Management of Agroecosystems for Persistent Pollutants

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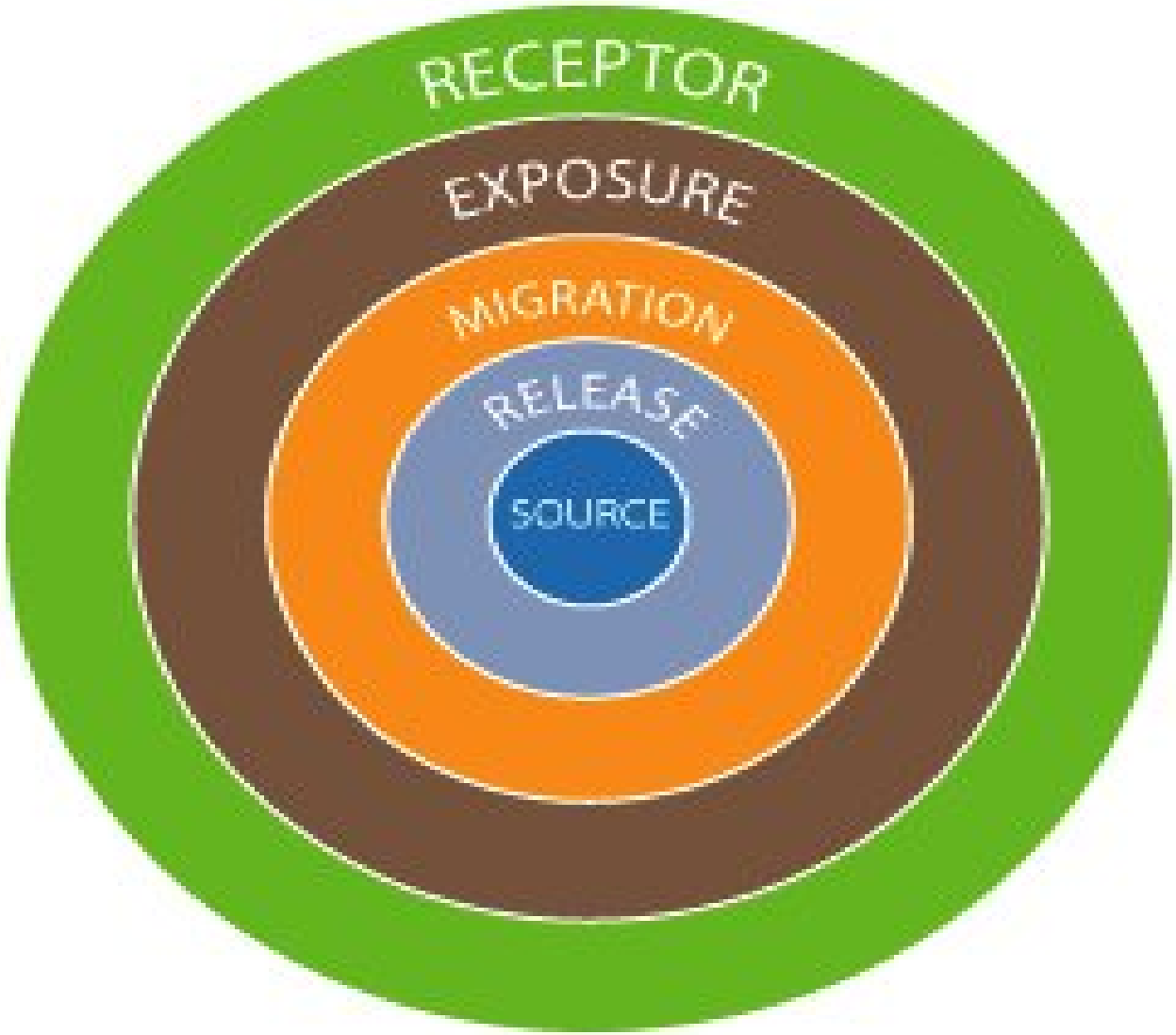
International Workshop, IUNG, Pulawy, Poland
March 10 - 12, 2005

Agroecosystems Base for Food Production

- European Union: 50% of EU land is farmed
- EU Policy (Common Agricultural Policy): enhance sustainability of agro-ecosystems
- European Council of Cardiff (1998), Vienna (1998), Helsinki (1999), Goteborg (2001): sustainable development
- U.S.A.: Concerned with biosolids addition to landfarms (not crops), and land application systems design and management for environmental safety

Source to Crop/Soil Receptor



East China Farmland Sulfur Deposition

- 73% of total annual sulfur deposition was deposited onto farmland
- Gaseous SO_2 (Dry deposition)
- Particulate SO_4^{-2} (Wet deposition)
- Air Pollution and Meteorological Factors
- Atmospheric deposition is one of the important sulfur inputs to soil-plant ecosystems

