



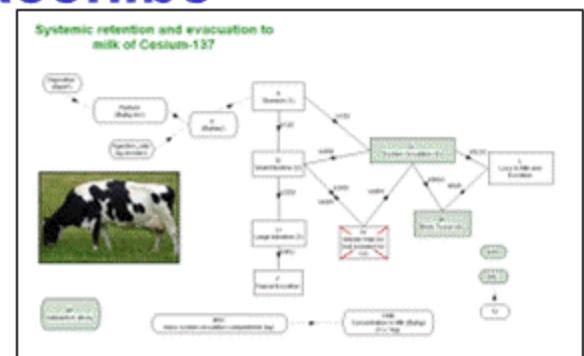
STUDIECENTRUM VOOR KERNENERGIE  
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE



# Biosphere Impact Studies

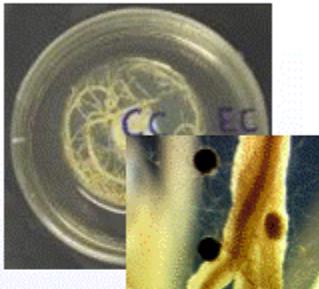
## Belgian Nuclear Research Centre

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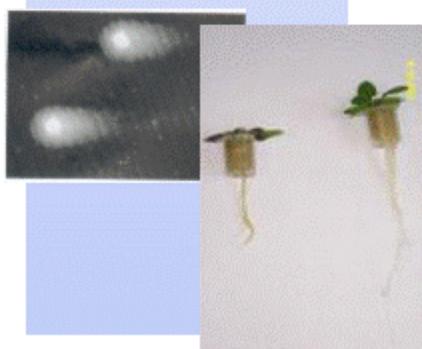


## Biosphere Impact Studies

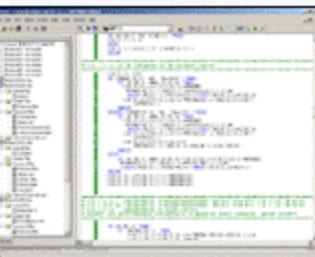
### 4 major interacting R&D domains



- Understanding behaviour of radionuclides in the biosphere
- Develop a groundwater-soil-vegetation interaction model to assess the long-term impact of perennial vegetation systems on dispersion of radionuclides
- Study biological effects induced in plants following radiation, radionuclide uptake and mixed contaminant exposure
- Develop, improve and apply models for assessing the radiological impact to man and environment



## 4 cornerstone activities



- Experimental studies
- Model development and modelling
- Database establishment
- Consultation, expertise

# Theme 1

## Process understanding of the behaviour of radionuclides in the biosphere

- Understanding the environmental processes governing radionuclide mobility and bio-availability in order to come to a better predictability of the transfer and resulting radiation exposure for man and environment

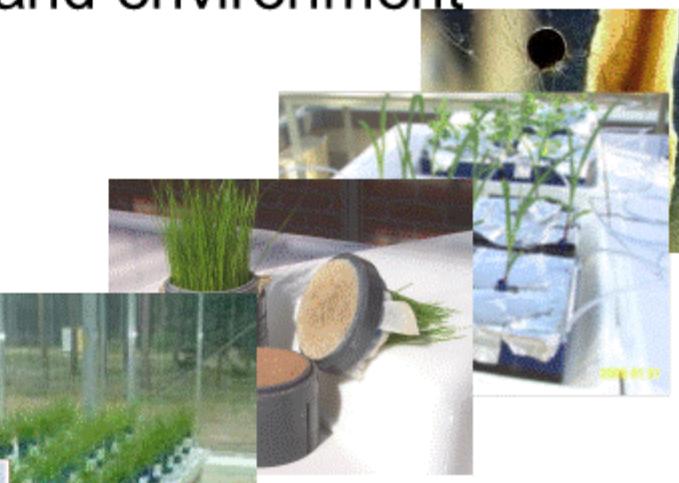
Accidents & routine releases: Cs, Sr, Co, Am



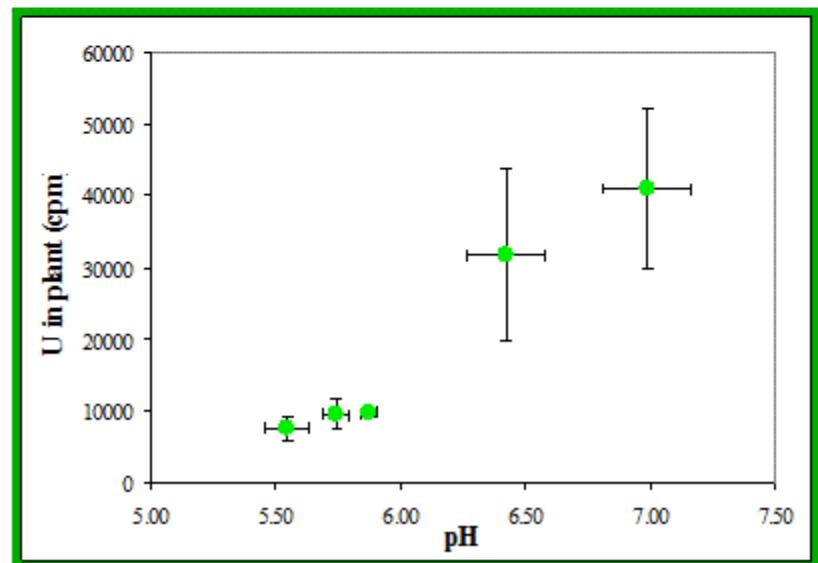
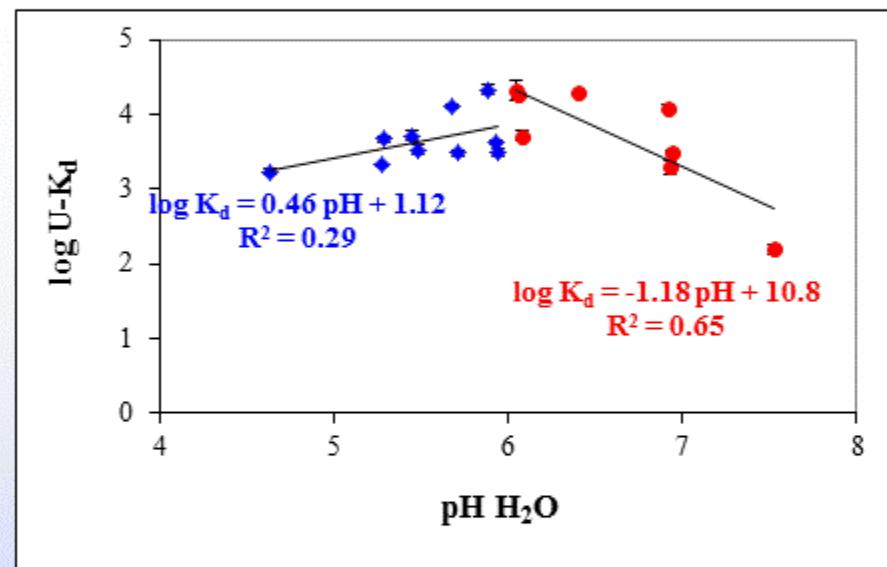
Natural Radionuclides: U, Ra, Th, Po



