

BUILDING SCIENTIFICALLY ROBUST EVIDENCE FOR ENVIRONMENTAL CRIME INVESTIGATIONS THROUGH EARTH OBSERVATION AND SCIENCE-POLICY PARTNERSHIPS

A. Riccardi¹, S. Rapach¹, D. Robertson², Tracy Morse², F. Sindico³

¹University of Strathclyde, Department of Mechanical and Aerospace Engineering

²University of Strathclyde, Department of Civil & Environmental Engineering

³University of Strathclyde, Law School

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The GEMM Network

The Global Environmental Measurement and Monitoring network (GEMM) is an international, interdisciplinary network connecting environmental science, data and policy to strengthen evidence-based environmental action

- **Identify** critical environmental data gaps and monitoring needs
- Develops approaches to **translate** evidence into usable information for decision-makers
- **Connect** expertise across engineering, environmental science, health, law, economics and policy
 - At Strathclyde expertise spanning engineering, environmental science and health, law, mathematics, economics and sustainable development.
 - Works across local, regional and global scales



- ❖ University of Strathclyde
- ❖ Stanford University
- ❖ University of California, Berkeley
- ❖ Université Laval, Québec, Canada
- ❖ University of Otago, Dunedin, New Zealand
- ❖ University of Waterloo, Canada,
- ❖ Mexican Photonics Cluster (Clúster Mexicano de Fotónica)

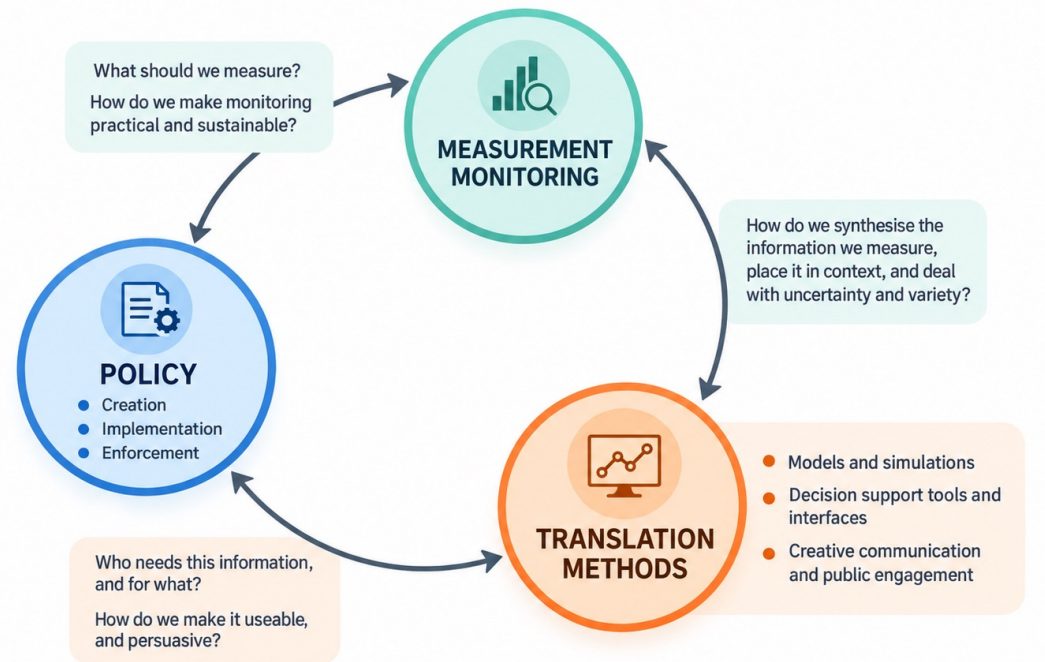
Measure what matters → understand and translate the evidence effectively → support policy creation, implementation and enforcement.

