The influence of the season on the levels of activities in crops following a short-term deposition of radionuclides to agricultural land

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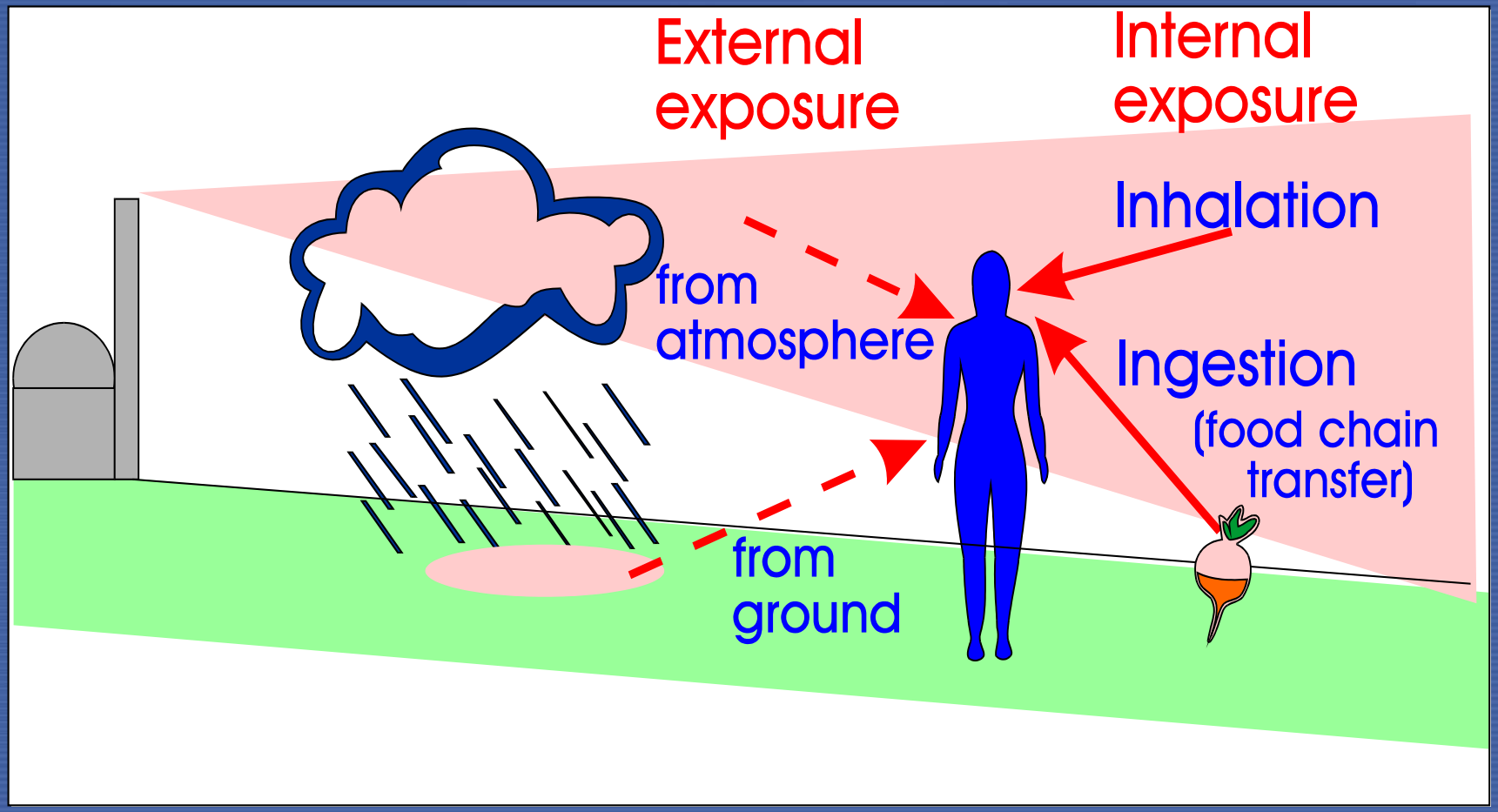
Exposure to people from releases of radionuclides to the environment



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Contamination routes for plant products

Short-term

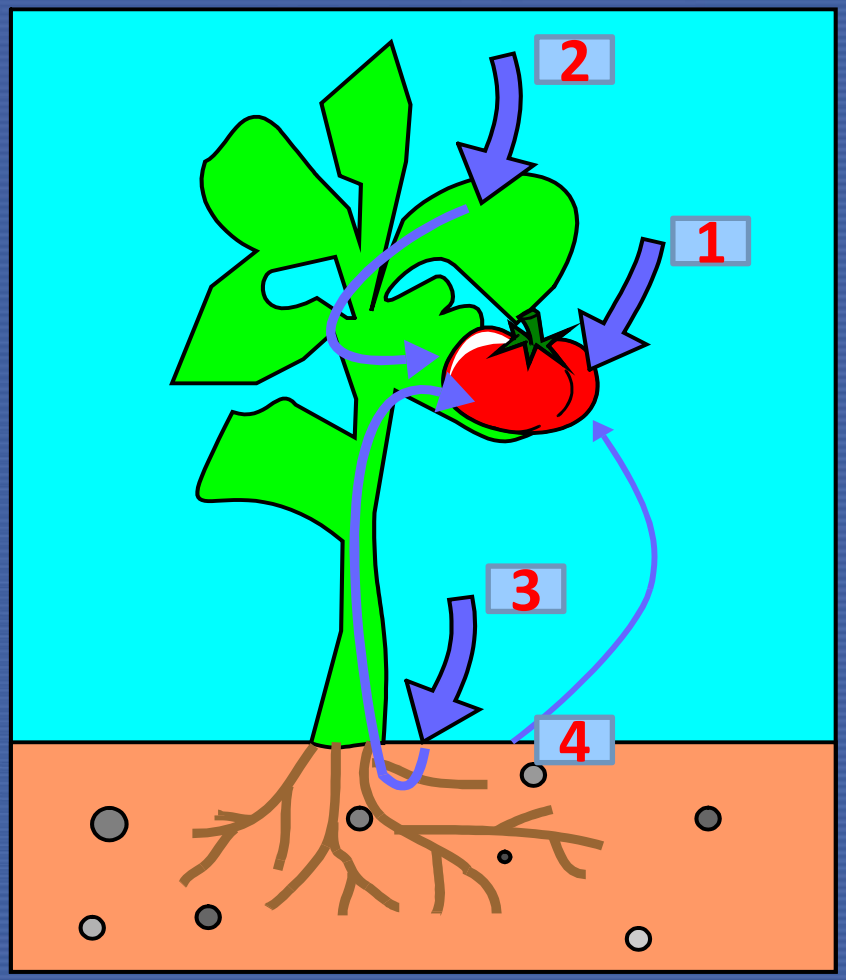
1 Direct deposition onto edible parts of plants

