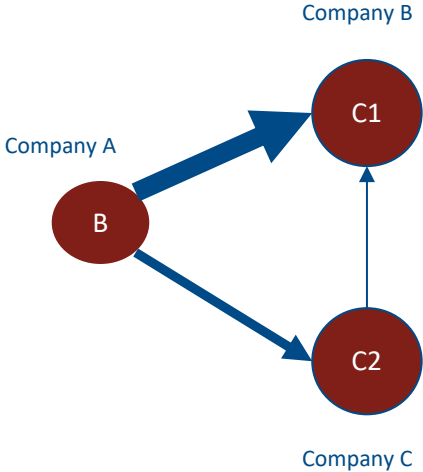


Problem Definition



Problem Definition

Data	Source	Destination	Product	Unities
15/06/2025	Company 12	Company 13	asdc	15
15/06/2025	Company 1	Company 4	dsads	23
15/06/2025	Company 6	Company 6	daskjklj	27
15/06/2025	Company 10	Company 9	wewew	77
15/06/2025	Company 3	Company 12	vxciyje	65
15/06/2025	Company 12	Company 14	weew	57
15/06/2025	Company 8	Company 13	erte	95
15/06/2025	Company 10	Company 11	jkiljk	18
15/06/2025	Company 4	Company 10	kkjklmlkm	36
15/06/2025	Company 7	Company 9	mnkn	31
15/06/2025	Company 11	Company 5	werewr	96
15/06/2025	Company 4	Company 13	werewr	15



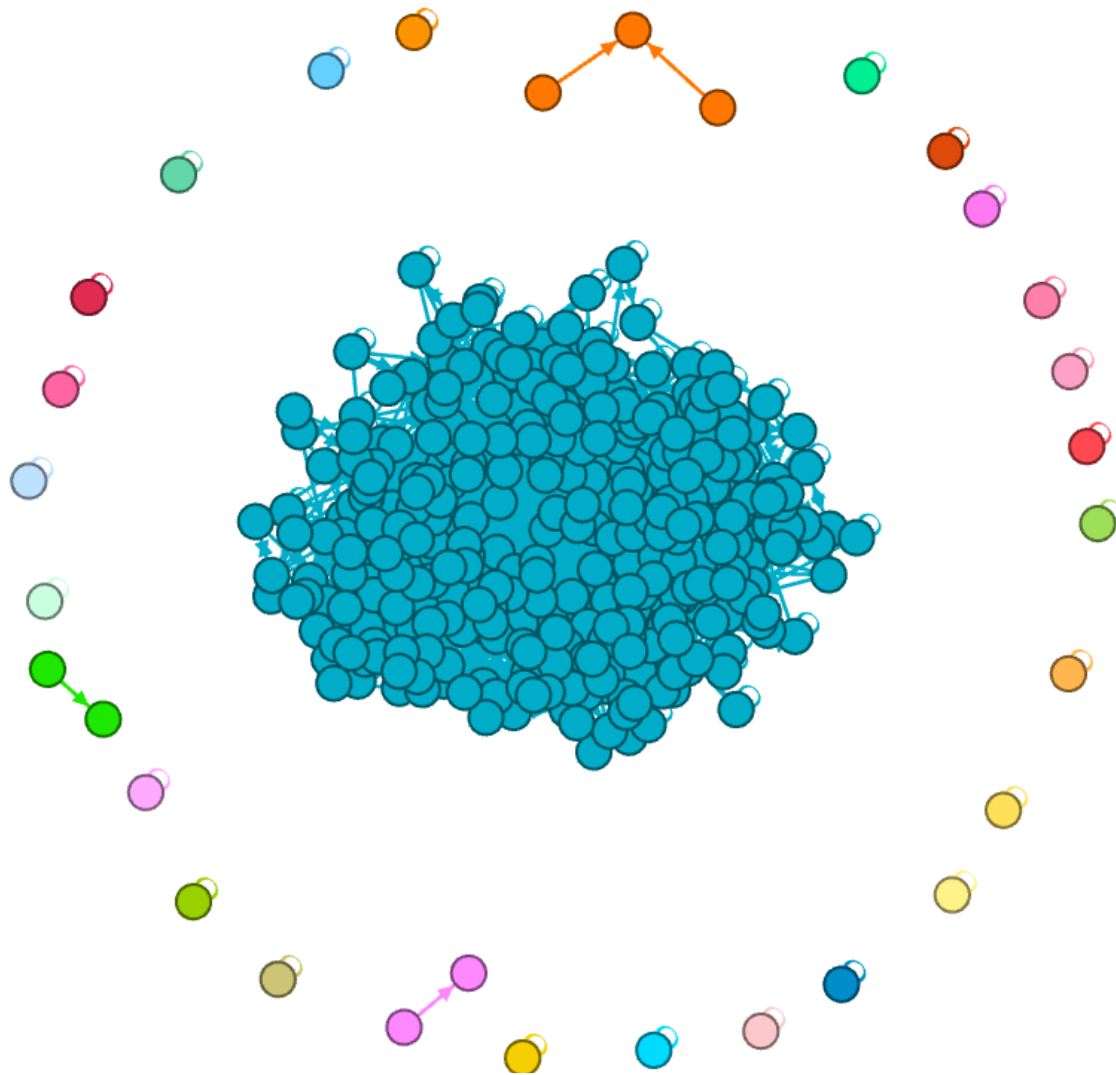
Find instances of illegal transport/disposal of waste by