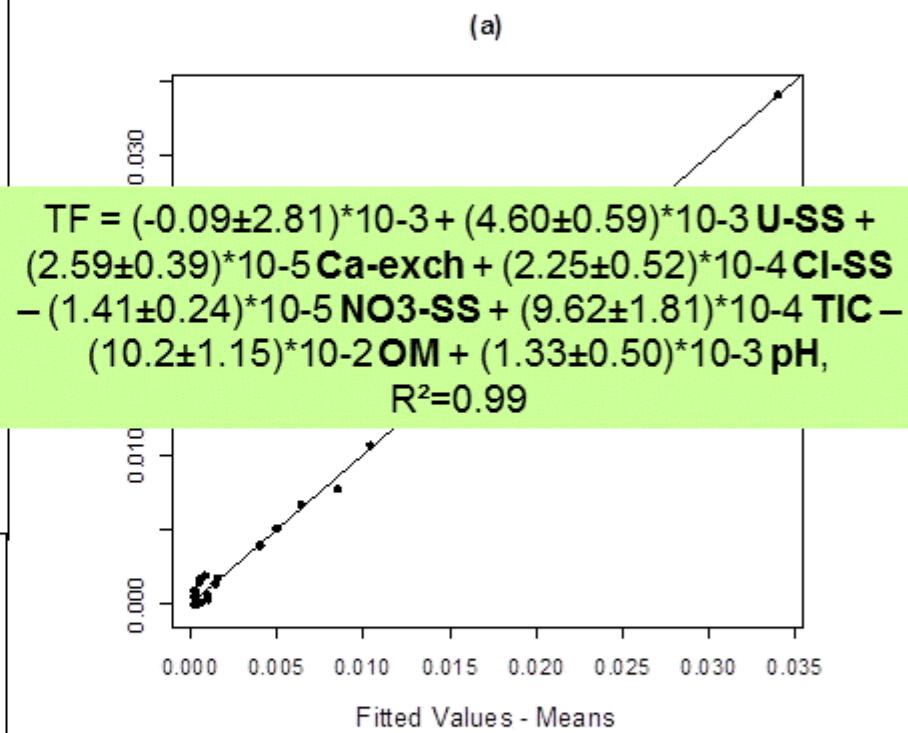
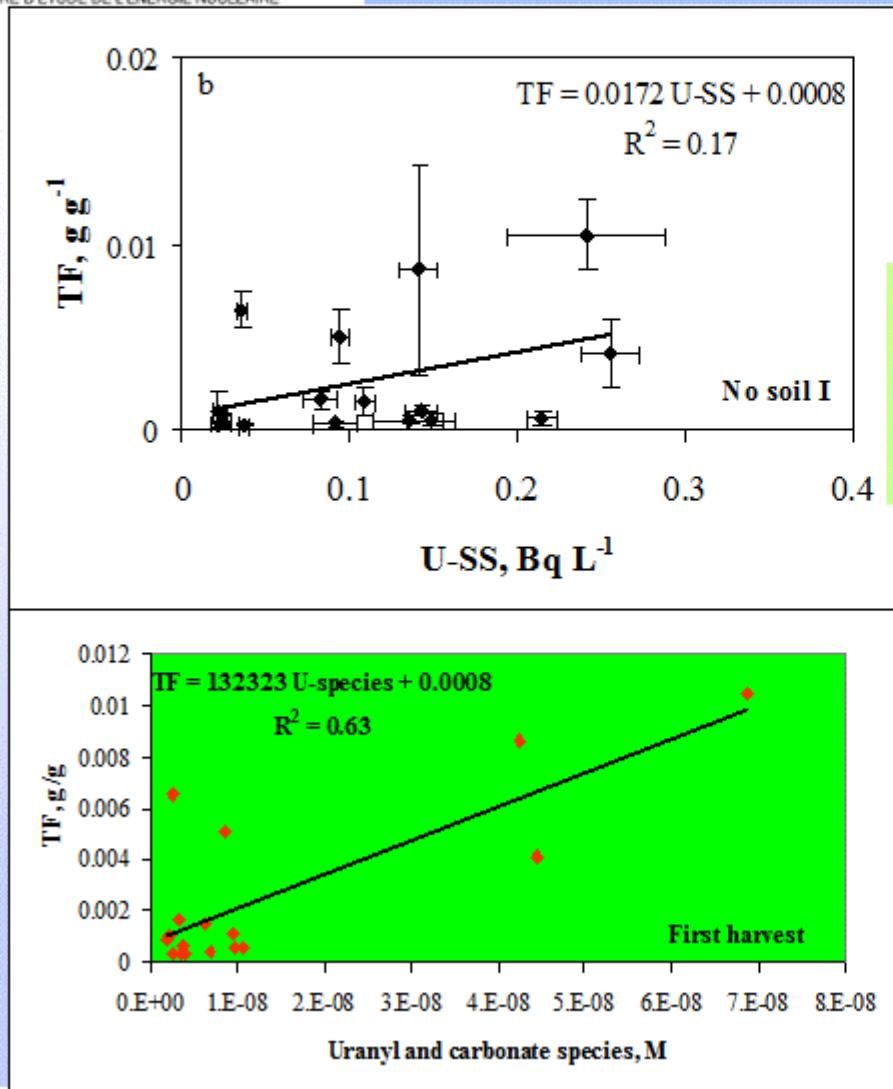
Critical RNs waste disposal: Tc, Se



## Some examples of influencing soil parameters on mobility and bioavailability

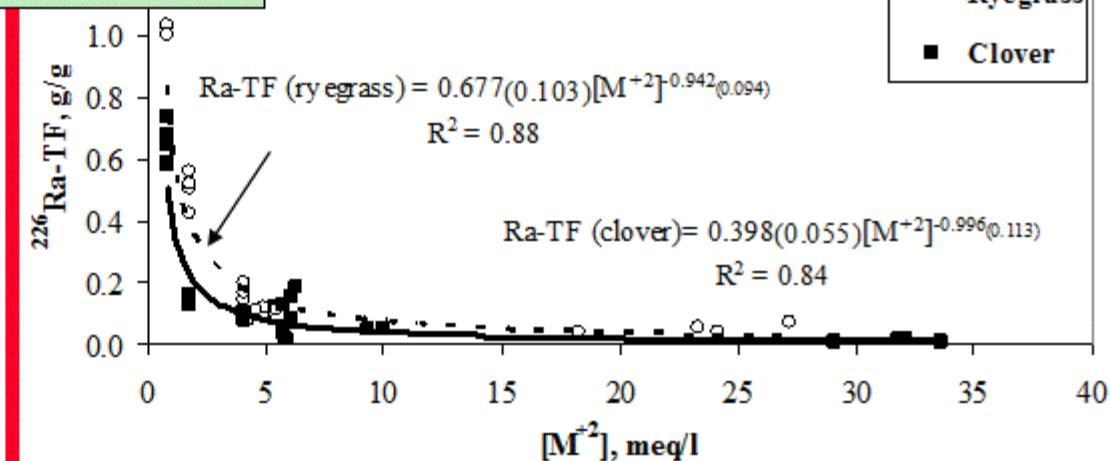
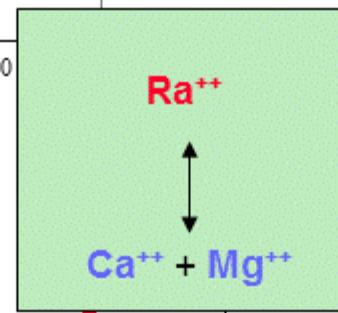
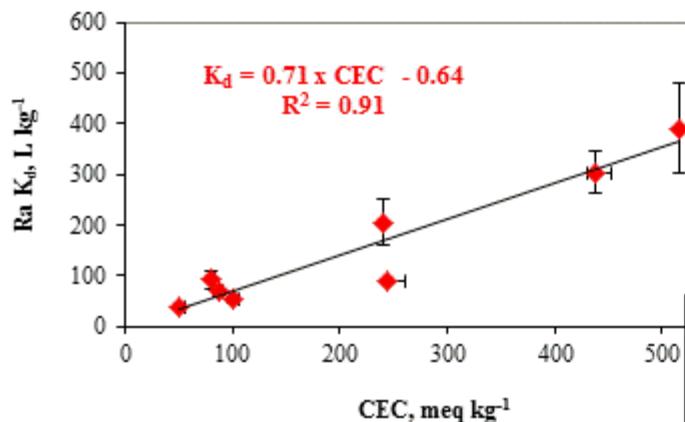