2 Deposition onto leaves
-> transport to the edible parts

Long-term

3 Deposition on soil and uptake through the roots

4 Resuspension of dust and re-deposition on leaves and fruits



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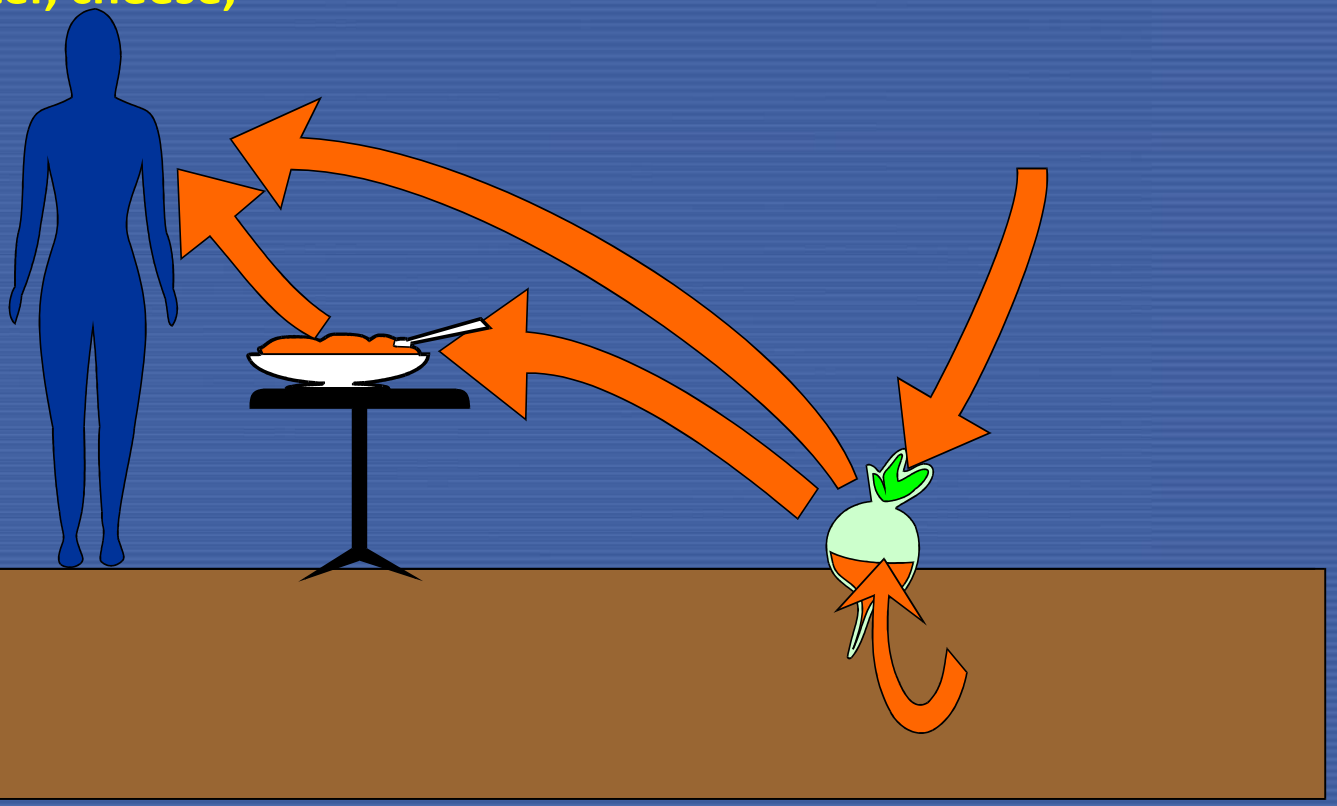
Food processing and preparation

- Crops can be directly ingested
  - leafy vegetables
- Products may be processed
  - Cereals -> bread
  - Milk -> butter, cheese,



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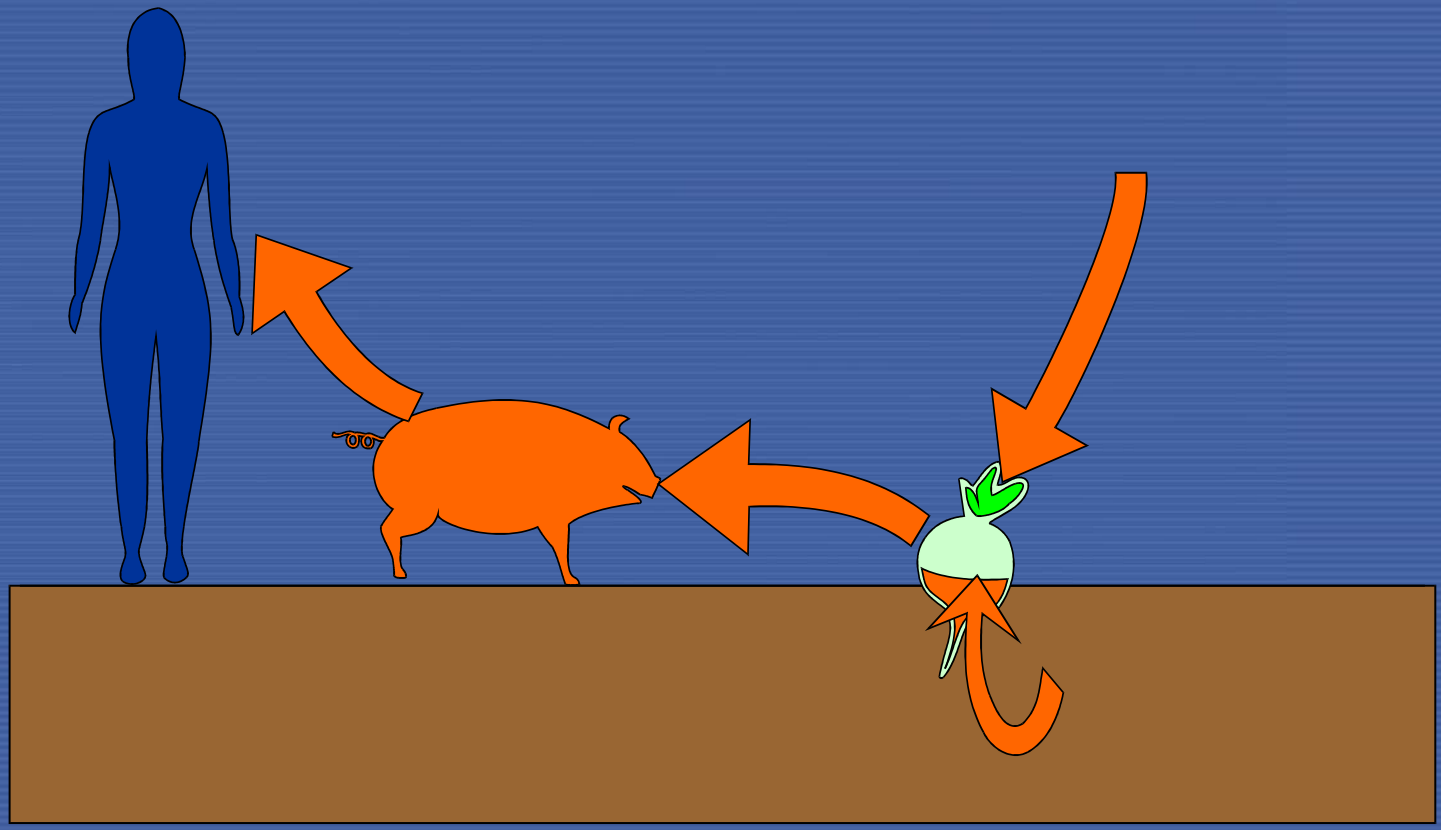
Transfer to animal products