GEMM: a cycle, not a data pipeline

GEMM connects measurement, monitoring, modelling and policy action across scales

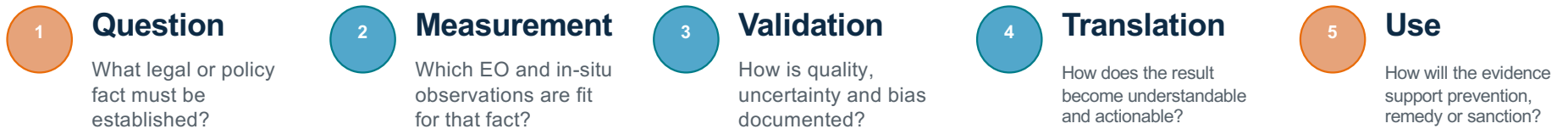
Policy asks: what must be measured, for whom, and how should the evidence be translated?

GEMM framing



What makes EO evidence “scientifically robust”?

Robustness is not a property of the image alone; it is a property of the whole evidence chain



For enforcement, the evidence chain must be transparent enough to be challenged, repeated and explained

Science-policy partnerships: co-design before observation

A partnership approach changes the order of operations

Data-first route

collect data
↓
interpret later
↓
hope it fits the decision

risk: technically impressive, legally weak

GEMM route

define decision need
↓
co-design measurement
↓
validate and translate evidence

target: scientifically robust and decision-ready

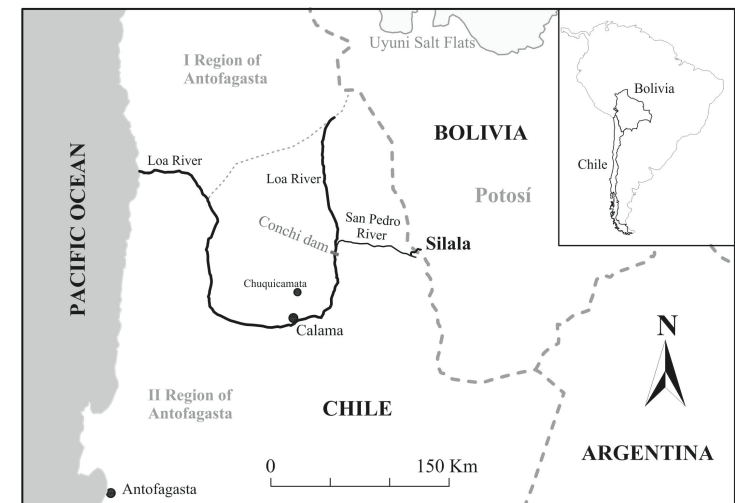
Two case studies show why this order matters

Case study 1 — Silala waters: law needed hydrology

BOLIVIA–CHILE / INTERNATIONAL WATERCOURSE

The question was not simply “where is the water?”

- Springs and wetlands in Bolivia feed a watercourse flowing into Chile
- Drainage channels altered and increased surface flow
- Core scientific question: natural flow vs human-enhanced flow
- The answer affected water-use rights and transboundary obligations



Source: International Water Law project

Silala: translating the legal issue into measurable variables

The legal dispute created three linked measurement questions:

Wetlands & channels

What infrastructure altered surface drainage and wetland conditions?

Surface flow

How much water moved across the boundary, and how did seasonality matter?

Groundwater system

How did springs, aquifers and gradients connect Bolivia and Chile?