Smelter Emissions in Romania has effects on Soil Quality

- Zlatna (Apuseni Mountains of Romania)
- Smelter & Mineral Processing
  - Gaseous SO_2, NO_X
  - Particles enriched in Pb, Zn, Cd, and Cu
- Crop uptake of lead in agricultural soil:
  - Turnips = 536 ppm
  - Cabbages = 347 ppm
  - Grass = 1,970 ppm
- European Commission limits on lead < 0.3ppm in cereals, fruit, and vegetables

Salinity Problem in Australia

- Tannery (industrial) contamination of irrigation water resulted in high salinity
- Salinity reduce crop yields
- Na^{+} caused clay dispersion and soil sealing
- Ca^{+2} and Mg^{+2} counteracts Na^{+} and stabilizes the soil
- Solution: Treatment of tannery wastes and recycling of chrome liquor & precipitation

Palestine Soil Quality has Decreased

- Excess use of Pesticides & Fertilizers
  - Large increase in population
  - Small surface area for production
  - Prohibited Insecticides: Pentachlorophenol, Chlordane, Aldecarb, Paraquat, Parathion

West Java Soil - Industrial Impact

- **Problem**: 90% reduction in rice yield
- Heavy metals from sewage sludge from textile industry
- Disposed directly into three rivers that are used to irrigate lowland rice
- B, Cd, Pb in soil
- Pb, Cd, Cu, Cr, B found in plant tissue, roots, and grain of rice
- **Remediation**: Vetiver Grass: Pb (60%), Cd (42%)
  - Zeolite (500 kg/ha): increased rice yield, reduced Pb, Cd (50%)
  - Water Hyacinth (Eichornia crassipes): Pb and Cd uptake

Uzbekistan Soil Quality affected by Metals and Organics

- Heavy Metals in soils near industrial cities
  - (Tashkent, Almalic, Becabad, Chirchic)
  - As, Zn at 10 and 6 times standard in Samarkand Region
- Organic chemicals
  - Local soil pollution of pesticide at pesticide depots
  - DDT prohibited since 1983
  - HCCH (Hexachlorocyclohexane) less than DDT

Baltic Soil Survey

- Belarus, Estonia, Finland, Germany, Latvia, Lithuania, Norway, Poland, Russia, and Sweden
- Agricultural soils (one site per 2500 km^2)
- Baseline values for chemical composition of agricultural soils in Northern Europe
  - Metal composition changes with area and country
  - Cannot use “global” values (average world-wide)
  - No major build-up of heavy metals observed
  - One element showing major build-up is Phosphorus (P)
  - Local but widespread sources (traffic or agriculture) may have more important impact than industrial emissions

France Soil Quality and Industry

- Metallurgical Plants in two towns (Auby and Noyelles-Godault):
  - Pb and Zn producing plants
  - Croplands within a radius of 4 km
- Results:
  - Wheat grains and lettuce leaves (50% of cases) were higher than standards set for humans
  - >66% of grass samples were too high for animal consumption

Malaysia and Thailand Soil Quality Australian Center for International Agricultural Research

- Problem: Residues in traded food commodities have resulted in banning food
- Research:
  - Characterize extent of inorganic chemicals in soils and crops
  - Monitor pollutants in soils and crops
  - Key elements: As, B, Cd, Cu, Cr, F, Hg, Pb, Zn
  - Contamination of soil by agriculture and industry
  - Relate soil to crop concentrations of metals

Hungary Soil Management

- 85% area is arable and suitable for farming or forestry (low metals, organics, nutrients)
- Several items of legislation
  - Ministry of Agriculture set up the Information & **Monitoring** System on Soil Protection (1992)
    - Organics: chlorinated pesticides, PCBs, dioxins
    - Metals: Cd, Zn, Hg, Pb, Cu, Cr (As sometimes too high)
    - Decrees (6/2001, 8/2001, and 50/2003) regulate useage of pesticides, fertilizers, and soil enhancers.

Beneficial Reuse and Sustainability: Organic Compounds in Land Applied Wastes in the U.S.A.

M.R. Overcash, R.C. Sims, J.L. Sims, K.C. Nieman, Jour. Env. Quality, Jan-Feb 2005

* Biodegradation
* Bound Residue Formation
* Leaching
* Crop Uptake
* Runoff

Beneficial Reuse and Sustainability: Organic Compounds in Land Applied Wastes in the U.S.A.