- Use of contaminated fodder
- Transfer to meat, milk, eggs



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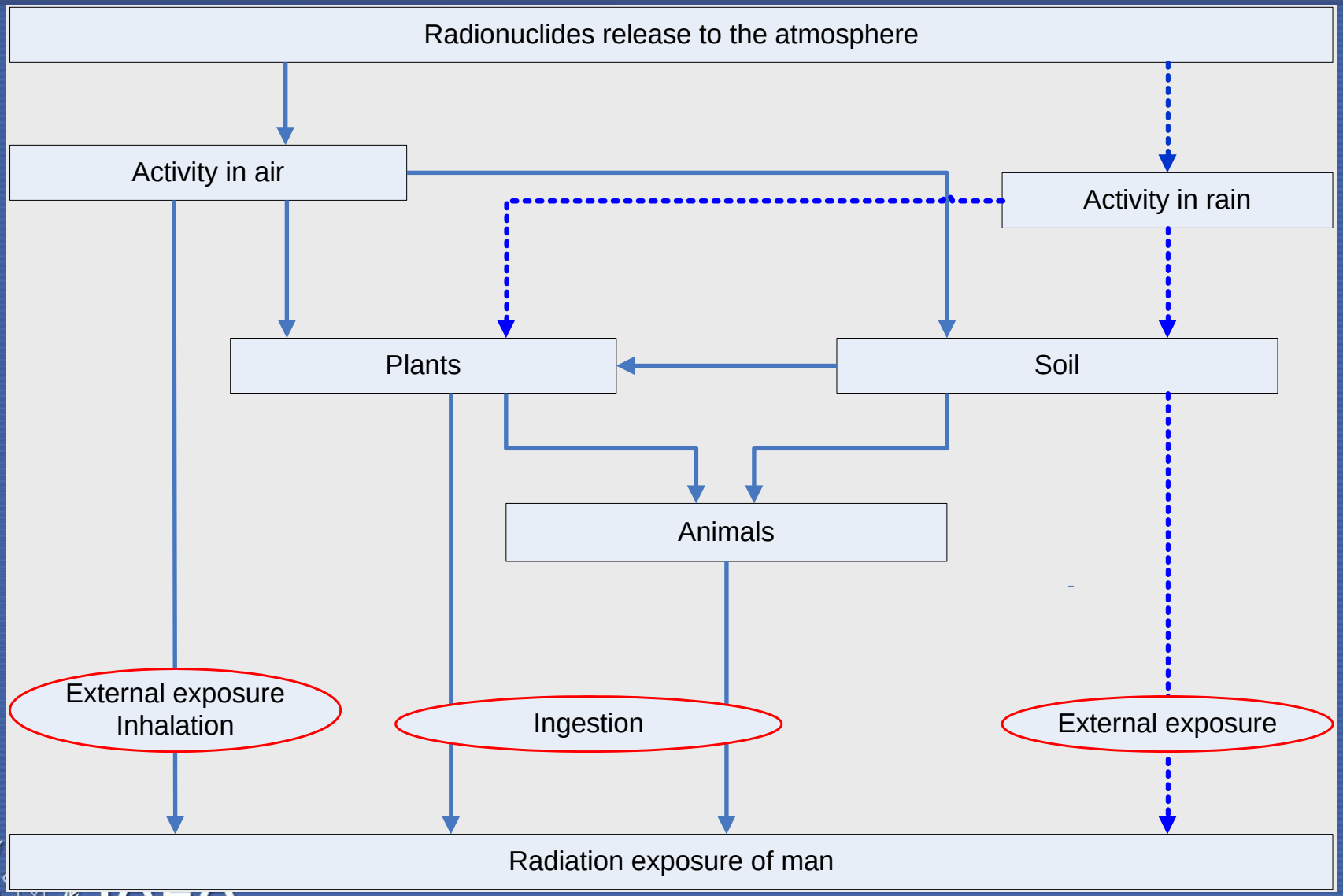
Radioecological model



Key factors determining exposures

- Radiological characterization
  - Deposition per unit area
- Environmental characterization
  - Ability of soils to sorb/fix caesium
  - Agricultural practice (e.g. use of fertilizer)
- Life style and economic situation
  - Degree of self-sufficiency
  - Spectrum of foods
    - Local vs regional/global food
- Information
  - Monitoring
  - Elaborating advise to locals
  - Dissemination

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Model processes and parameters

- **Key processes following direct deposition on the leaves (1st year)**
  - Dry deposition of radionuclides to soil and vegetation
  - Interception of wet deposited radionuclides by vegetation
  - Growth dilution and weathering loss from vegetation
  - Transport of radionuclides in plants to the edible parts

- **Key processes following direct deposition on the leaves (following years)**
  - Uptake of radionuclides by plants from soil
  - Migration and fixation of radionuclides in soil
  - Intake of radionuclides by domestic animals
  - Transfer of radionuclides to meat, milk and eggs
  - Modification of activity levels in foods during processing and culinary preparation.