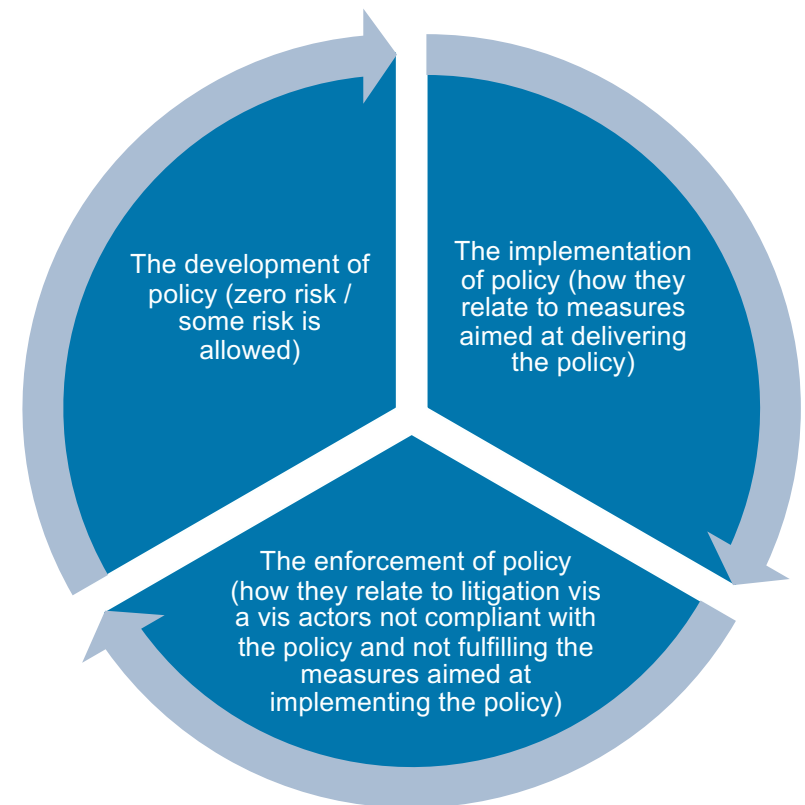
The insights had to connect hydrological science to the legal threshold and assessments latterly: International watercourse, equitable use, significant transboundary harm

Silala: the evidence lesson for enforcement

Measurement was necessary, but not sufficient

- Drawn-out legal dispute over what specific goals were set by the court
- Scientists, lawyers and decision-makers must agree on the evidentiary target early
- The litigation strategy should shape what is measured and monitored
- Models are persuasive only when assumptions and uncertainty are transparent

Co-design turns measurements into evidence



What EO can add in a Silala-type investigation

EO is strongest when it provides spatial context, historical reconstruction and repeatable monitoring around targeted field evidence

Context catchment, wetlands, slope, vegetation, surface-water traces

Change channels, infrastructure, wetland restoration or degradation, seasonal dynamics

Corroboration independent observations to test field campaigns and model assumptions

Communication maps and time-series that explain uncertainty to legal and policy audiences

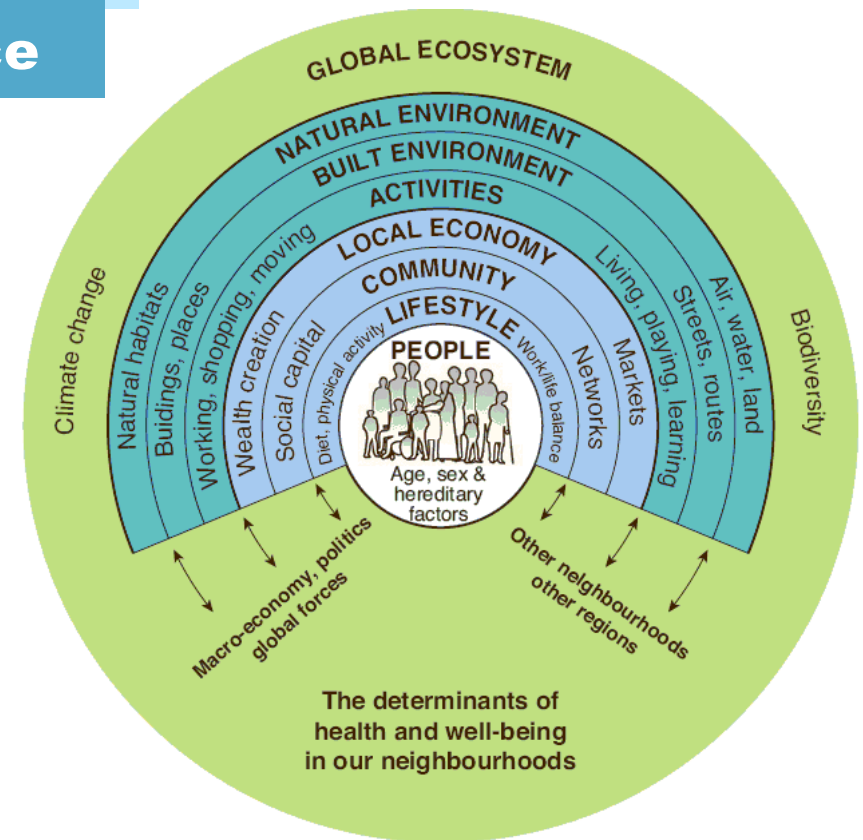
Key caveat → EO products must be explicitly tied to the evidentiary question and validated against hydrological observations