- Tracking the movement of waste/materials through the entries in Waste Registration logs. (MIRRs)
- Monitoring the appearance and disappearance of waste to detect omissions by identifying discrepancies in data
- Identifying false or suspicious data, as well as imbalances and inconsistencies in the records
- Analyse trends to understand the activities of key players and anticipate potential problems.



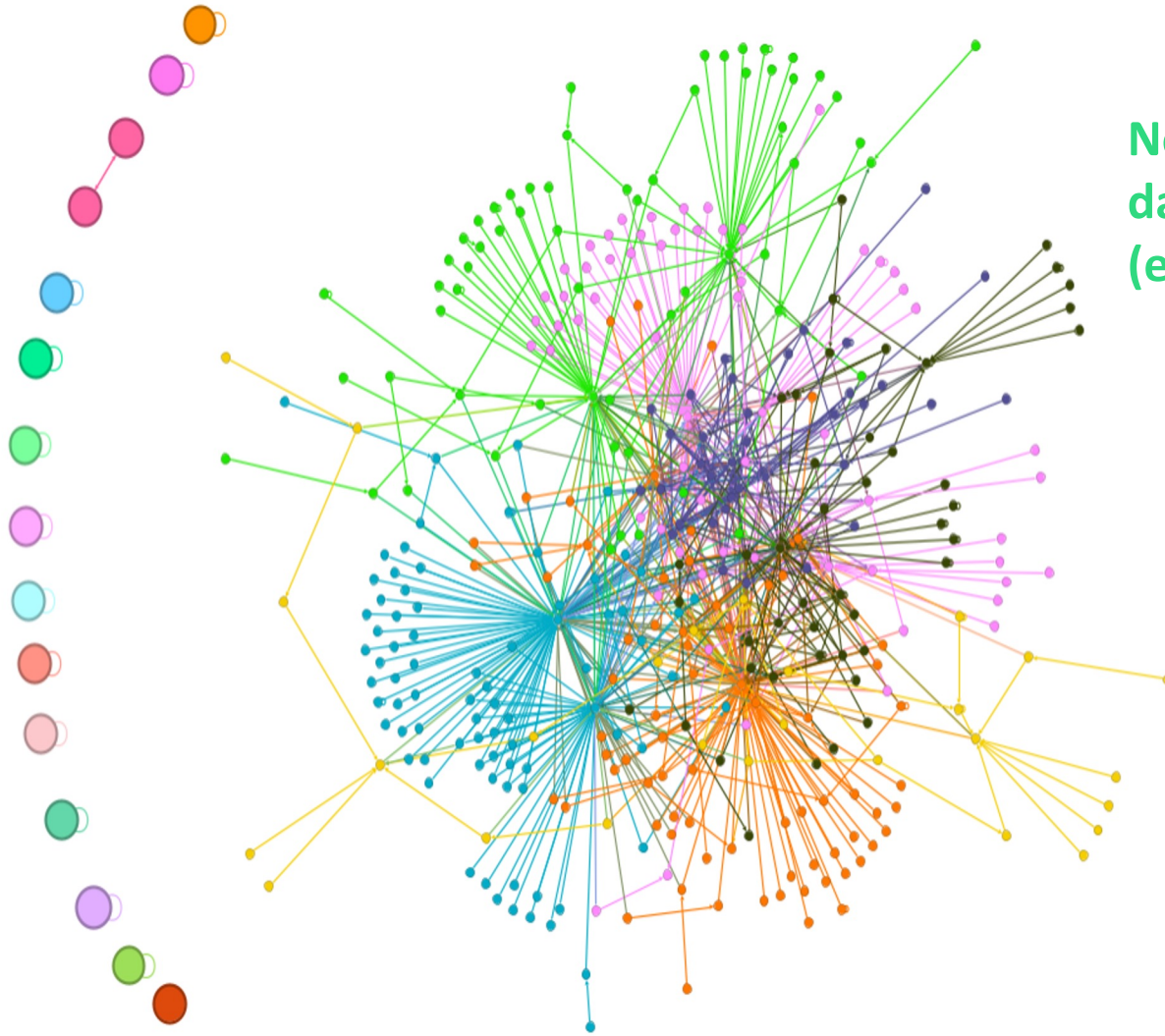
Detecting Anomalies

- Anomaly detection identifies observations or patterns that deviate from expected behaviour.
- Here, it helps detect discrepancies, inconsistencies, imbalances, and potentially illegal transport.
- Isolated Subgraphs
- Isolation Forest (iForest)
- Local Outlier Factor (LOF)
- Autoencoder



Isolated nodes in e-GAR network

- Disconnected from the main network
- 90% are absent from MIRR records
- Waste shipments sent to the same entity.