- Mathematical models of crop uptake

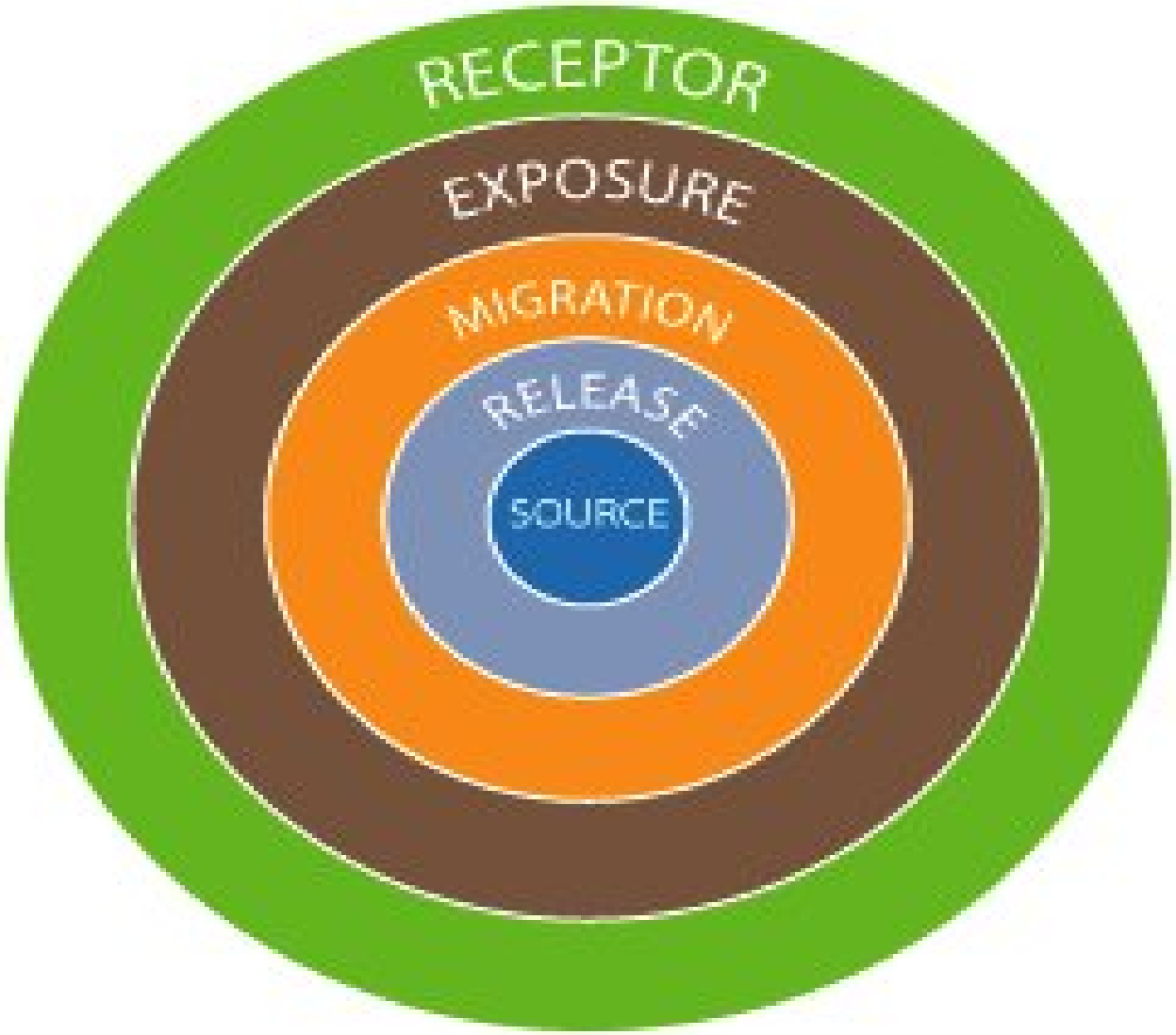
  Utilized on a limited basis

  – Minimal field-based behavior and performance validation.

