

EO for EU Soil Monitoring Compliance

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Ecological Impact

- **Heavy-metal contamination** (especially Cr(VI)) from:
 - > Leather-tanning
 - > Electroplating effluents
- **Leads to:**
 - > Loss of soil biodiversity
 - > Reduced soil fertility
 - > Disruption of ecosystem services
- **Scale:**
 - ≈ 60–70% of EU soils affected

Economic Impact

- **Soil degradation costs the EU:**
 - ~€50 billion per year
- **Driven by:**
 - > Loss of agricultural productivity
 - > High remediation and compliance costs

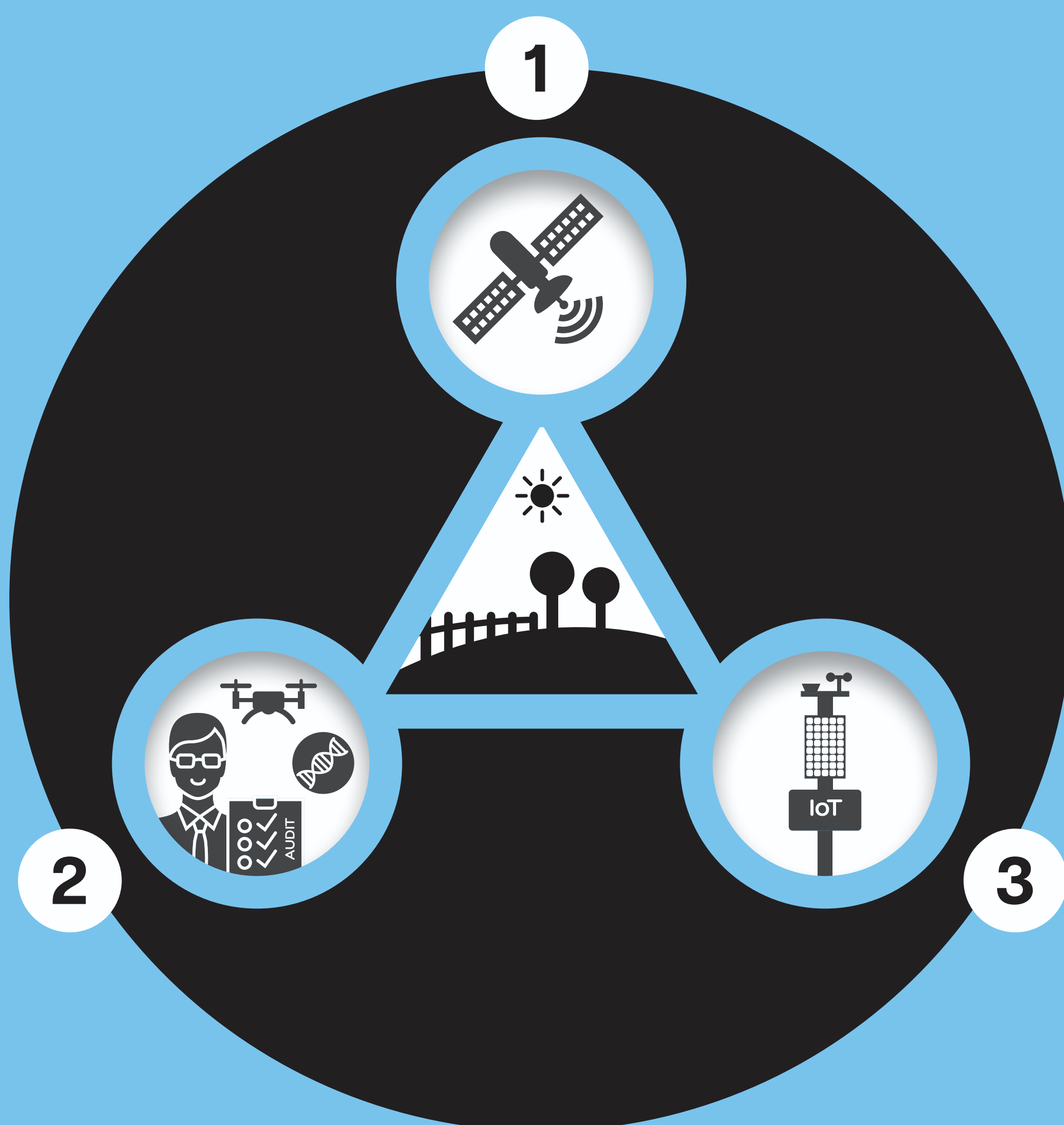
Social Impact

- **Contaminated land leads to:**
 - > Food safety risks
 - > Threats to human health
 - > Decline in rural livelihoods
- **Pollution pathway:**
 - > Chromium waste; groundwater and irrigation systems; food chain