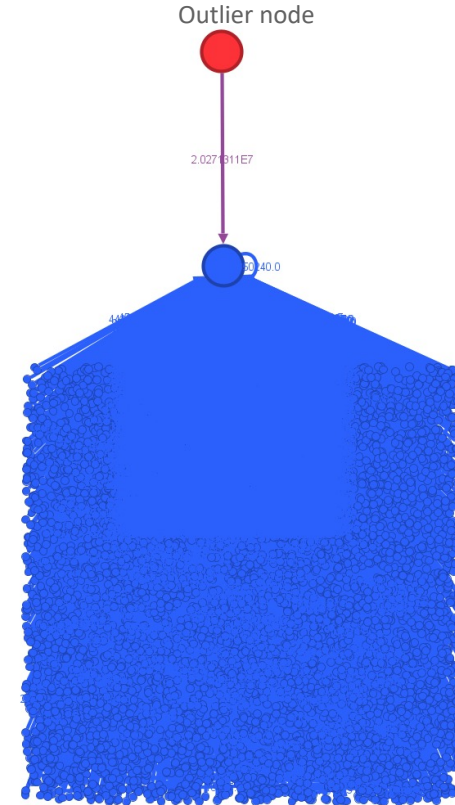


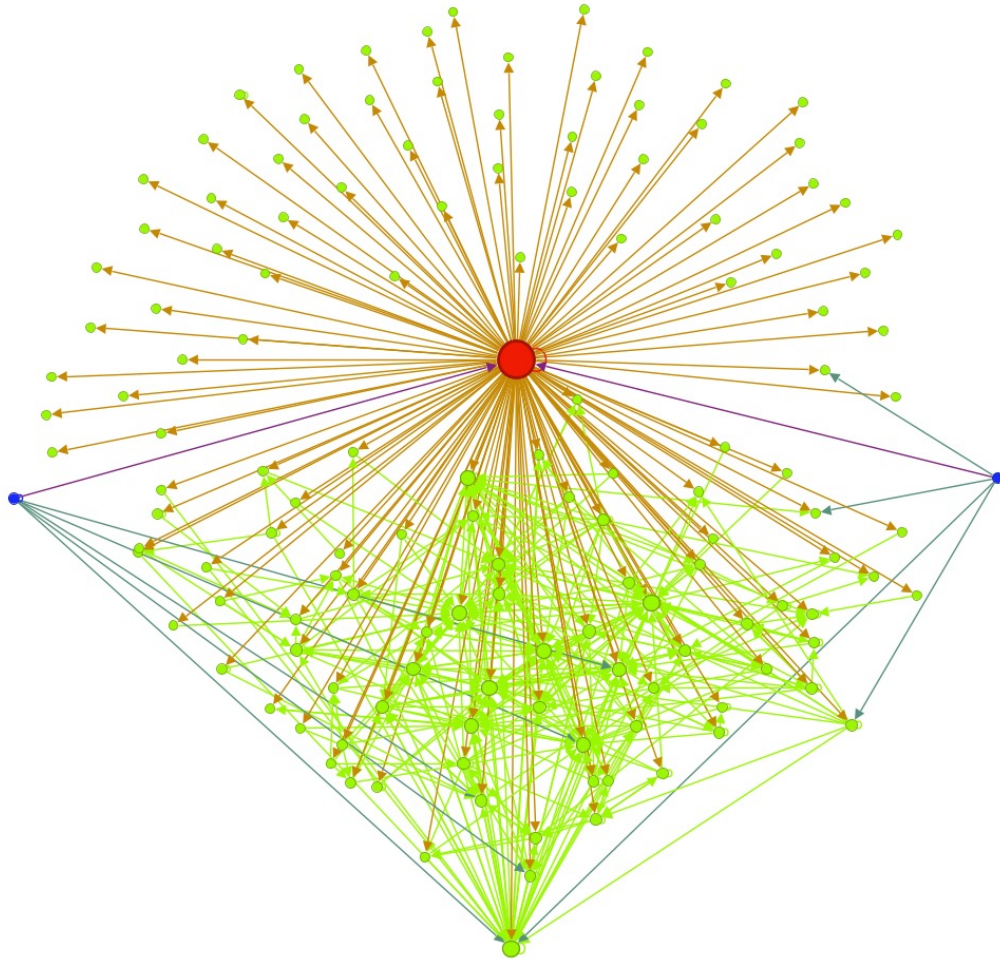
Nodes involved only in dangerous-goods transport (e-GAR)

- Isolated nodes found
- Highly connected communities
- Peripheral nodes representing independent entities that deliver waste.

Highest ranking outlier node