# Predicting U-uptake

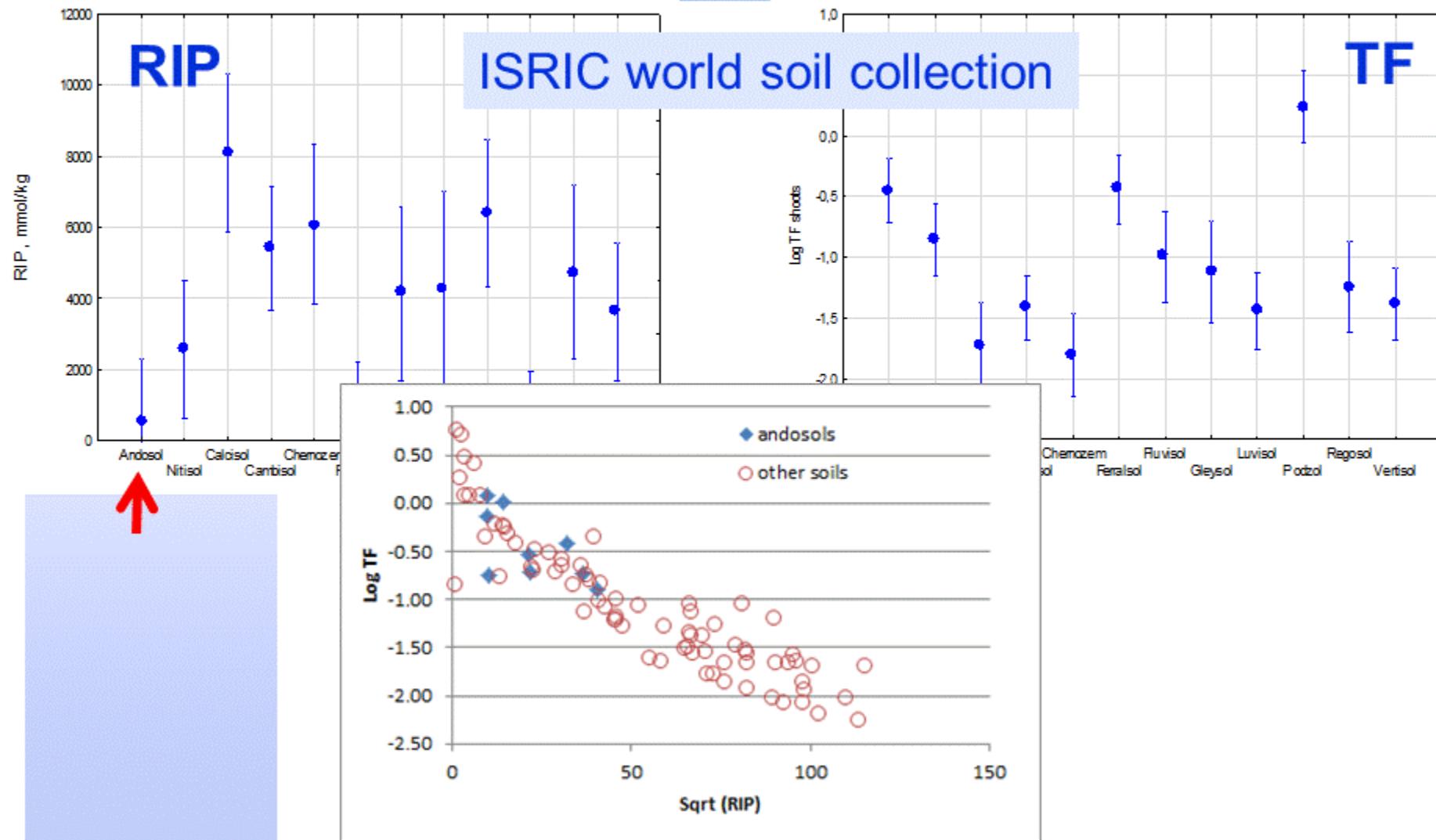


# Some examples of influencing soil parameters on Ra mobility and bioavailability

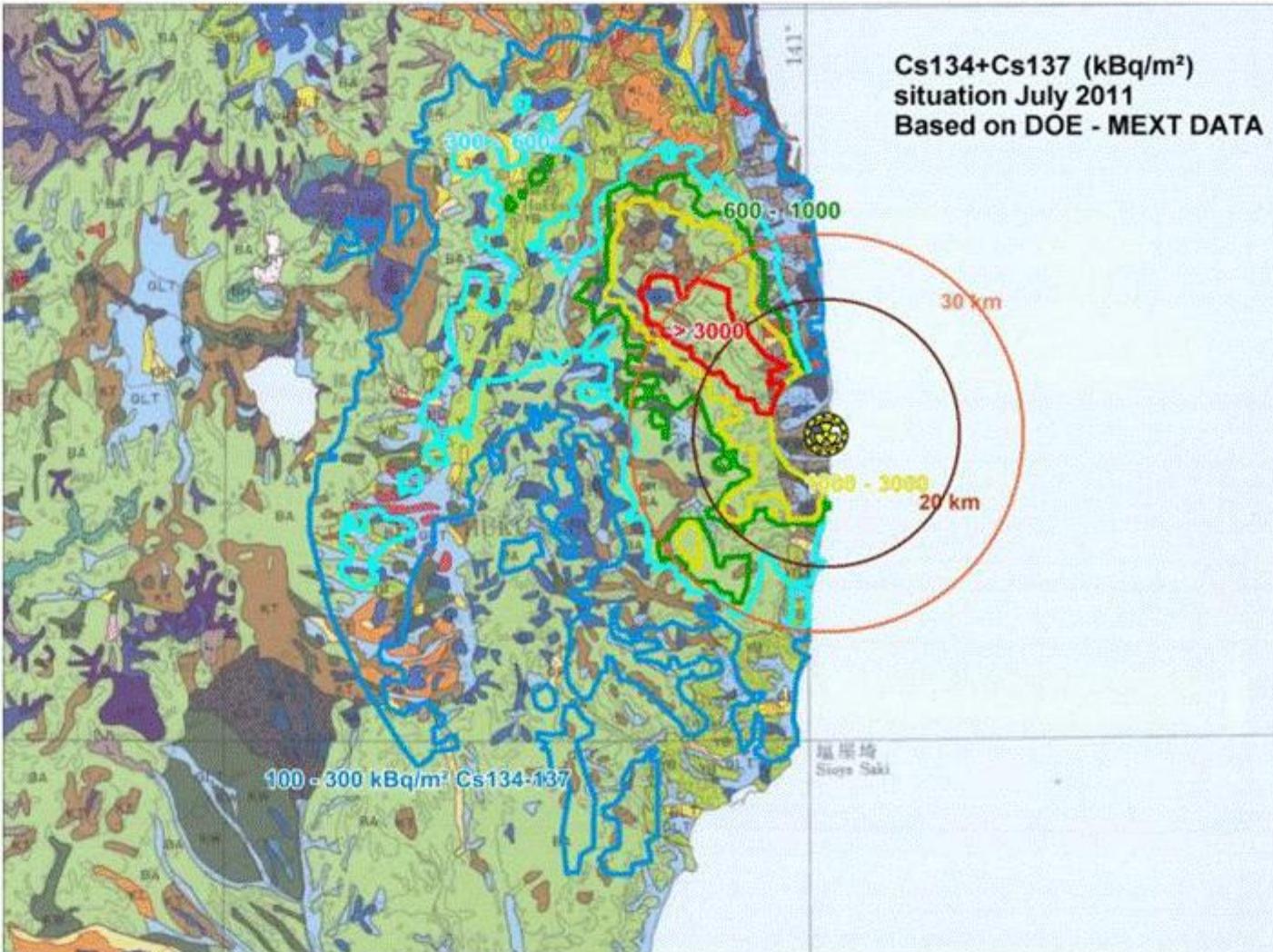
Vandenbroue et al., Chemosphere, 2007



# Andosols relatively low RIP and high TF



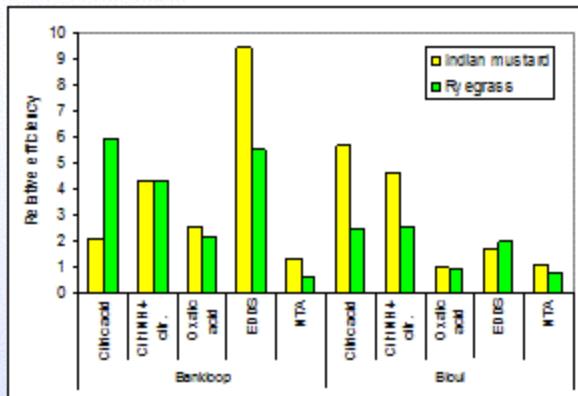
# Fukushima deposition and soil map



# Contaminated land management

- Phytomanagement

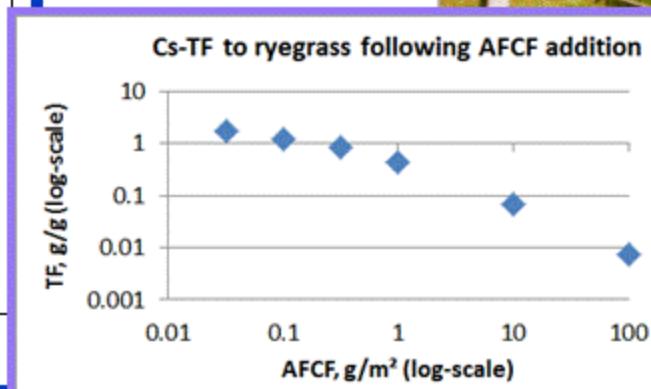
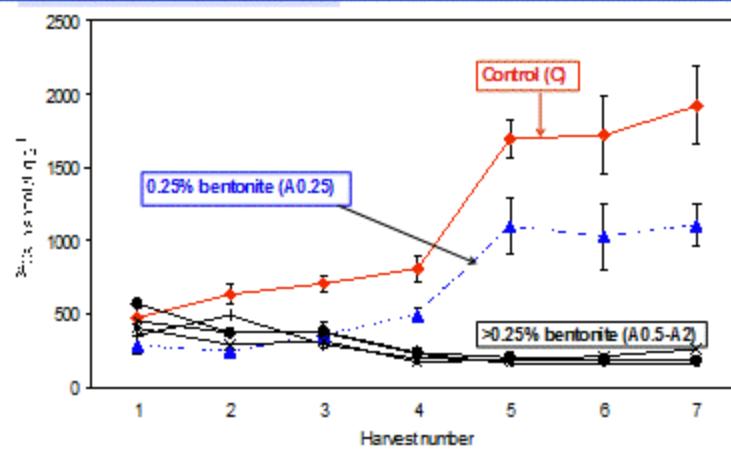
- Enhanced phytoextraction