Case study 2 - Malawi: environmental health as evidence

ONE HEALTH / WATER · WASTE · ANIMALS

Here the evidence challenge is not a single disputed boundary, but complex exposure pathways

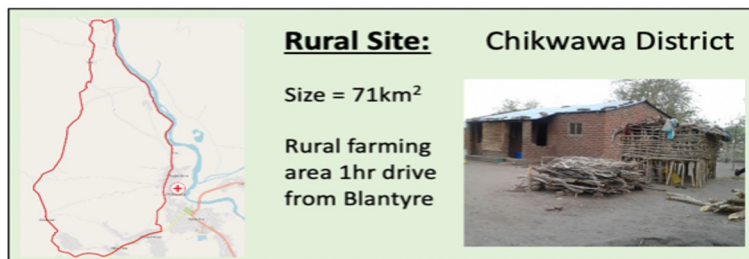
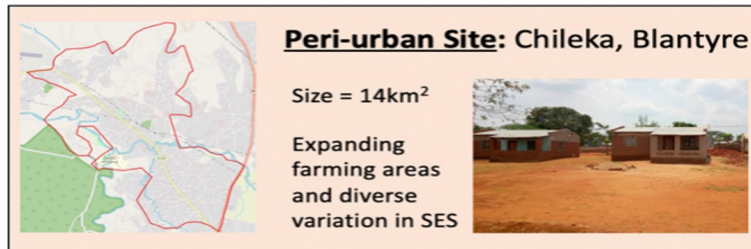
- Environmental health challenges are linked to water, waste, food safety and animal-human-environment interactions
- Data must identify critical points in transmission pathways, not just describe contamination
- Measurement must remain usable where finding, capacity and competing priorities constrain action



At least 24% of all deaths worldwide were attributable to the environment (WHO, 2016)

Source: Barton and Grant 2006

Malawi: measuring across human, animal and environmental compartments



Human



Animal



Environment

Cocker D, Sammaro M et al (2022):
<https://doi.org/10.12688/wellcomeopenres.17581.1>

<https://www.drumconsortium.org/>

Malawi: field evidence shows transmission across the wider environment

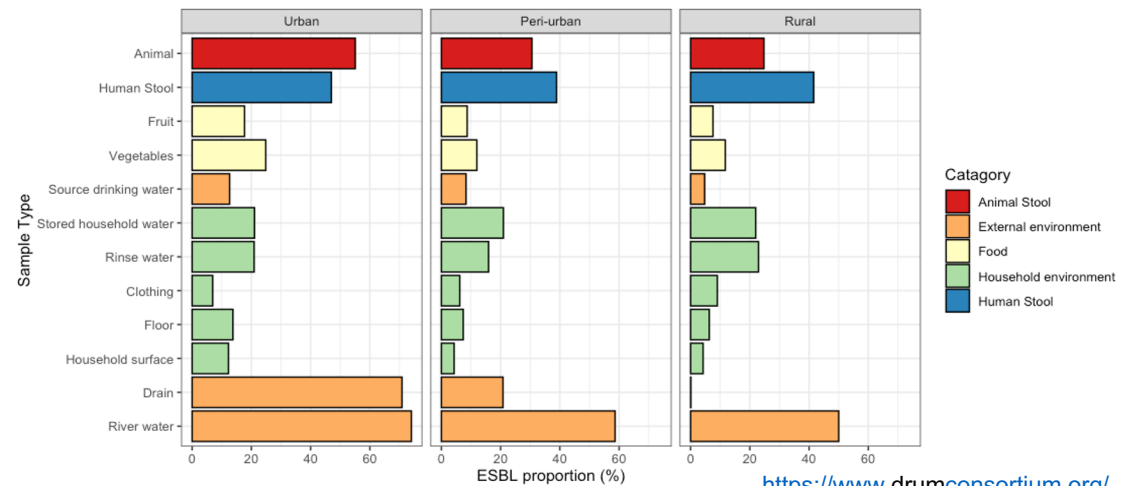
The relevant “scene” is not just the river, the household or the market, it is the interaction between them