  – Small amount of integrated mathematical modeling and experimental result

  – Connect models with full-scale performance and monitoring

Source ⟶ Crop/Soil Receptor



Management of Agroecosystems for Persistent Pollutants

- Levels Eco- Bio- Risk Soil Quality Criteria

toxicity avail(access)ability

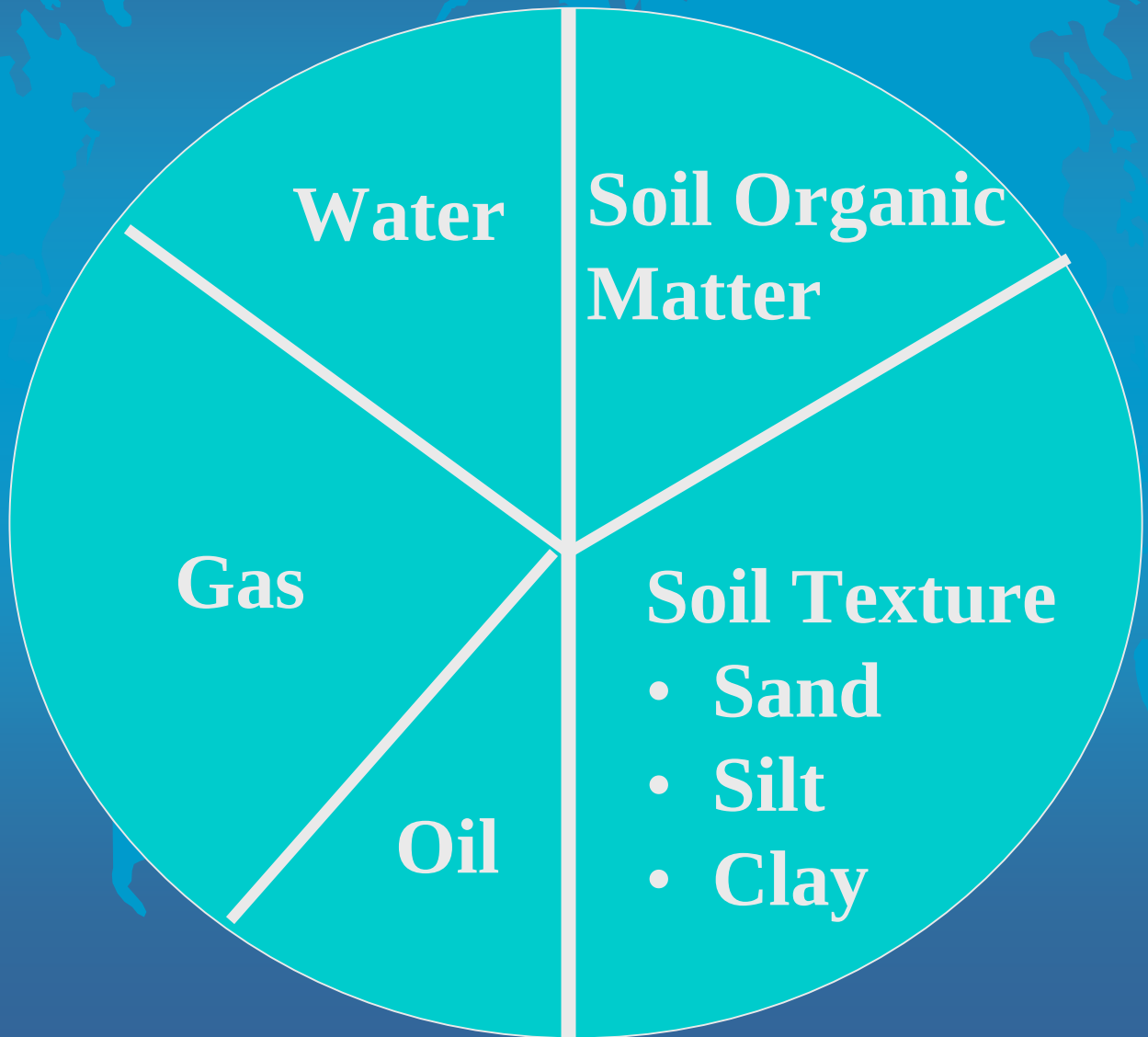
Site - Soil Assimilative Capacity (SSAC)

CROP SAFE CONCENTRATION (CSC) and Environmental Sustainability

Chemicals affect Agricultural Soils

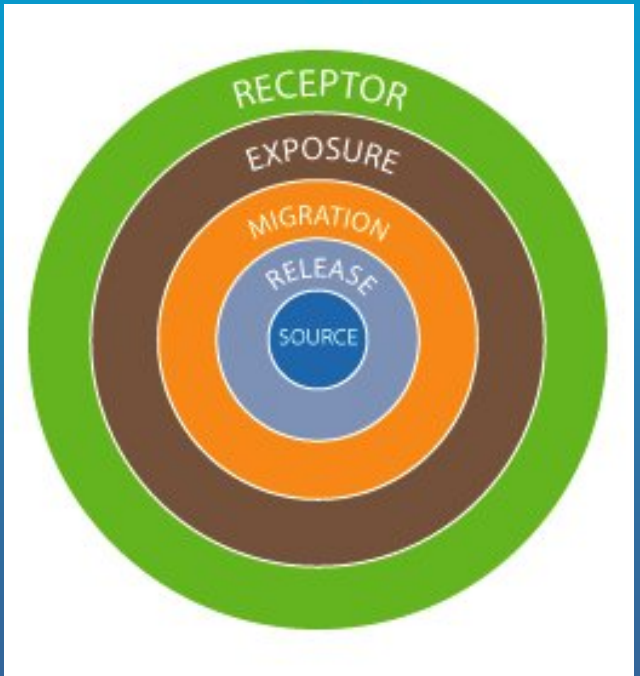
- **Heavy Metals**
  - Irrigation water - Atmospheric Fallout
  - Landfill leachate - Sewage sludge
- **Organic Chemicals**
  - PAHs, PCP, PCBs
- **Pesticides**
  - 85% applied in soil (major), water, or air
- **Fertilizers (Phosphorus, Nitrogen)**
  - Overuse
- **Soil Erosion** - globally most important