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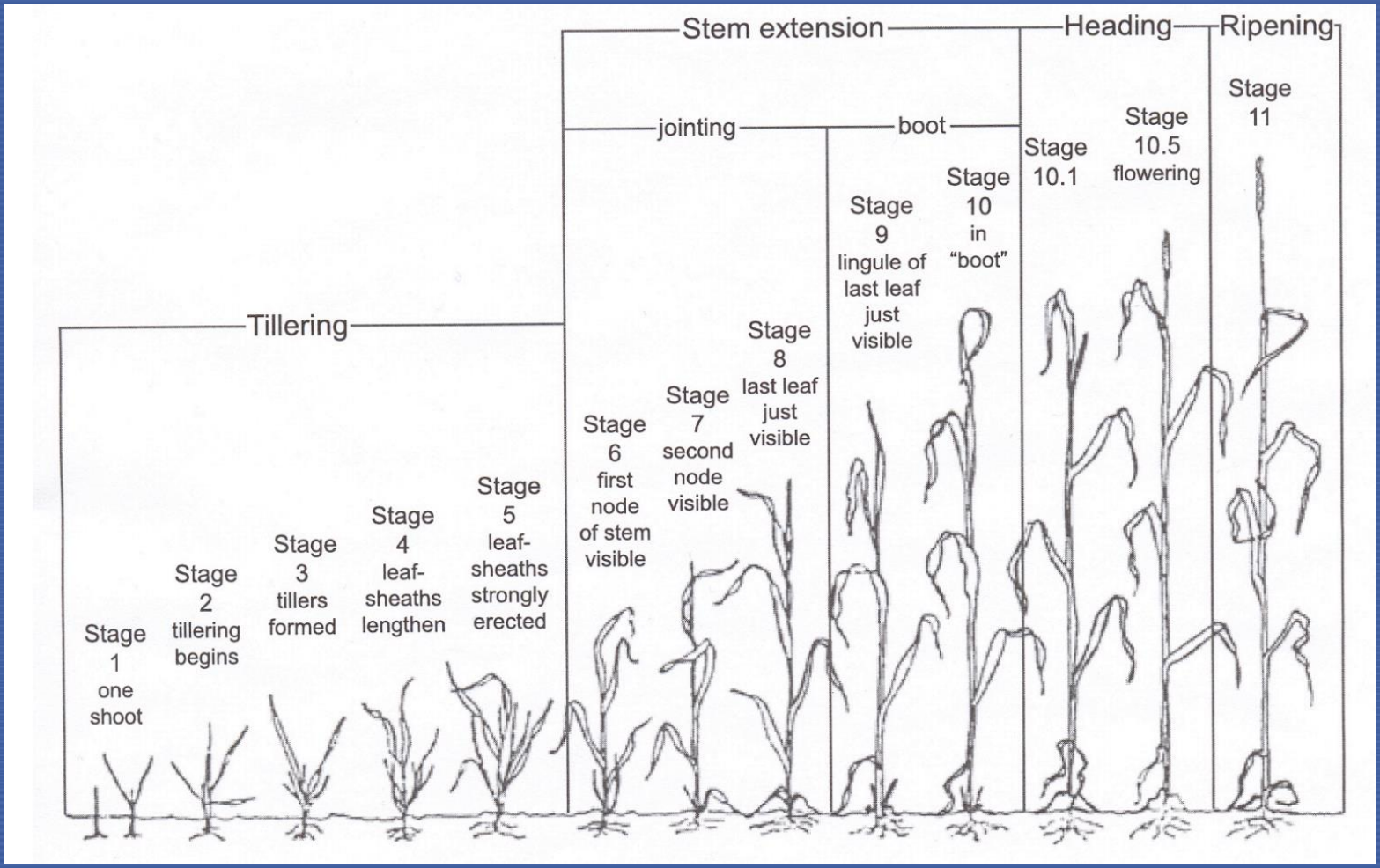
Seasonality of growth



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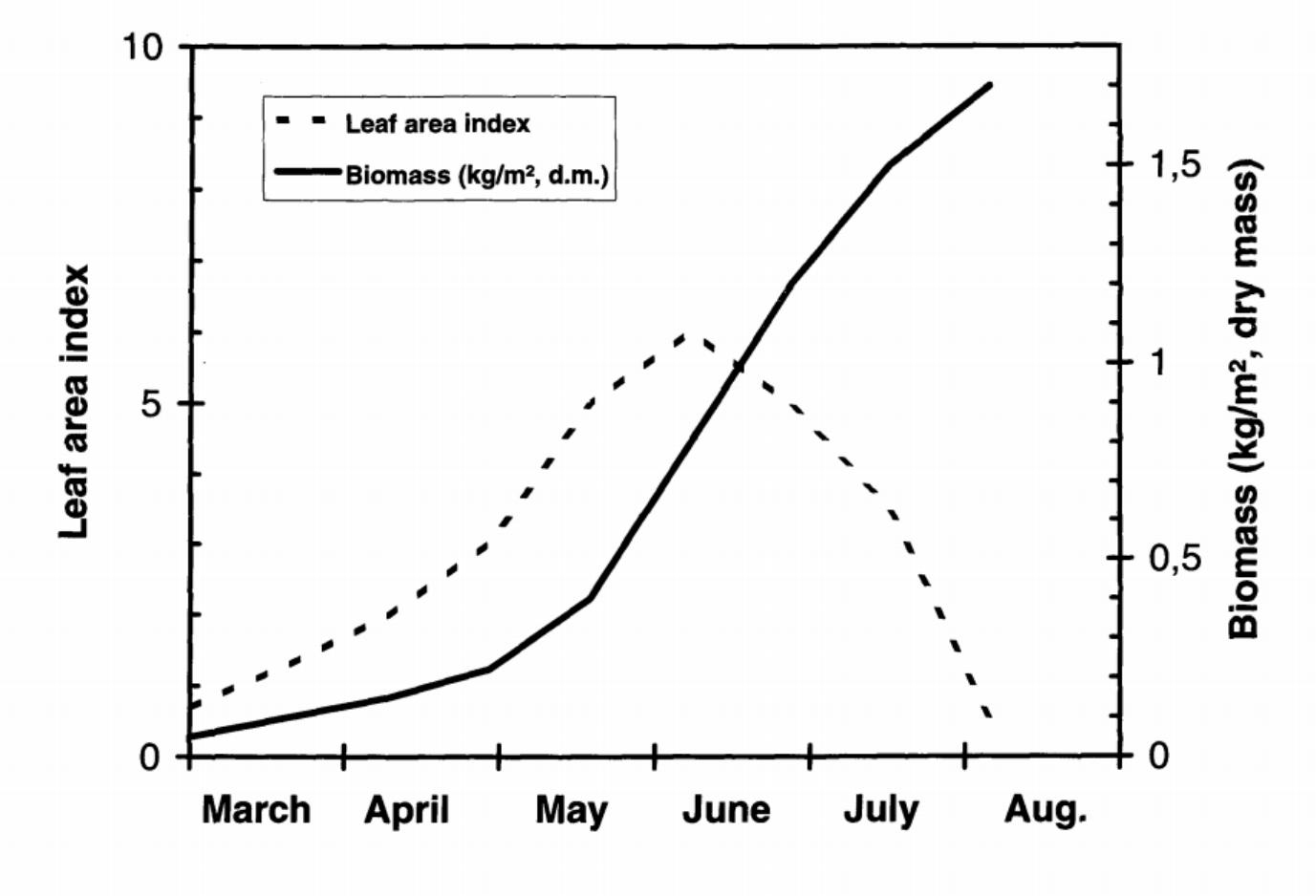
Development of leaf area and biomass



MÜLLER, H. PRÖHL, G., ECOSYS 87: A dynamic model for assessing radiological consequences of nuclear accidents, Health Phys. 64 (1993) 232-252.