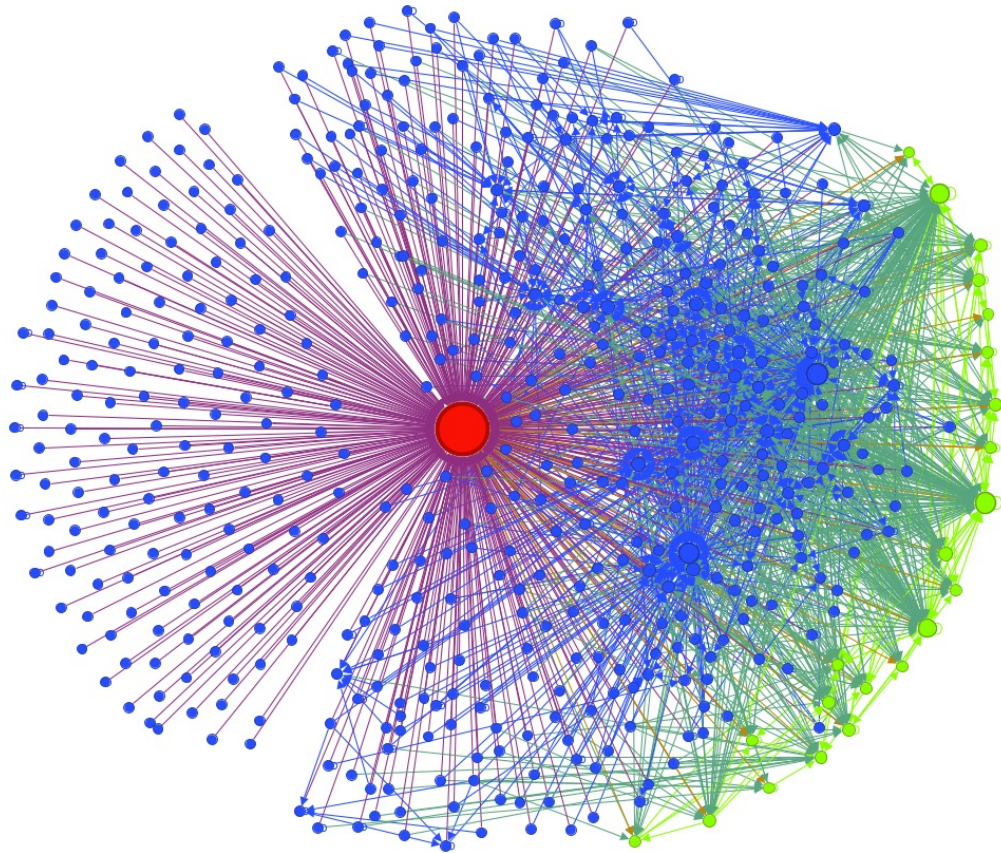
- Independent producer with only one transport more than 20M kilos of waste.
- Unregistered user not found in form B.
- Corresponding MIRR declared with quantity 99.9% less.
- Highest incoming transport of the adjacent node among thousands of transports.