Key Contamination Sources

- **Leather tanning industry:**
 - > ~80% of global production uses chrome tanning
 - > Discharges Cr-rich sludge and wastewater
- **Electroplating industry:**
 - > Releases Cr(VI)-containing effluents
 - > Chromium oxidizes in soil – increases toxicity

Solution – GeoBioRemediation (Two-Layered Approach)



Layer 1

Triangular Auditing (EO, Drones, In-Situ)

1: (Earth Observation)

SAR (Synthetic-Aperture Radar)

- Uses C-band (~5.3 GHz) and L-band (~1.2 GHz)
- Enables all-weather, day-night monitoring
- Penetrates top soil layers (few cm)
- Detects:
 - > Soil moisture variations
 - > Subsurface structural changes
 - > Metal-induced compaction patterns

Multispectral (Sentinel-2-like)

- Covers visible to near-infrared spectrum (450–880 nm)
- Tracks vegetation health using:
 - > NDVI (Normalized Difference Vegetation Index)
 - > PRI (Photochemical Reflectance Index)
- Acts as an indirect proxy for soil health and stress

SWIR Hyperspectral

- Detects Cr(VI) spectral signatures:
 - > ~2200 nm (clay-OH overtone)
 - > ~2350 nm (Cr-OH combination band)
- Data fusion from multiple sources:
 - > CubeSat SWIR (~10 nm bandwidth, 5 m resolution)
 - > Sentinel-2 (10–20 m resolution)
 - > EnMAP / PRISMA (~30 m resolution)
- Output:
 - > High-resolution (5 m) Cr(VI) probability maps

2: Drones (UAV-Based Monitoring)

- Low-altitude UAV flights for high-resolution mapping
- Equipped with:
 - > SWIR spectrometer (1 nm resolution, 2100–2500 nm)
 - > Multispectral camera
- Provides:
 - > Centimeter-level spatial detail
 - > Validation of satellite-derived signals
 - > Targeted hotspot identification

3: In-Situ Validation (Ground Truthing)

- Ground-based measurement tools:
 - > Field spectrometers
 - > Portable XRF devices for heavy metal detection
- Functions:
 - > Spot sampling and calibration
 - > Verification of Cr(VI) presence and concentration
 - > Improves model accuracy and reliability

Satellite EO >> Drone Mapping >> Ground Truth (In-Situ) >> AI Fusion >> 5m Cr(VI) Map

Layer 2

BioRemediation Biochar Bacterial Consortia

Application of pyrolyzed biomass (10–20 t/ha)

- Increases soil pH
- Provides adsorption sites for Cr(VI)
- Use of aerobic Cr(VI)-reducing bacteria:
 - > Pseudomonas sp.
 - > Bacillus sp.
- Mechanism:
 - > Enzymatic reduction of toxic Cr(VI) to Cr(III)
- Outcome:
 - > Converts chromium into less toxic and stable form
 - > Reduces Cr(VI) mobility and bioavailability