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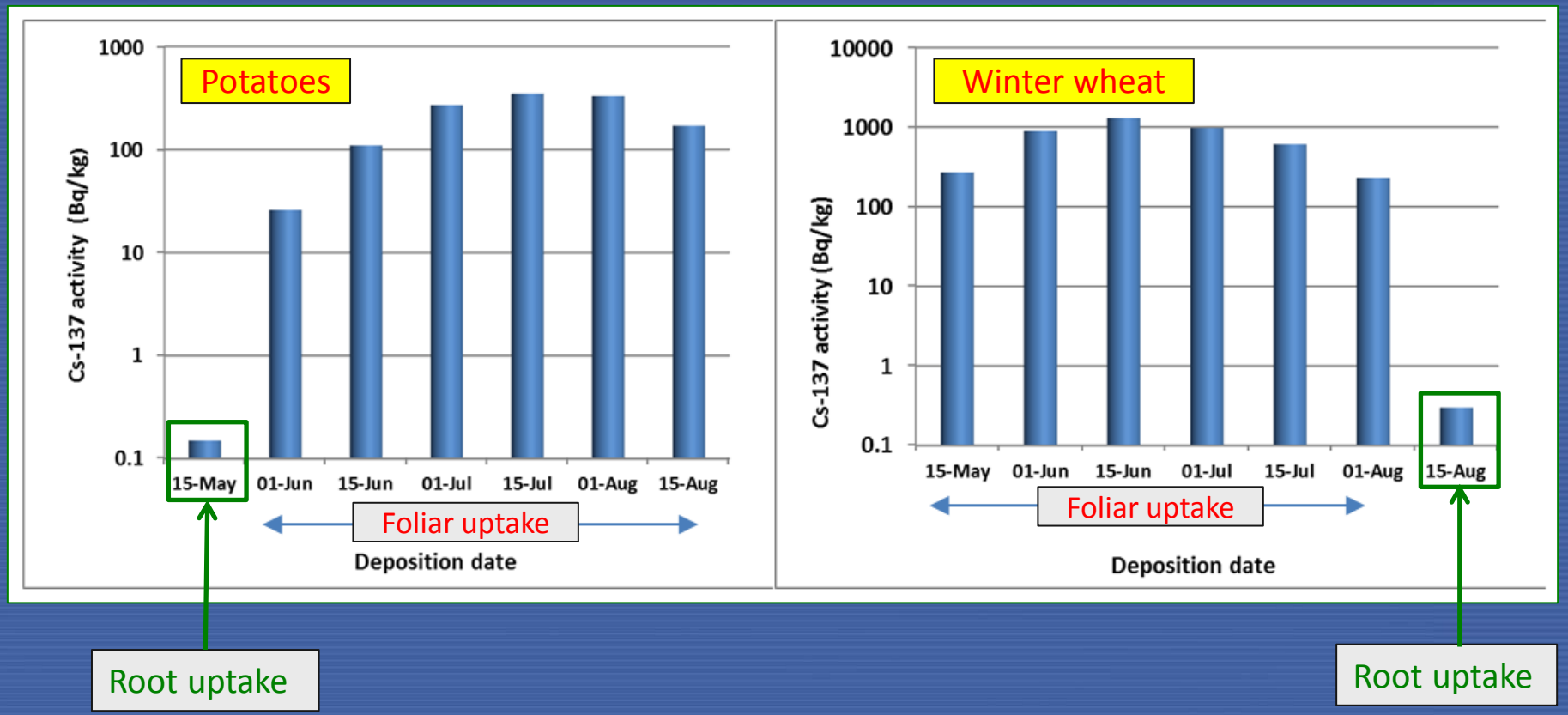
Comparison of activities in potatoes and wheat following different dates of deposition

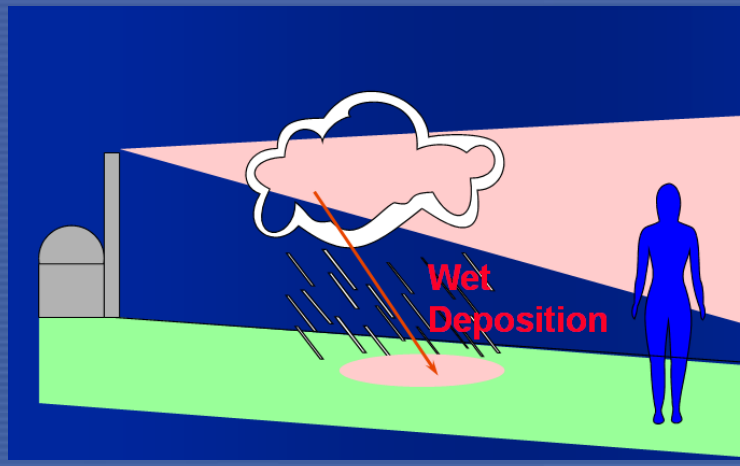


Starting point of the simulation is a **time-integrated Cs-137 activity in air of 1000 Bq h/m²**. Depending on the actual stage of development, this leads to a **deposition on the foliage of ca. 4000-7000 Bq/m²**.

Rainfall and deposition

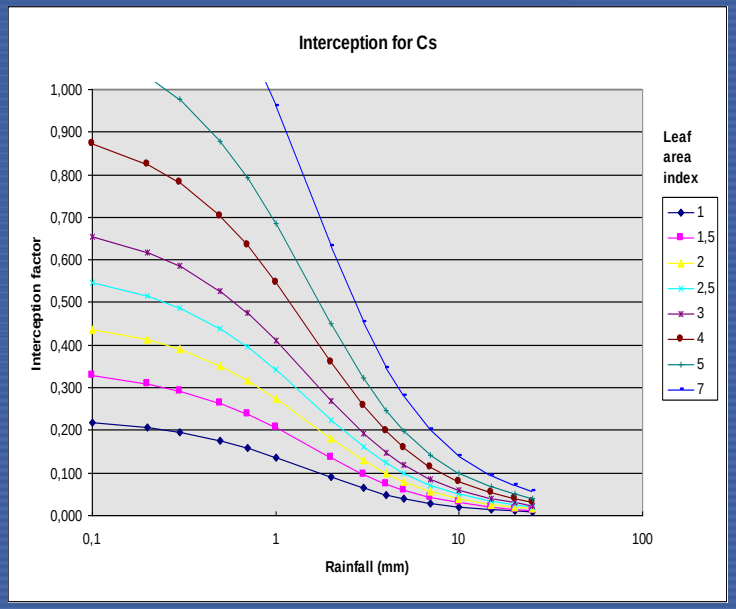
Rainfall during the passage of the plume

- Increase of deposition to the ground due to washout
- Increase of deposition with increasing rainfall (intensity)



Fraction of activity retained by crops (interception) …

- … decreases with amount of rainfall
- … increases with the development of crops
- … highest during the peak season