Top outlier node

- Very low incoming to outgoing quantity ratio (weighted imbalance ratio $< -0,8$)
- Sending to a large number of independent entities
- 90% dissimilarity between MIRR and eGAR



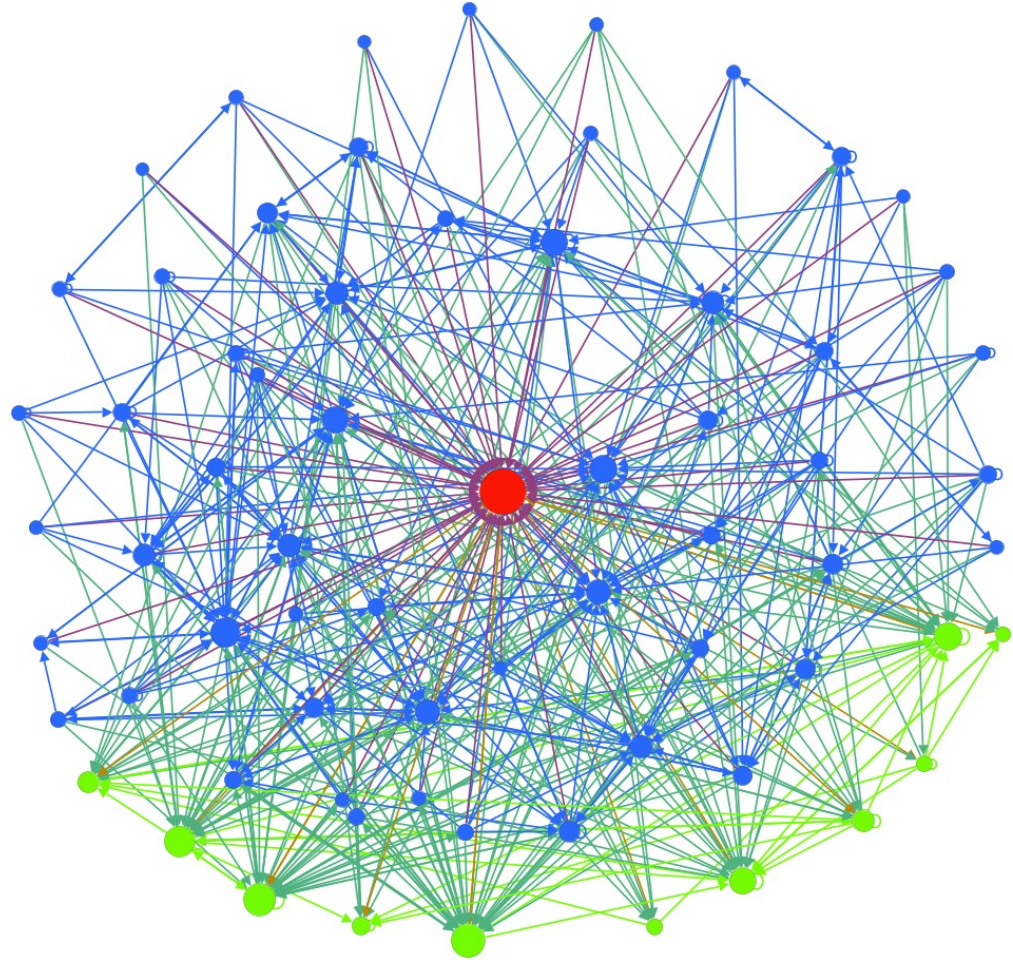
Sink node

- Behavior contrasting to the previous node
- 96% of the received weight is designated for disposal.
- Outgoing weight registered in MIRR is 30% greater than eGAR

*Blue nodes represent incoming waste transports, and green nodes represent outgoing waste transports.