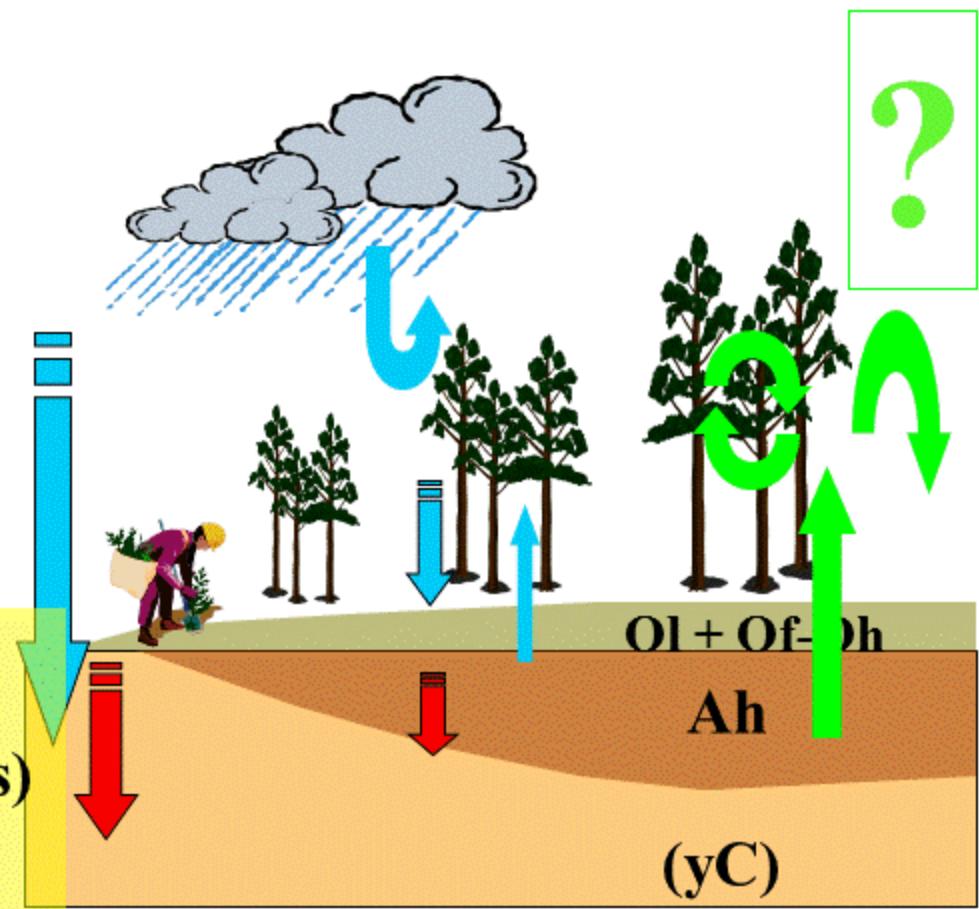


- Alternative landuse



- Amendments to decrease mobility and uptake





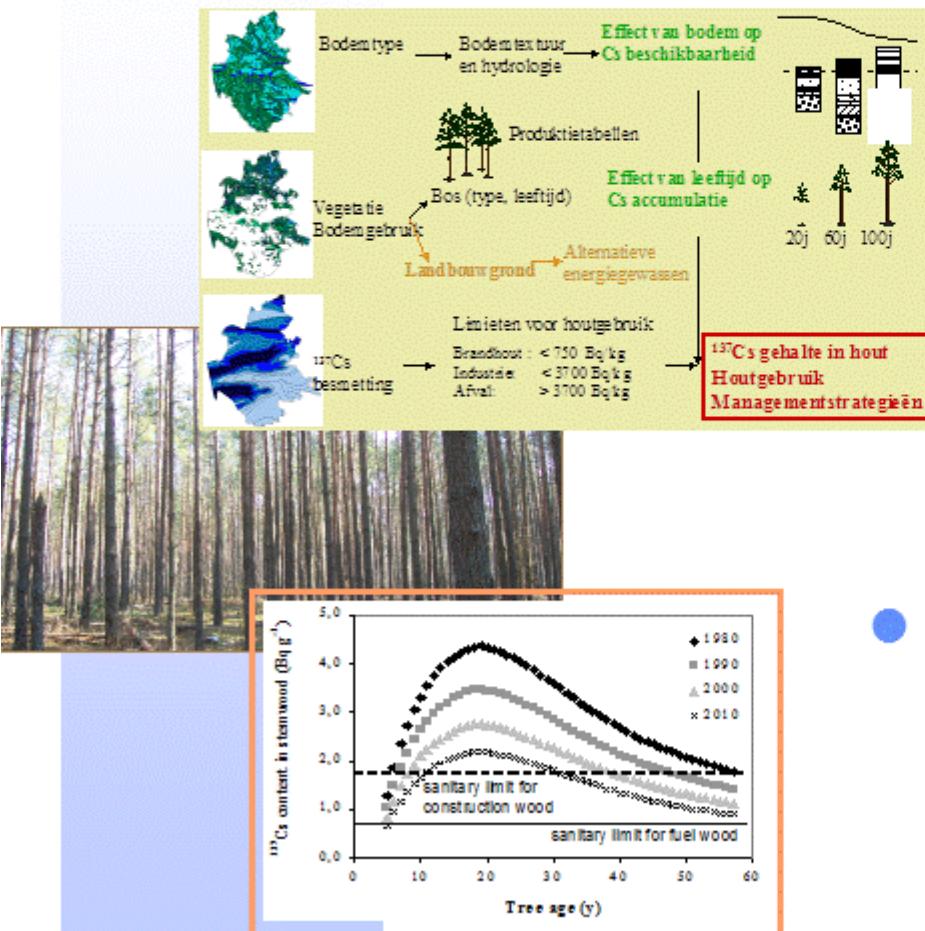
**RN inventory and distribution**

**Dynamics of RN cycling (fluxes)**

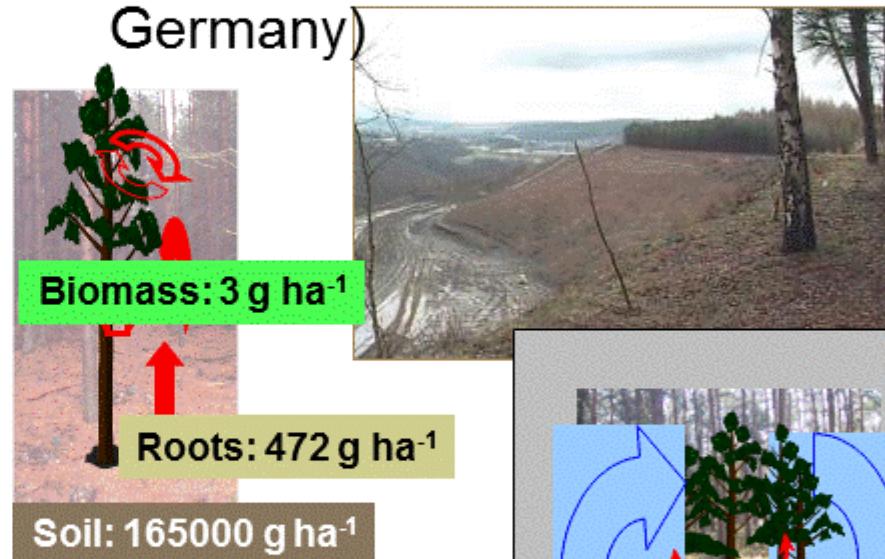
**Effect on/of water budget/flux**

# Biogeochemical cycling of radionuclides in relation to management of contaminated