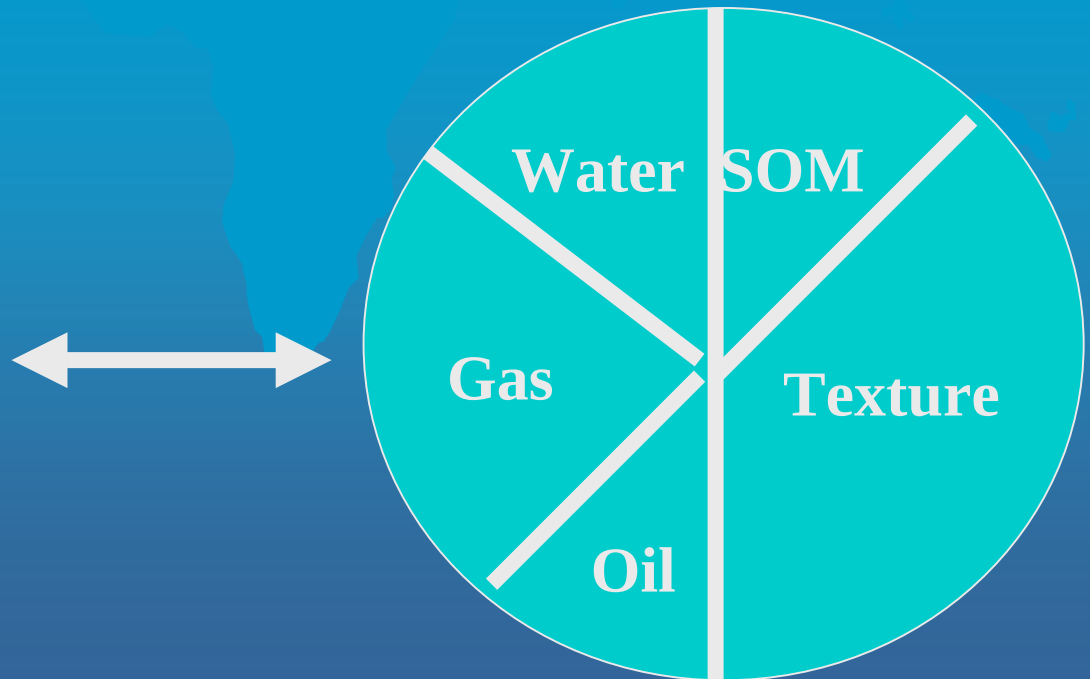
Soil Quality Components Affect Biological Response (Crops)