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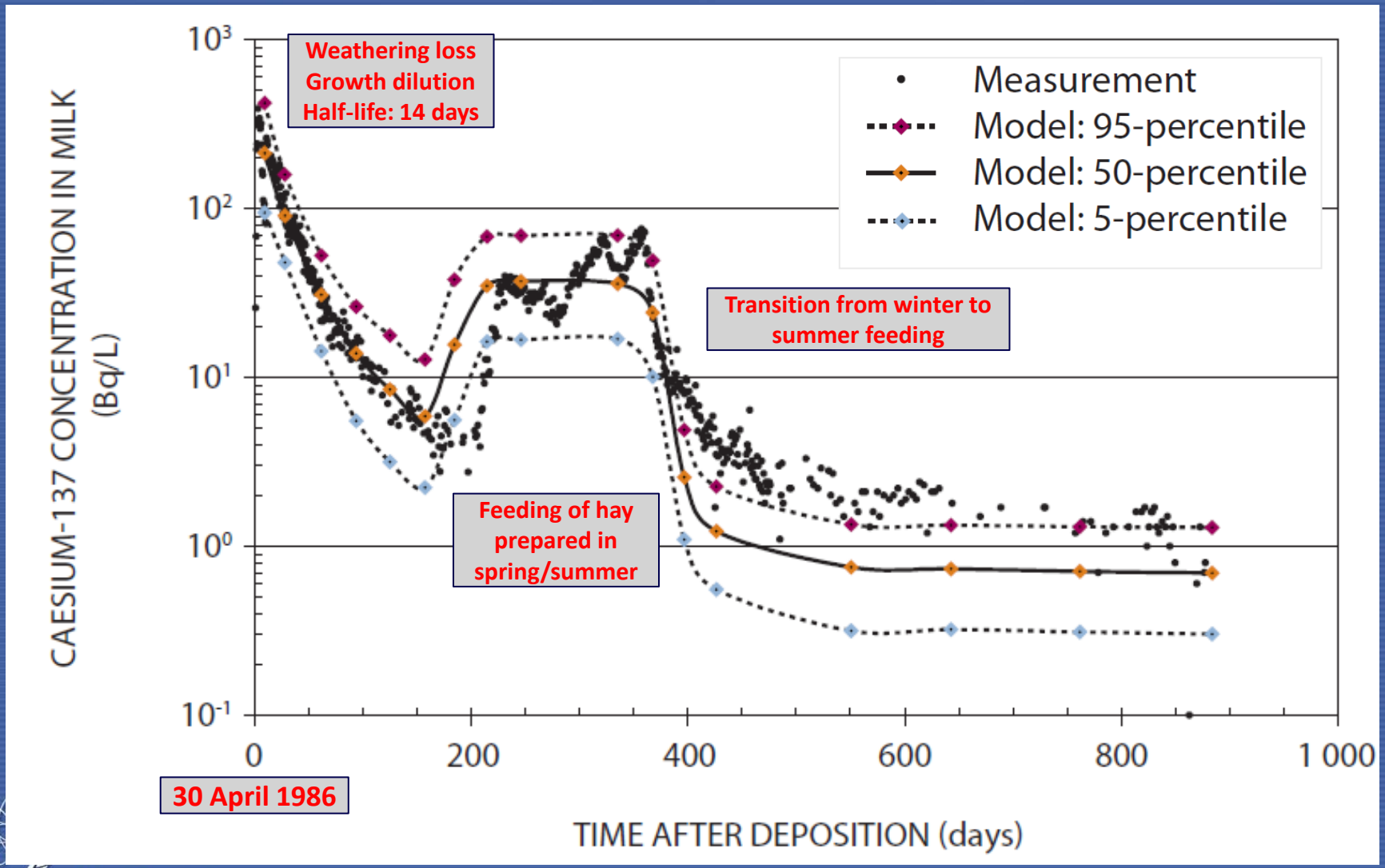
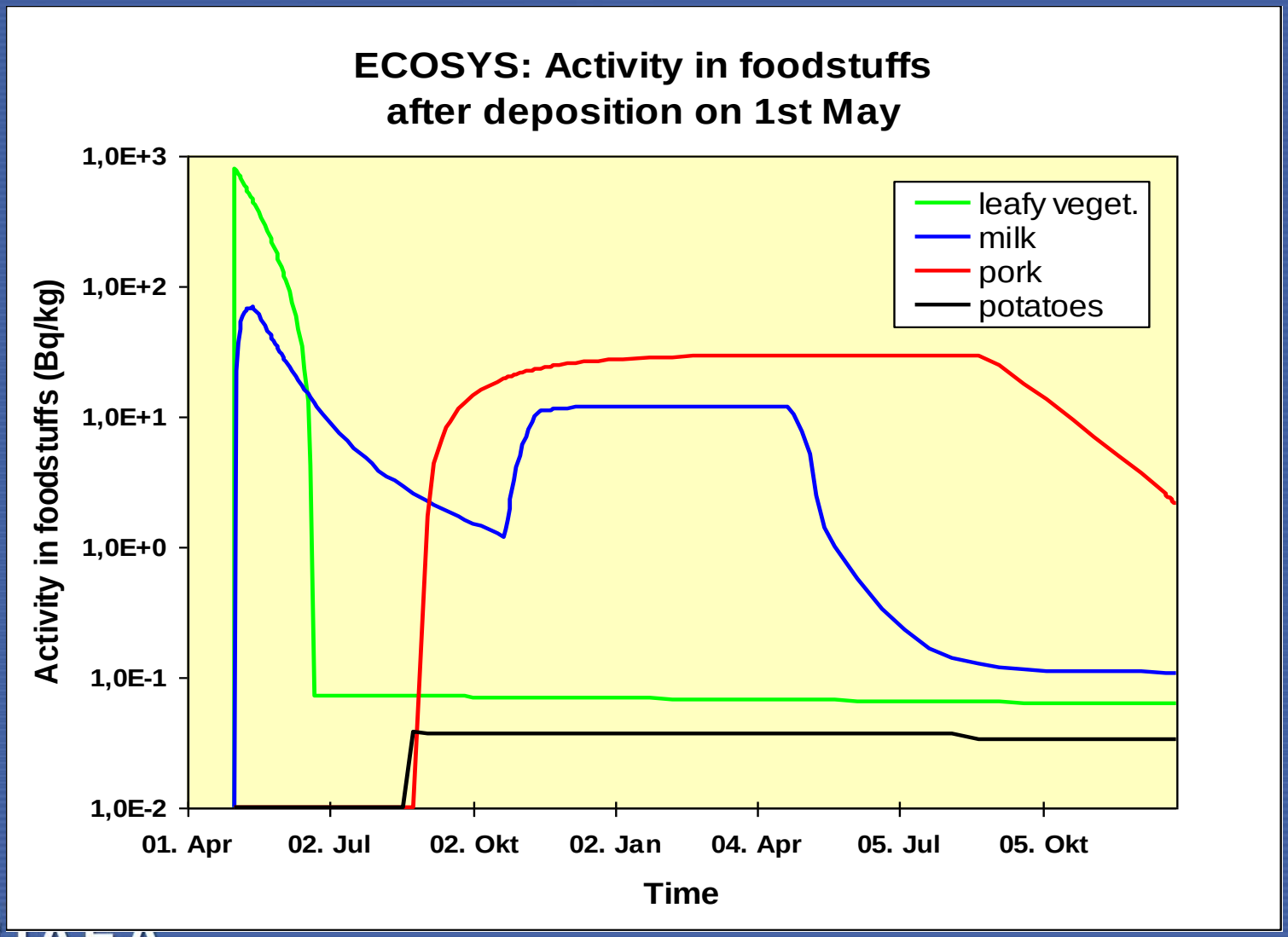
Seasonality of Cs-137 in milk following the Chernobyl fallout in spring