- High bacterial colonization in people and animals
- High bacterial presence in riverine environments
- Transmission linked to water, sanitation and hygiene; waste management; food safety

High levels of ESBL colonization in participants

High levels of ESBL colonization in animals

High levels of ESBL present in the riverine environment



Evidence must connect samples to systems

<https://www.drumconsortium.org/>

Malawi: exposure pathways are visible, local and dynamic



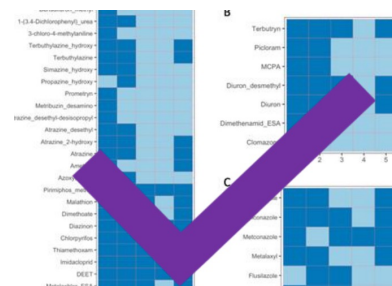
faecal management



solid waste



food hygiene



chemical exposure

Metal	Site1, N = 27	Site2, N = 28			
Al	24.00 (20.71)	21.19 (20.83)	Mo	1.51 (2.05)	1.47 (
As	0.80 (0.58)	2.13 (1.70)	Ni	11.78 (6.00)	0.70 (
Ba	111.33 (34.73)	139.46 (40.36)	Pb	0.06 (0.01)	0.01 (
Cd	0.01 (0.01)	0.00 (0.00)	Rb	14.00 (0.01)	44.26 (
Ce	0.01 (0.01)	0.01 (0.01)	Sb	0.01 (0.01)	0.56 (
Co	0.40 (0.54)	0.49 (0.71)	Sn	0.05 (0.13)	0.59 (
Cr	0.01 (0.01)	0.88 (0.64)	Th	15.44 (71.99)	970.46 (
Cs	0.01 (0.01)	0.04 (0.01)	U	11.05 (9.00)	12.49 (
Cu	7.29 (2.50)	7.29 (2.50)	V	0.10 (0.06)	0.04 (
Fe	50.62 (74.63)	50.62 (74.63)	W	2.75 (2.02)	1.88 (
La	0.01 (0.00)	0.01 (0.00)		0.01 (0.00)	0.00 (

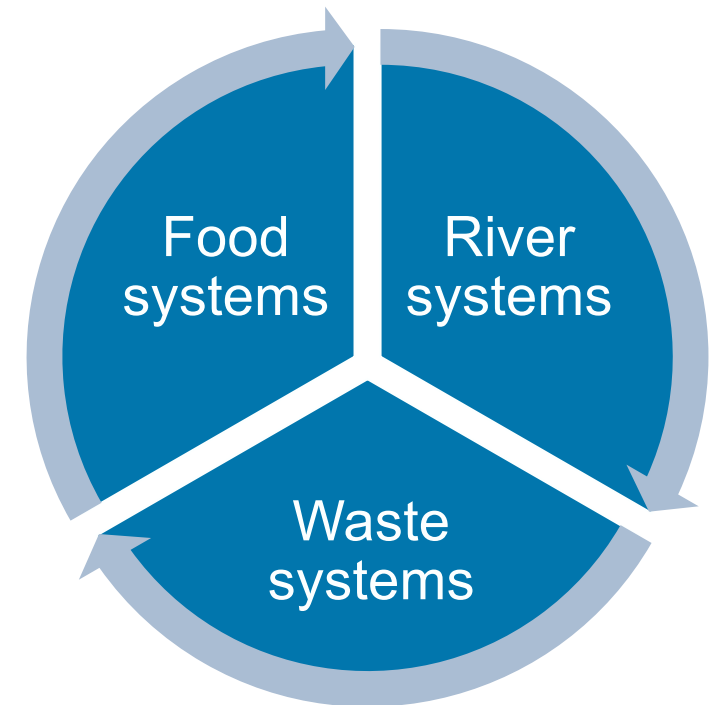
These are not isolated “samples”; they are spatially patterned contact opportunities