sites and waste disposal

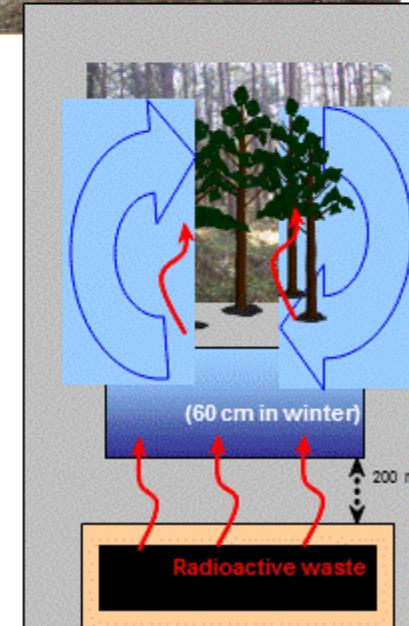
- Processes and dynamics of  $^{137}\text{Cs}$  cycling in forest of Belarus



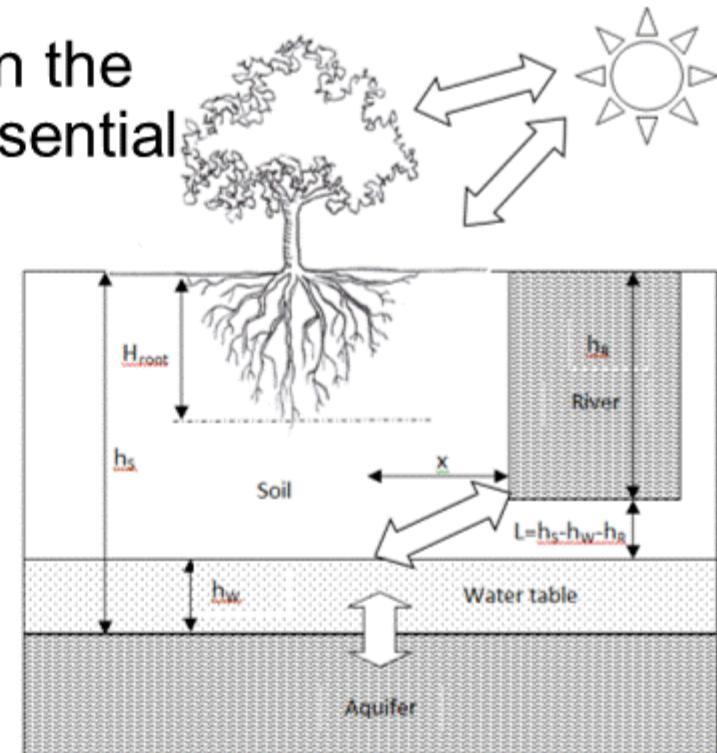
- Impact of (re)vegetation on RN recycling at U-mining site (SE Germany)



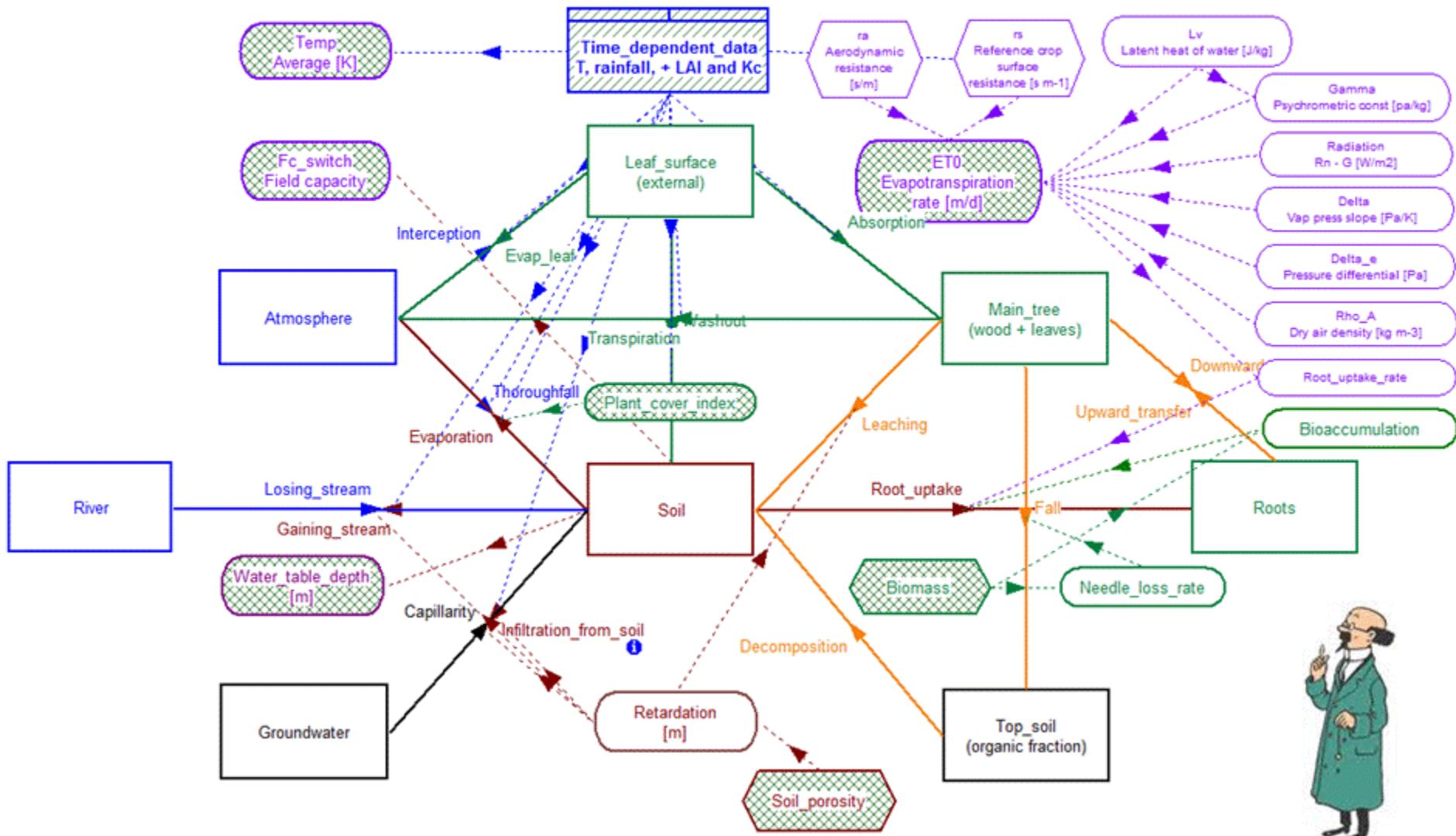
- Biomass, water and element cycling in forest area affected by a shallow water table