Agroecosystems Base for Food Production

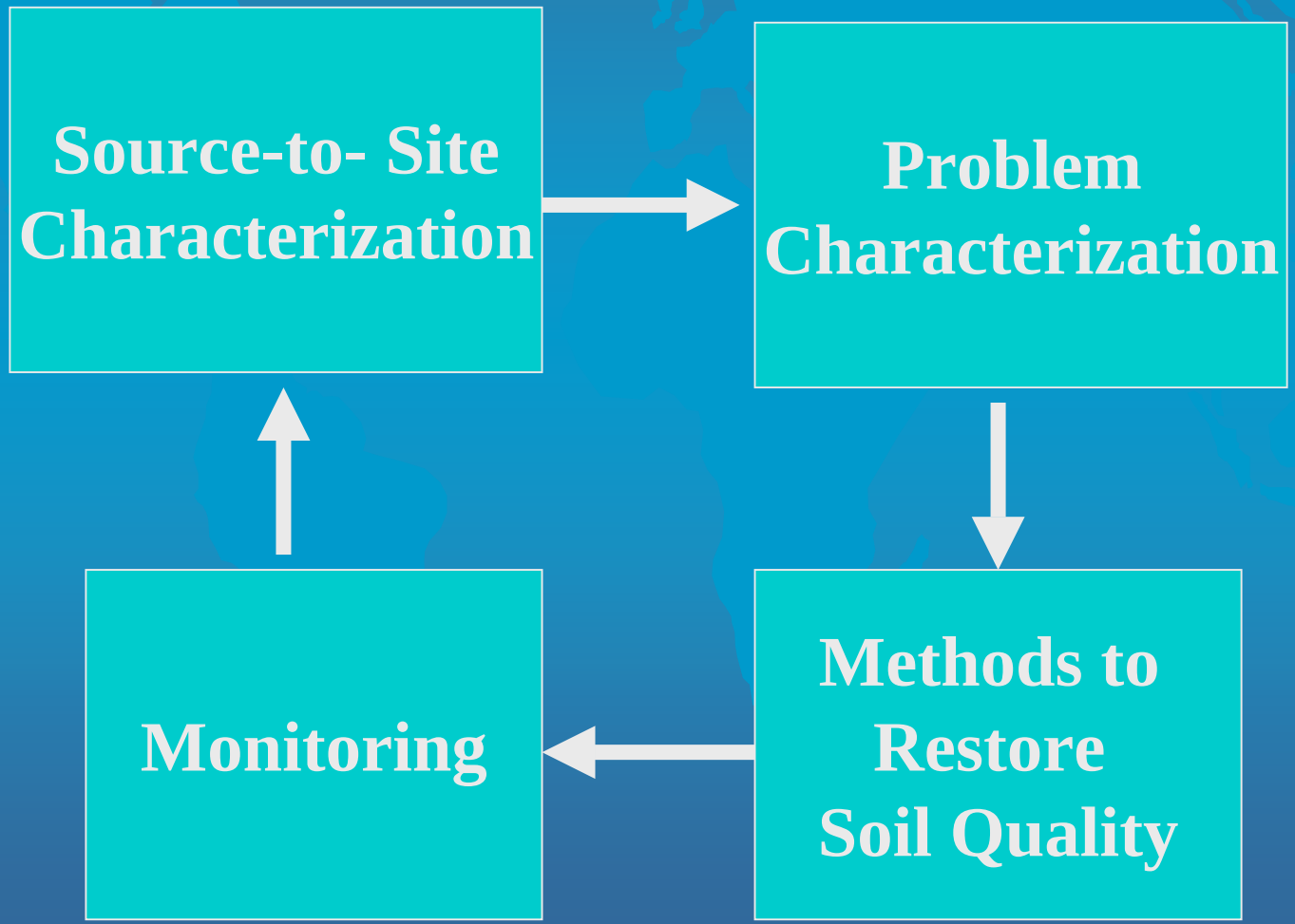
- Management Strategies
  - Source Control/Elimination
  - Soil Treatment
  - Monitoring





Management Strategy (4 Steps)

- Methodology



Source & Site Characterization

- **Sources of Pollutants to Agricultural Soil & Crops**
  - Air/ Atmosphere
    - Chemical Source (Industry, Agriculture, Nature)
    - Meteorological
    - Air Pollution
  - Water
    - Ground Water
    - Surface Water
    - Precipitation
  - Solids
    - Sewage sludge (Biosolids)
    - Animal Manures * Industrial Residues

Source-to- Site Characterization

Source-to-Site Characterization

- **Site Characterization (Crop-Soil System)**
  - **Chemicals (Pollutants)**
  - Soil Structure and Texture
  - Depth to Ground Water
  - Aeration and Moisture Control
  - Fertility
  - Pest & Weed Management
  - Site as “Receiver System” from the Source

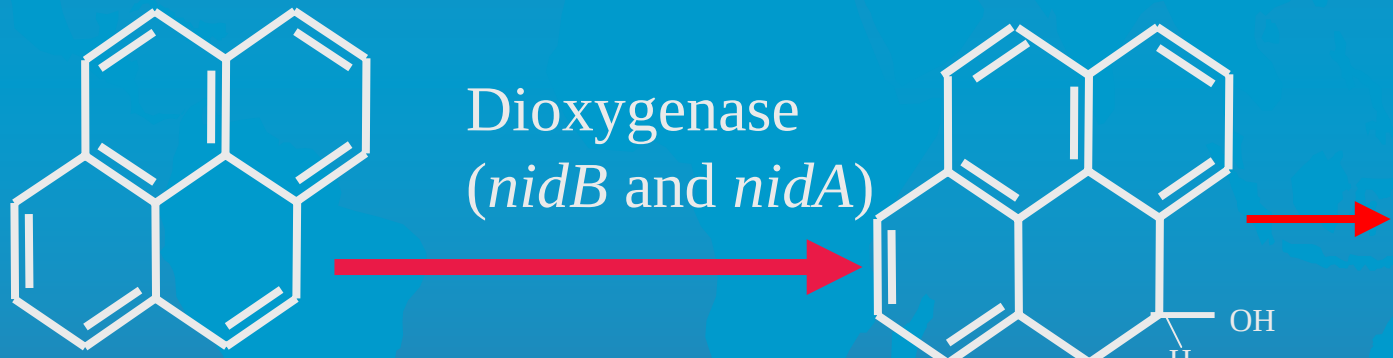
Source-to-Site Characterization

- **Levels or Concs.**
- **Ecotoxicity**

Site Characterization

- **Genetic Probes**
  - Evaluate presence of competent microbes
  - PAHs
  - Journal of Biodegradation, 16(5): 475-484,2005
    - Development of a Catabolically Significant Genetic Probe for PAH-Degrading Mycobacteria in Soil
    - Hall, Miller, Sorensen, Anderson, & Sims