(UNSCEAR 2008, dairy farm near Munich, Germany)



Result: time-dependent activity in foodstuffs



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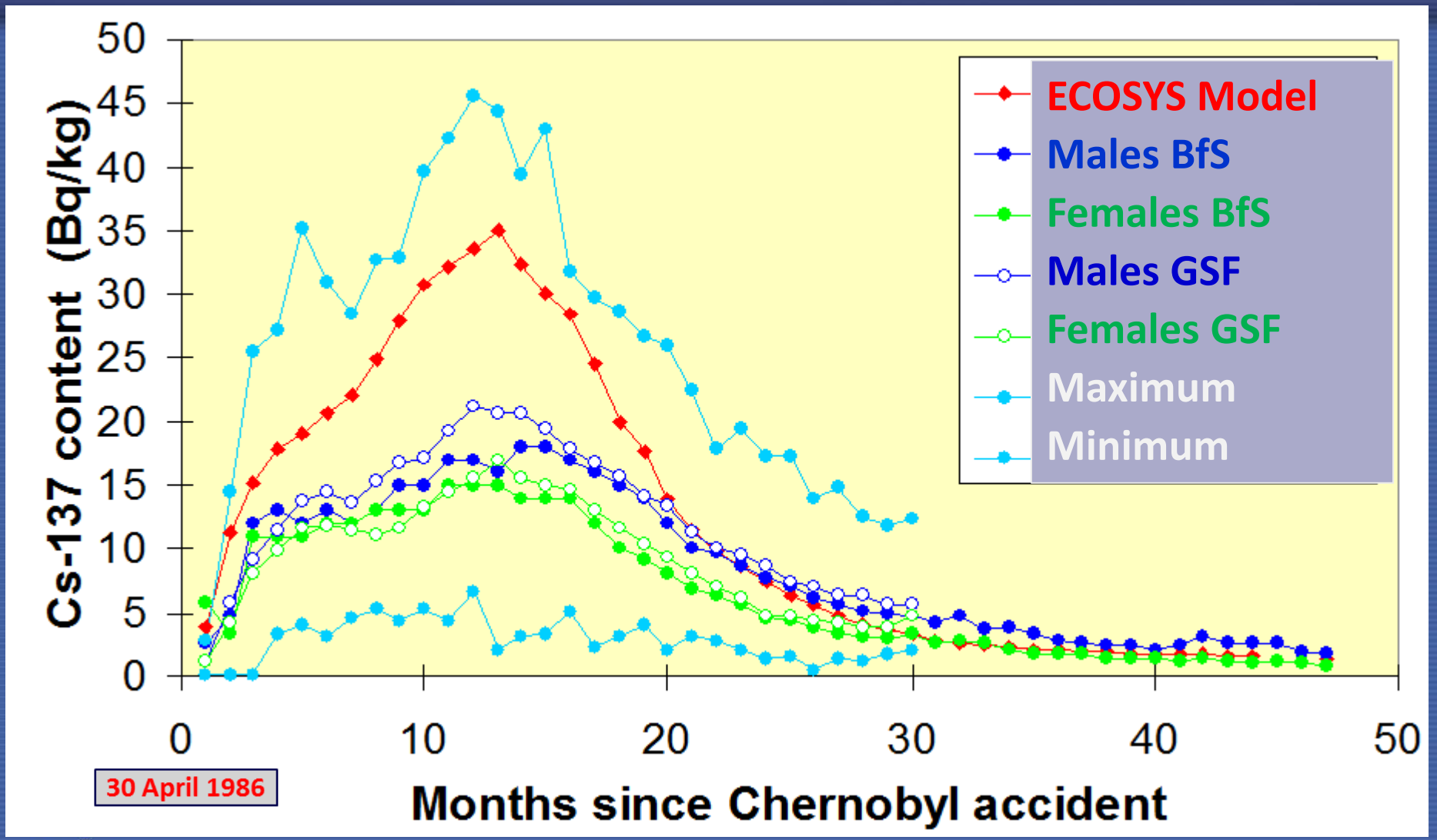
Cs-137 whole body counting (near Munich)



Müller, H, and Pröhl, G., The radioecological Model ECOSYS: Concept and Applications, Proc. Intern. Workshop on Improvement of Environmental Transfer Models and Parameters, Tokyo, Japan, 5-6 February, 1996

Summary

- **The uptake of radionuclides through leaves may be very effective**
  - Subject to pronounced seasonal variations in the plants' development stage
  - The uptake through leaves is much more effective than uptake through the roots.
- **Crops grow during different time slots within the overall vegetation period**
  - Activity levels in different products may vary substantially, because the crops may be affected at very different stages of development.
- **The radiological evaluation of radionuclide depositions occurring during the vegetation periods requires**
  - The careful characterization of the environmental conditions of the affected areas
  - The growing periods of crops cultivated in the area
  - The use of crops as food or feedstuffs
  - The agricultural practices in animal husbandry

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Conclusions – What does this mean?

1000 Bq/kg Cs-137

- Levels in **food other than infants foods** for international trade as provided by the Codex Alimentarius

10000 Bq/m^2 Cs-137-deposition during the peak season

- Cereals: Less than 10000 Bq/m^2 (10 kBq/m^2) (dry deposition) would cause Cs-137 in the order of 1000 Bq/kg