- Couple Cl in forest model with a water table model
- Consider explicitly the link between the environment and the plant i.e. root uptake and evapotranspiration
- Explore element cycling depending on the element chemistry or analogy with essential elements



# Model construction



## Key processes included

At groundwater level:

- Infiltration (field capacity, retardation) and land runoff
- Variable water table height
- Losing / gaining stream (hydraulic conductivity)
- Capillary rise from aquifer

At plant level:

- Variable biomass depending on water table height
- Interception, absorption and washout
- Root uptake rate (macroscopic linear root-water model)
- Loss of foliage

Evapotranspiration:

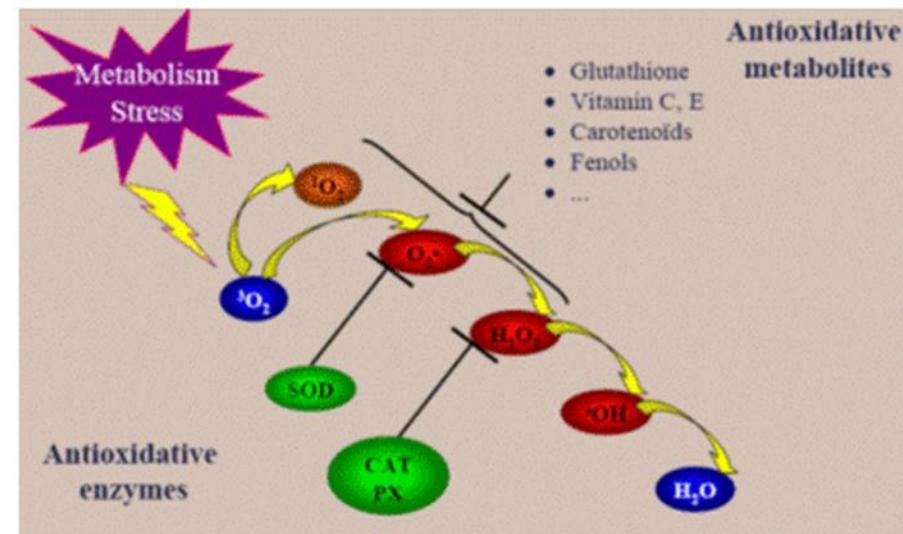
- Net solar radiation
- Stomatal and aerodynamic resistances
- Vapour pressure and heat capacity
- Psychrometric constant
- Decoupling of evaporation and transpiration (Beer's law)

## Effects induced in plants following exposure to radiation, radionuclides and mixed contaminants

- Environmental impact assessment context
  - ICRP-Paradigm “if man is protected, then environment is protected” contested
  - Framework for environmental protection in development
  - Legislation forthcoming
- Lack of quality data and understanding mechanisms
- Lack of chronic effects and multiple stressor studies
  - Need for these studies for justified setting of standards

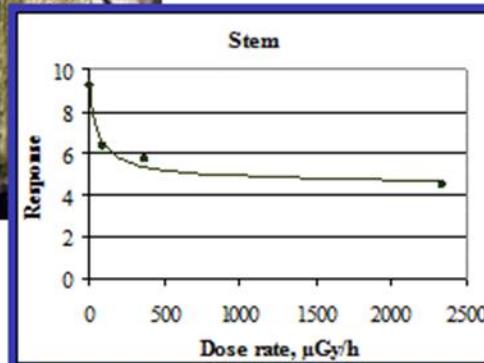
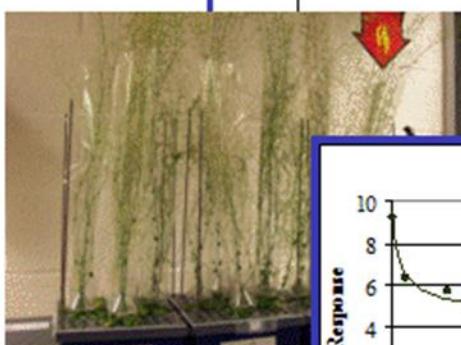
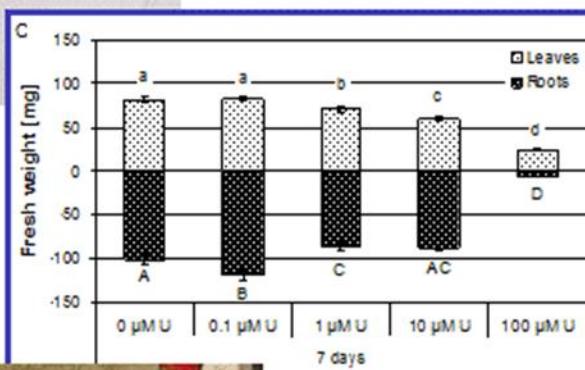
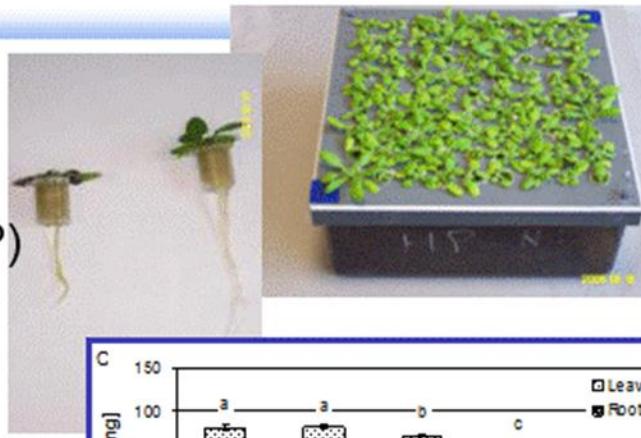


- Biological effects induced in plants by radiation and/or radionuclide uptake
  - Analyse biological effects applying a multi-biomarkers approach (oxidative defence/signaling, DNA damage, DNA repair) viewed as early responses for individual disturbances (growth, reproduction)
  - Advanced molecular and genetic techniques
    - Metabolomics, transcriptomics



## Exposure conditions evaluated

- Exposure of *A. thaliana* to
  - U, gamma, U+Cd, U+gamma
  - Alfa-bèta-gamma (~ liquid discharges of NPP)
  - U-Th-Cd (~ discharges from U-mining areas)
  - (gamma-neutrons → space conditions)
  - Effect of environmental conditions
- Similar exposure planned with Lemna