What EO can add in Malawi-type environmental health investigations

EO can help turn site-based evidence into spatial intelligence for risk-based action

- Map settlement density, drainage corridors, informal waste sites and river proximity
- Track seasonal flooding, vegetation, land-use change and access constraints
- Prioritise field sampling and identify where interventions could break transmission pathways
- Communicate risk to government, donors and local communities

The EO output is not the end product; the end product is a usable risk narrative



Two cases, one evidence logic

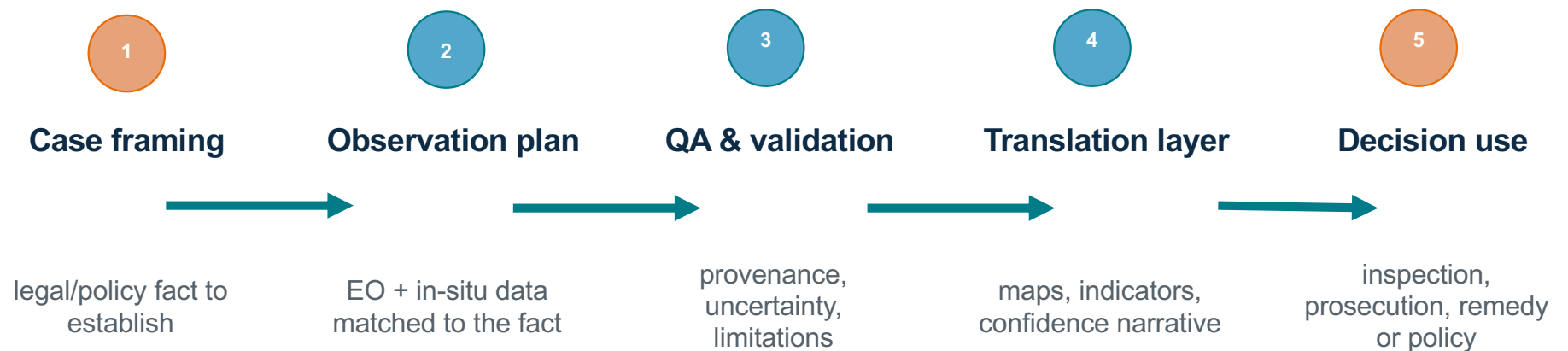
The cases are very different, but both show why “policy → measurement → translation” must be designed as one cycle

Evidence context	Silala waters	Malawi environmental health	Common GEMM lesson
Decision need	Legal status and transboundary obligations	Risk-based environmental health action	Start with the decision, not the dataset
Measurement issue	Surface/groundwater system; channels; wetlands	Human-animal-environment pathways	Measure the system that the decision depends on
EO role	Spatial context, change history, corroboration	Exposure mapping, prioritisation, communication	EO supports the evidence chain
Translation risk	Hydrological facts not aligned with legal strategy	Rich data not translated into feasible action	Co-design the final evidentiary product

The common failure mode is not lack of data. It is a broken translation chain

A GEMM evidence dossier for investigations

A practical output of science-policy partnership can be an evidence dossier that is built for scrutiny



For an enforcement audience, the dossier makes the scientific judgement auditable and the legal relevance explicit



Take Home Messages

1

Robust evidence starts with the decision question

2

EO becomes enforcement-ready only when validation, uncertainty and translation are designed in to a larger monitoring system

3

Science-policy partnerships are the mechanism that keeps the evidence chain intact

Thank you for listening

EMAIL: seonaid.rapach.2020@uni.strath.ac.uk