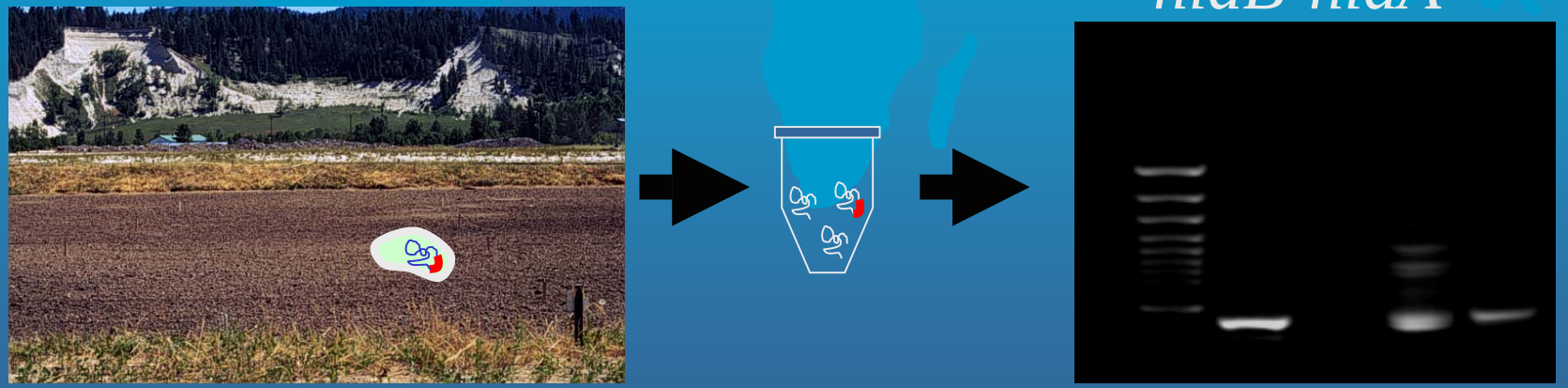
Dioxygenase: First Step in Pyrene Degradative Pathway by Mycobacteria



Pyrene

Pyrene cis-4,5-Dihydrodiol

Environmental Gene Probe



Problem Characterization

- Persistence/ Accumulation
- Crop Uptake
- Mobility (to water)
- Aerial Deposition
- Erosion

Problem Characterization

- **Bioavailability**
- **Risk Assessment**
- **Soil Quality Criteria**

Soil Treatment Alternatives

- Degradation/ Transformation
- Immobilization/ Unavailable
- Extraction/Removal
- Stabilization (of erosion)

Methods to Restore Soil Quality

- Soil Treatments
- Source-to-Receptor Change

Soil Treatment Alternatives

- **Phytoremediation**
  - Inoculate seeds of plants with microbes for soil remediation
  - Example: Mycobacteria on plant seeds for dispersion of bacteria through soil and remediation of hydrophobic chemicals that have low water solubility
  - National Science Foundation Grant(U.S.A.) to Utah State University