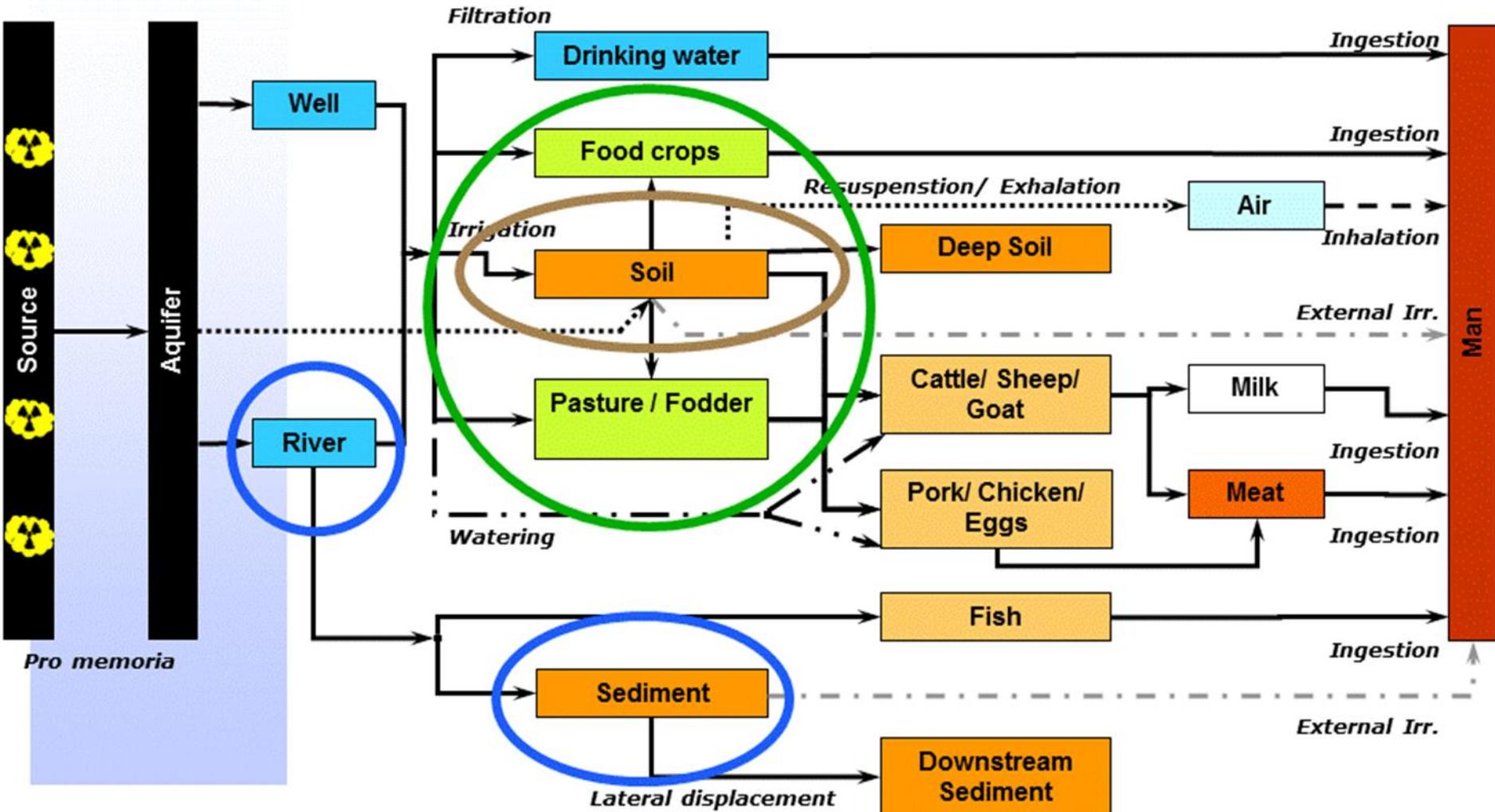


## Environmental impact assessment Tool development/studies

- Evaluate effect of radiological liquid and atmospheric discharges from Belgian NPP on environment
- Project: Strategic Environmental Assessment for High Level Waste Disposal - Effects on Environment
- ERA for low-level waste
- ERA for MYRRHA reactor, for BP (waste treatment facility)



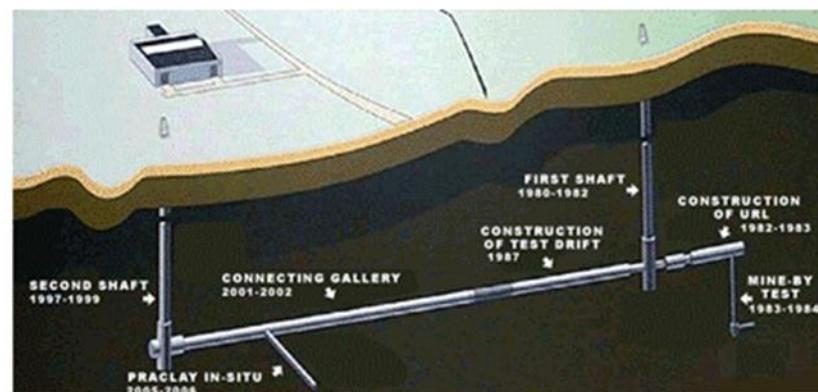
# Develop and improve models for assessing radiological impact to man & environment



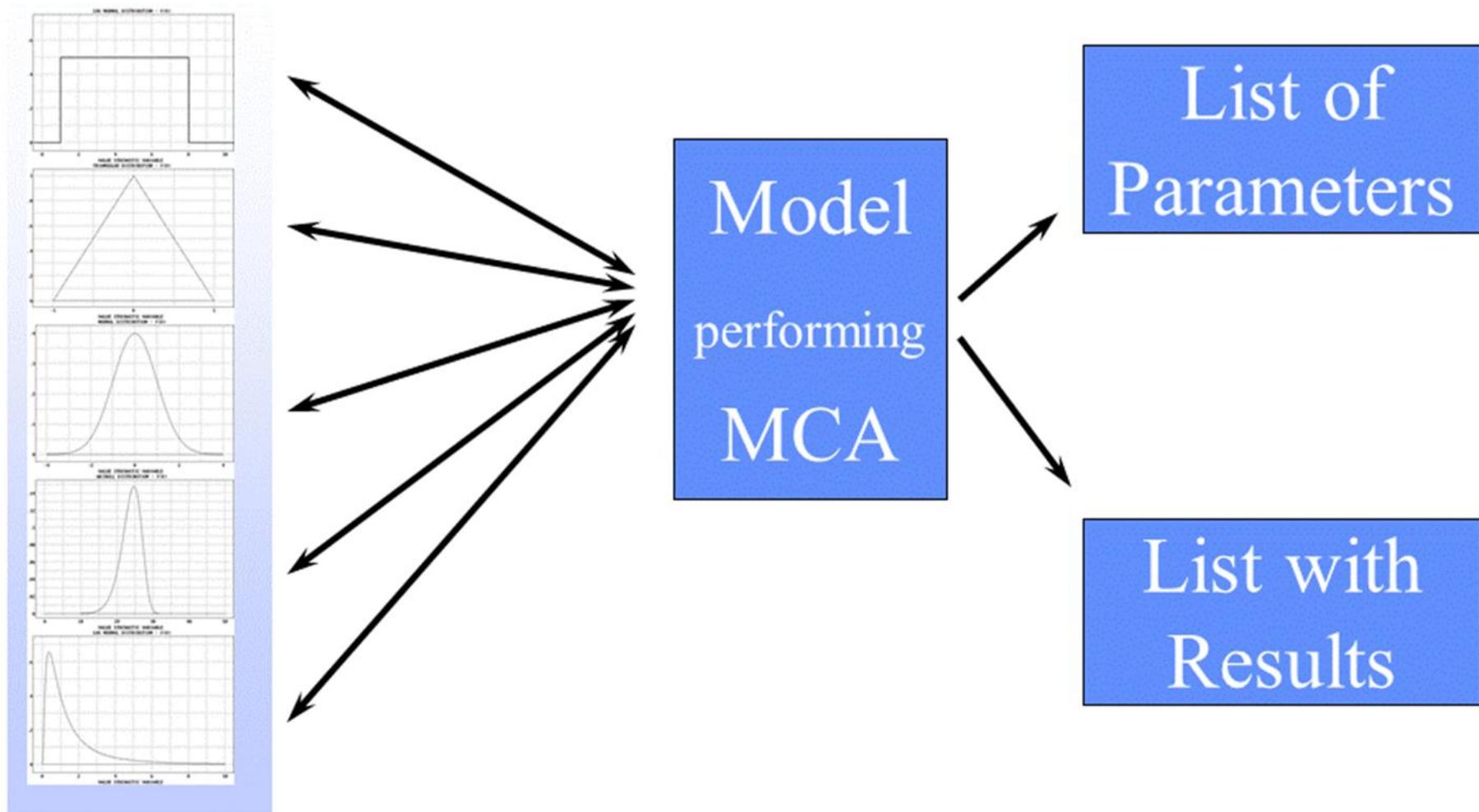
- A compartmental, mainly equilibrium model (decay and leaching rate are considered)
- Semi-empirical approach (aggregated transfer factors are used)
- Analytical equations
- Can perform deterministic and stochastic calculations (Monte Carlo)
- Can perform sensitivity analysis

## The assessment context is very important

- Assessment as realistic as possible ?
- Present day conditions ?
  - Technology, society, living habits
- Radionuclides (incl. daughters) ?
  - Cl-36, Se-79, Tc-99, I-129, Cs-135, Ra-226, Pa-231, Np-237, U-238, Pu-239, ....
- Time frame ?
  - Fixed? Time of maximum peak flux?
- Annual effective doses ?
  - Infants and adults
- Deterministic – stochastic
- ...