Mycoremediation

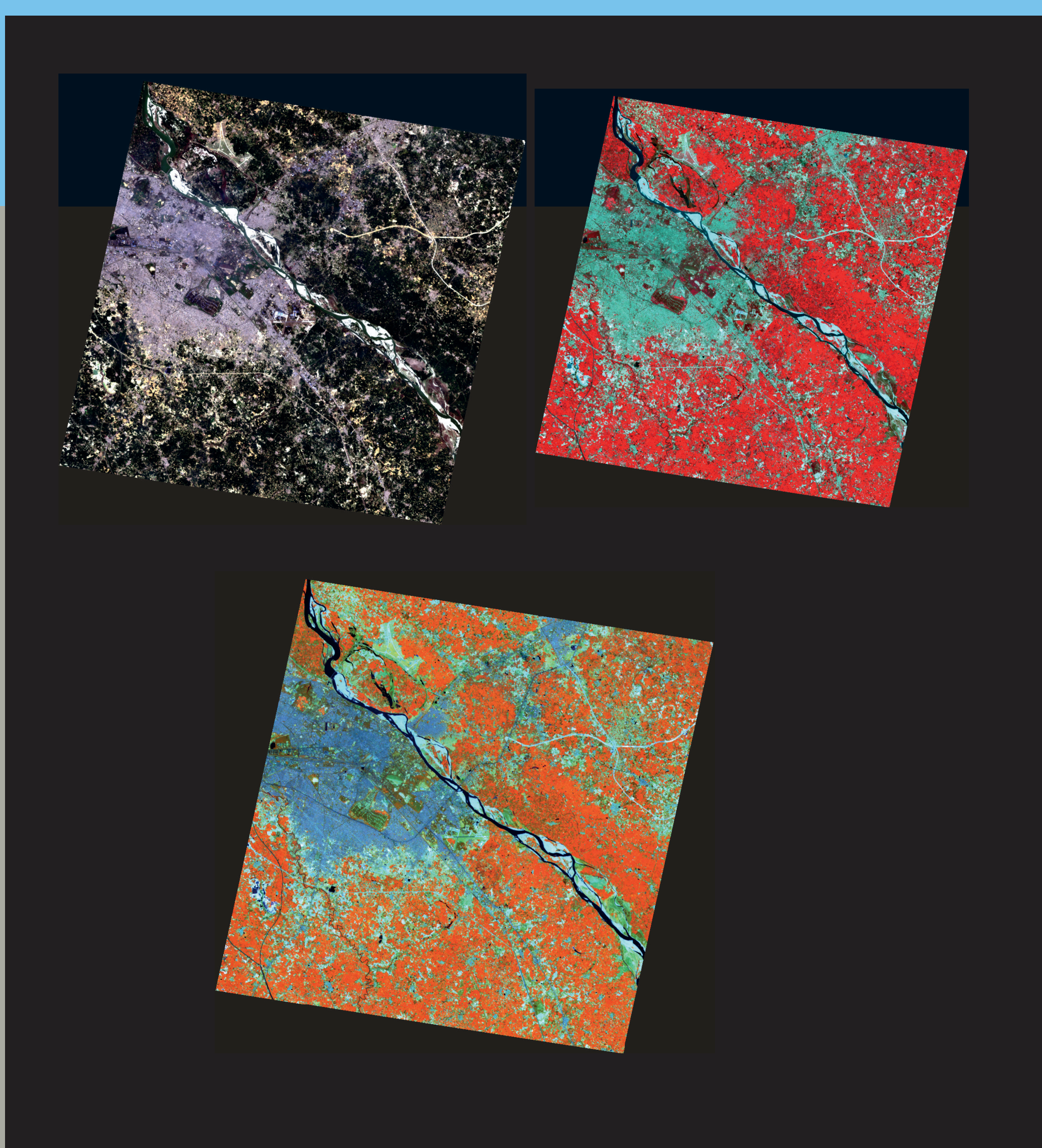
- Application of white-rot fungi:
 - > Phanerochaete chrysosporium
 - > Trametes versicolor

- Secretes enzymes:
 - > Laccase
 - > Peroxidase
- Function:
 - > Further reduces Cr(VI)
 - > Immobilizes Cr(III) in fungal biomass

Phytoremediation

- Use of hyperaccumulator plants:
 - > Astragalus bisulcatus
 - > Atriplex spp.
- Process:
 - > Uptake and sequestration of Cr(III)
- Outcome:
 - > Contaminants stored in harvestable biomass
 - > Biomass removed for:
 - > Safe disposal
 - > Valorization (circular use)

Biochar >> Bacteria >> Fungi >> Plants >> Safe Removal



SDG

- SDG 9:** Industry, Innovation and Infrastructure
- SDG 13:** Climate Action
- SDG 15:** Life on Land (broader scope than 15.3)
- SDG 12:** Responsible consumption and production
- SDG 2:** Zero Hunger
- SDG 3:** Good Health and Well-being

GBF Targets Addressed

- Target 2** Ecosystem Restoration
- Target 3** 30x30 (Protected & Conserved Areas)
- Target 4** Species Conservation
- Target 7** Pollution Reduction
- Target 8** Climate Change & Biodiversity Nexus
- Target 10** Sustainable Agriculture
- Target 11** Ecosystem Services
- Target 21** Data, Monitoring & Knowledge
- Target 22** Participation & Inclusivity

EU Compliances

- EU Soil Monitoring & Resilience Directive
- EU Soil Strategy for 2030
- Industrial Emissions Directive (IED)
- EU Water Framework Directive (WFD)
- Zero Pollution Action Plan (Air, Water & Soil)
- EU Nature Restoration Regulation (2024)

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