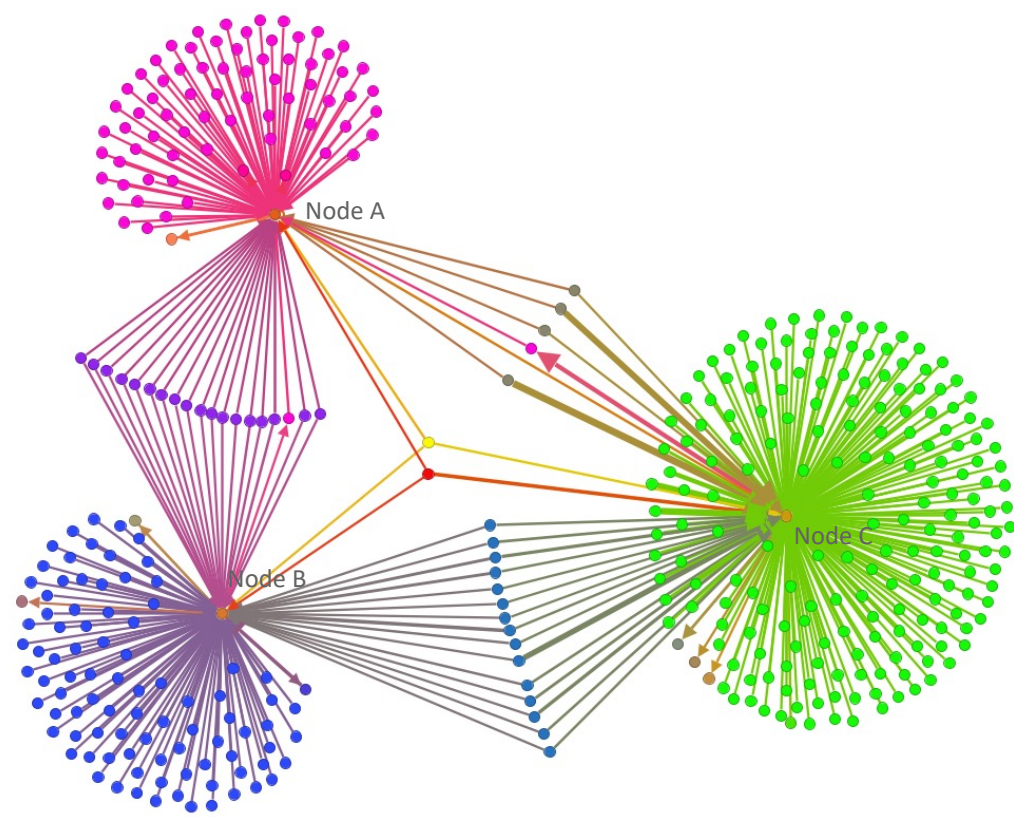
Outlier

Network quite balanced with transports to well connected nodes but a large difference of 50% between MIRR and eGAR entries incoming quantities.



*Blue nodes represent incoming waste transports, and green nodes represent outgoing waste transports.

Fraudulent Patterns



Lessons from waste-transport networks

- Combining e-GAR and MIRR records reveals missing actors, implausible quantities, and inconsistencies in reported waste flows.
- **Graph-based anomaly detection** identifies suspicious companies and transport patterns that warrant investigation.
- **Network visualisations** make the detected anomalies easier for inspectors to interpret and verify.
- **An anomaly represents an investigative lead, not proof of fraud.**