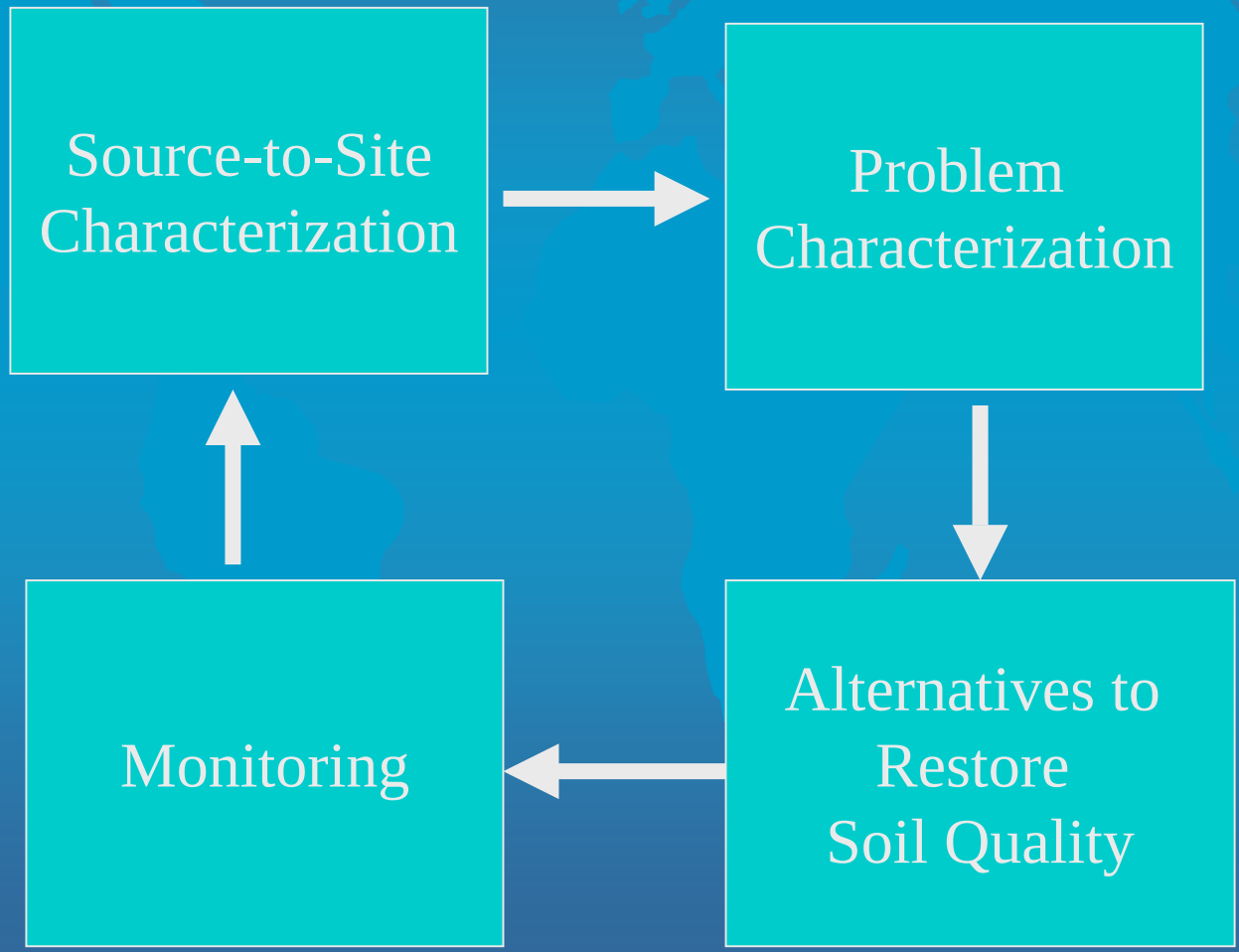
Monitoring is Critical

- Sources
- Site - include **crop** and **soil**
- Treatment(s)

Monitoring

Management Strategies

- Methodology



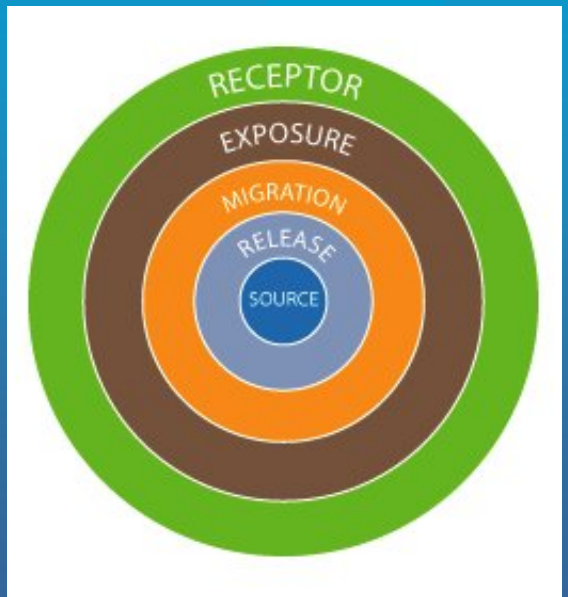
Management of Agroecosystems for Persistent Pollutants-Summary

Source-to-Site Characterization

Problem Characterization

Monitoring

Alternatives to Restore Soil Quality

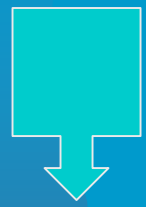


CROPS

Management of Agroecosystems for Persistent Pollutants

- Source Treatment Monitoring Risk Assessment

Site - Soil Assimilative Capacity (SSAC)



CROP SAFE CONCENTRATION (CSC) and Environmental Sustainability