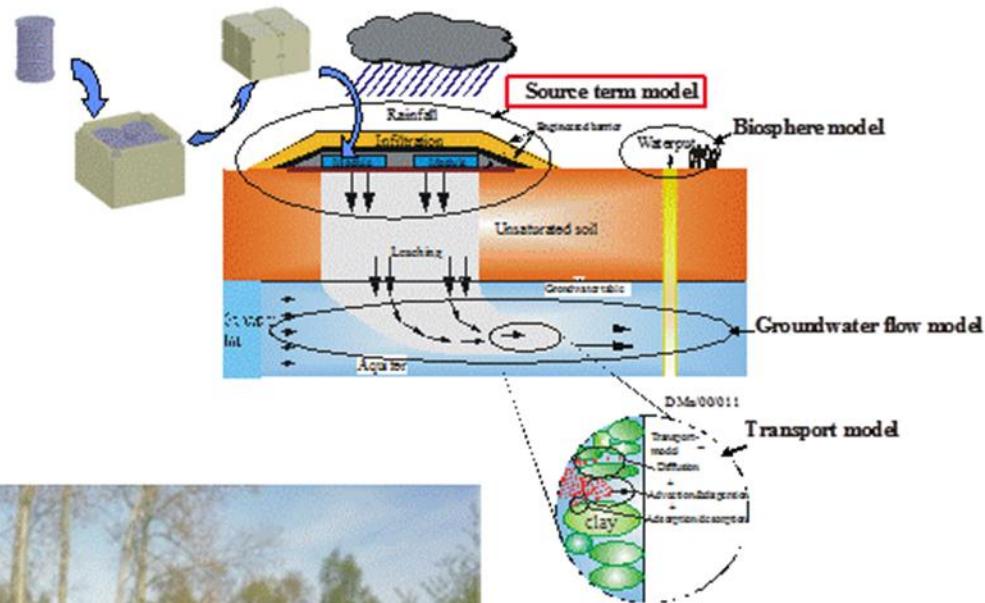
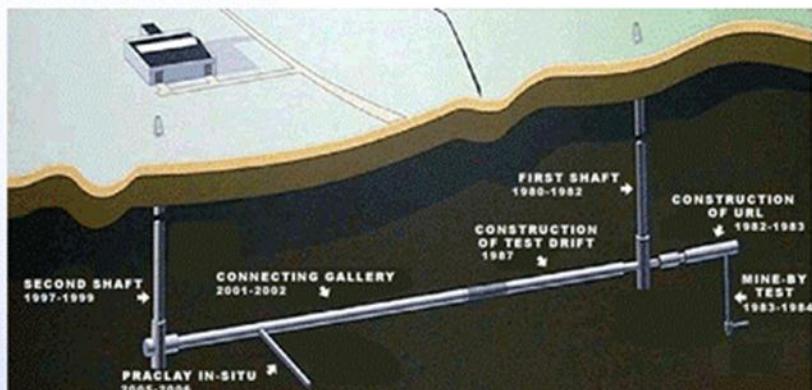


## Sensitivity and Uncertainty can be derived from Monte Carlo Analysis

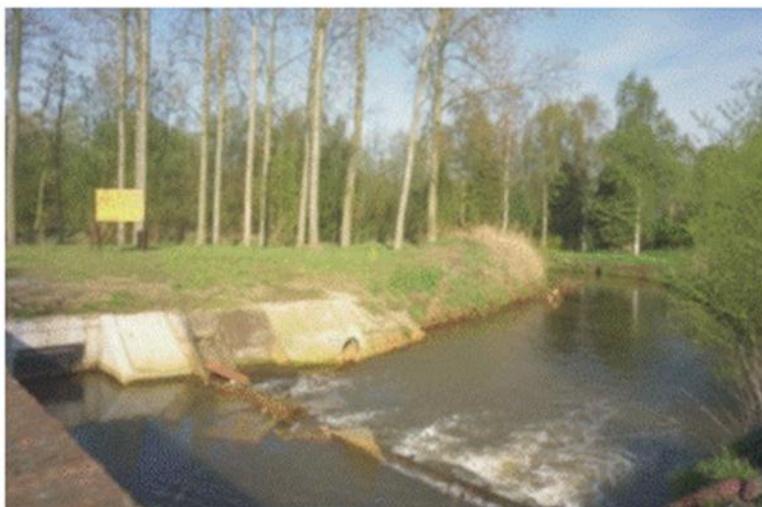


# Human impact assessment – modeling (1)

- Biosphere impact assessment for high-medium and low-level waste disposal

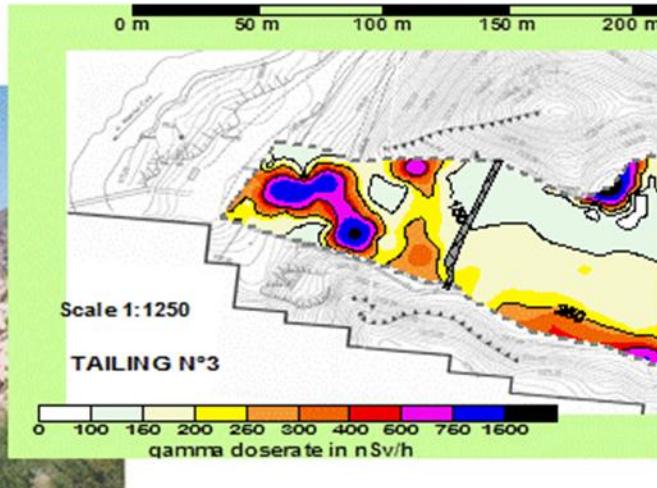


- Routine releases

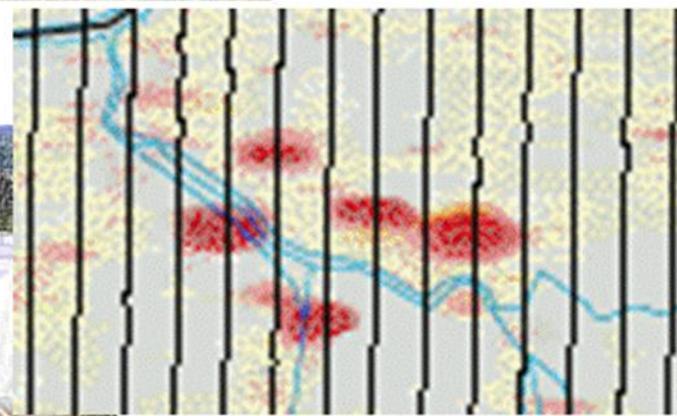


## Human impact assessment – modeling (2)

- Uranium mining and milling



- NORM industry



Rhodania (Zelzate) and Rupel area

## The group of **Biosphere Impact Studies** of SCK•CEN (Mol, Belgium), past colleagues, + PhD students

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- Miet Boonen
- Eline Saenen
- Geert Biermans
- Arne Van Hoeck
- Fabricio Fiengo Peres
- Chhavi Bhatt
- Jean Wannijn
- Robin Nauts
- Paul Bens
- Jef Sannen
- Hildegarde Vandenhove
- Yves Thiry, Caroline Vincke, François Goor, Lise Duquène, Anne Strazeck, Geert Olyslaegers, Catherine Van den Hoof



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#### **SCK•CEN**

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Centre d'Etude de l'Energie Nucléaire

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