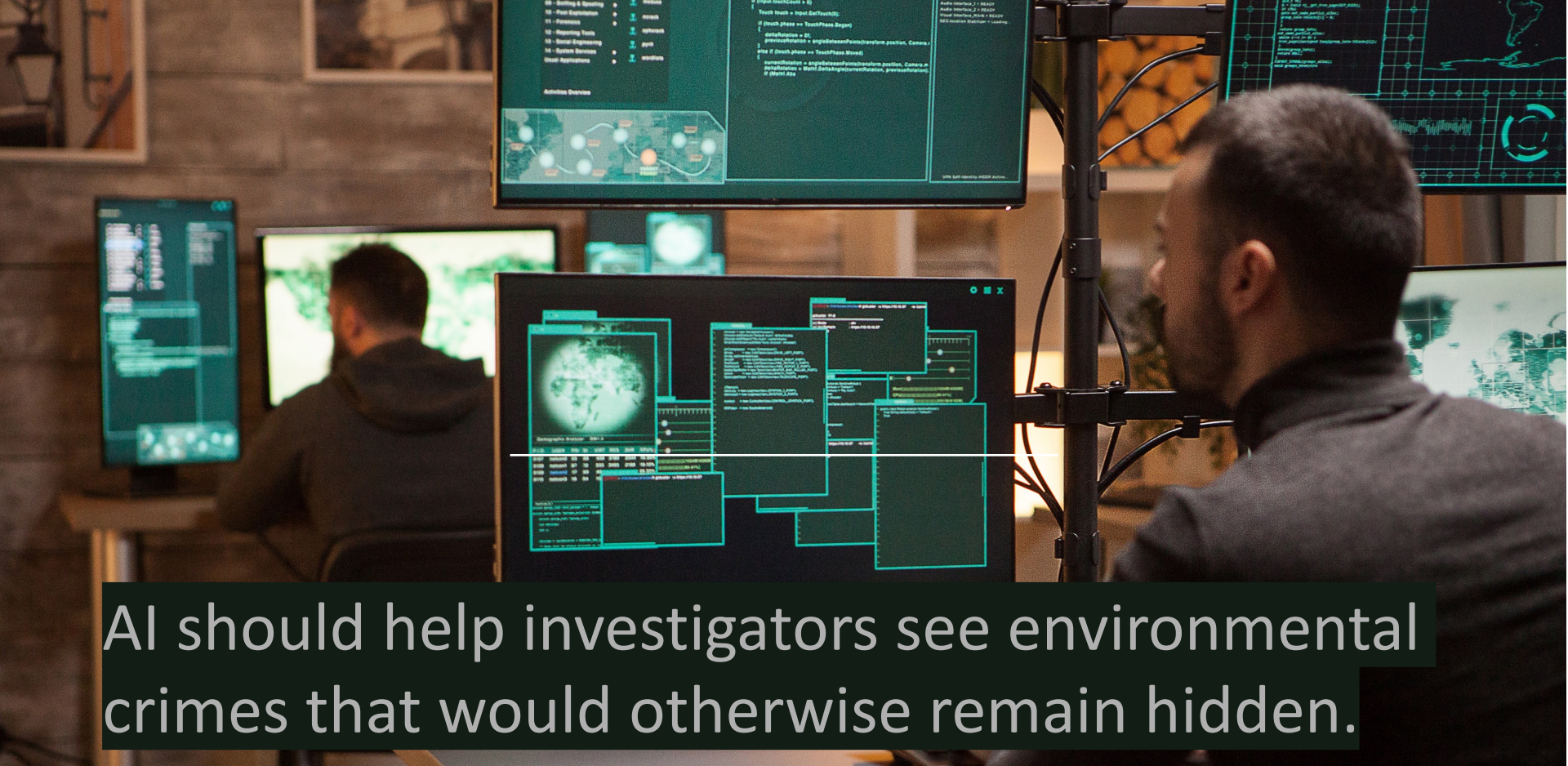
AI for environmental protection

- Earth-observation models help locate illegal waste sites and monitor changes over time.
- Network analysis reveals suspicious actors, transactions, and inconsistencies in waste-transport records.
- Effective deployment depends on reliable data, explainable results, domain expertise, and human validation.
- Sustainable AI must also consider the energy and environmental costs of developing and operating these systems.

AI can strengthen environmental protection by helping investigators identify where to look and what to examine.

Its value, however, depends on trustworthy data, explainable results, and close **collaboration between AI researchers and environmental authorities.**





AI should help investigators see environmental crimes that would otherwise remain hidden.



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