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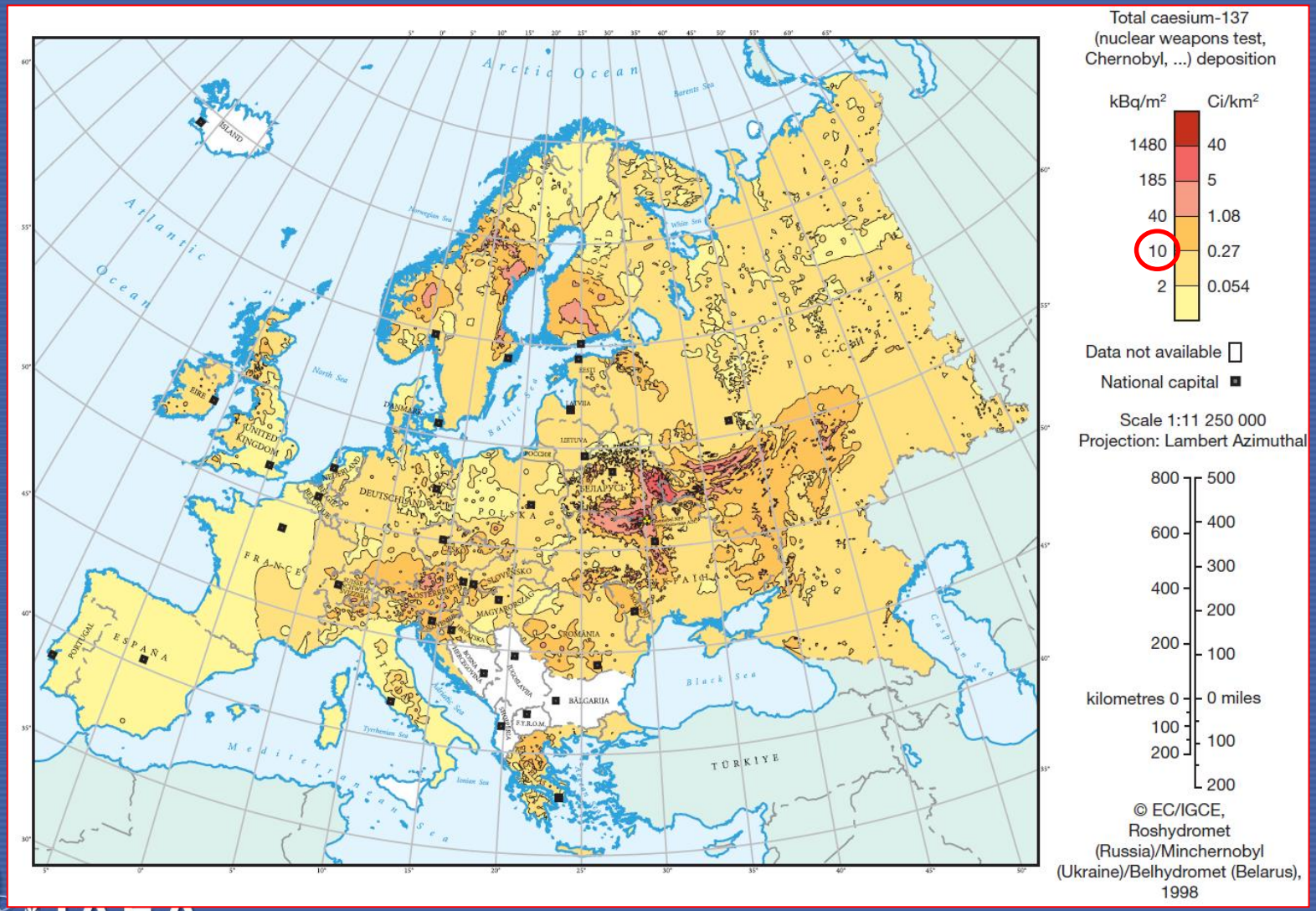
Total Cs-137 deposition in Europe



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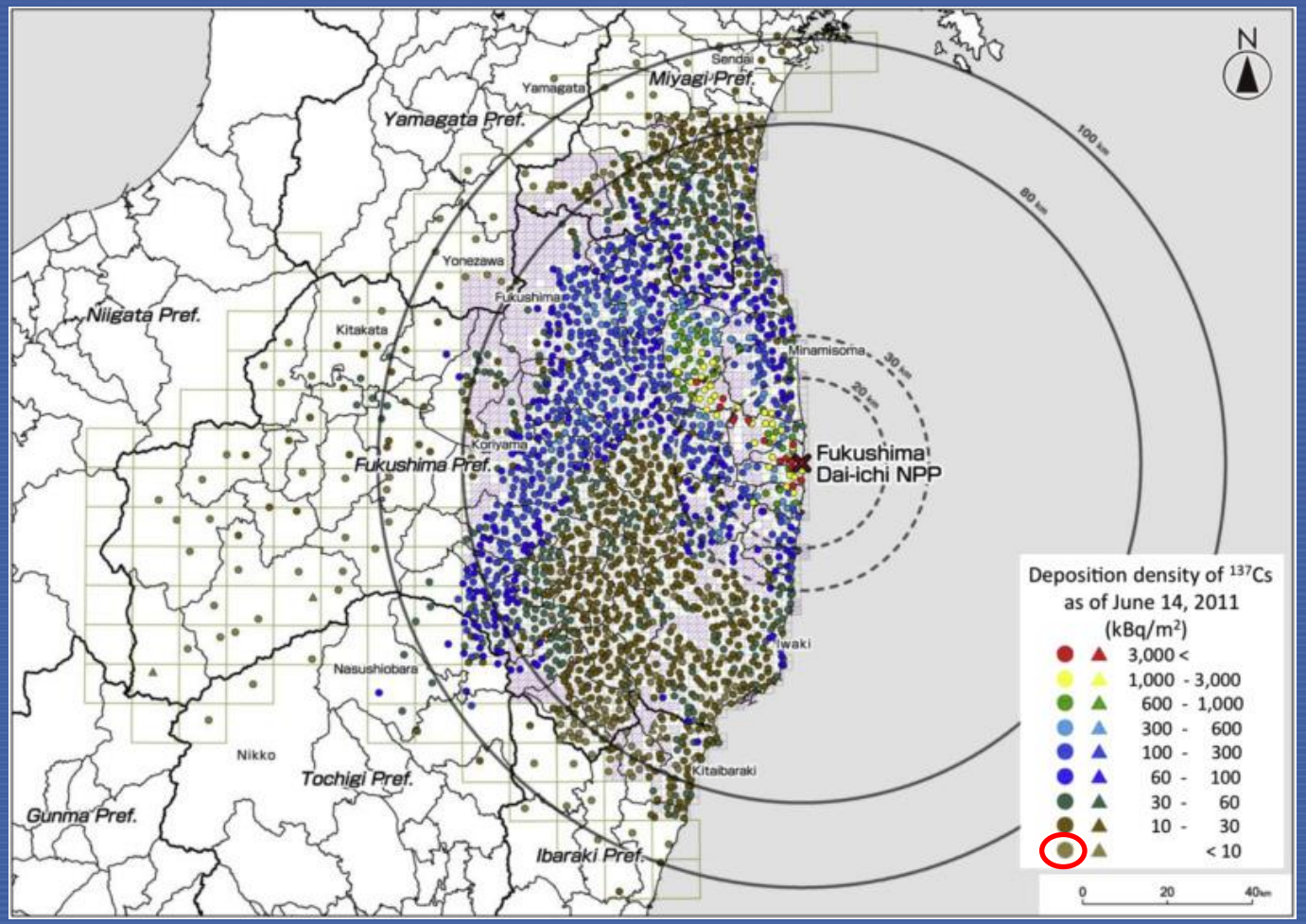
Deposition density map for Cs-137



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Kimiaki Saito, et al: **Detailed deposition density maps constructed by large-scale soil sampling for gamma-ray emitting radioactive nuclides from the Fukushima Dai-ichi Nuclear Power Plant accident,** Journal of Environmental Radioactivity, Volume 139, 2015, 308–319

Conclusions (cont.)

The Chernobyl and the Fukushima accidents occurred early in the year, during the transition of winter to spring:

- Only few crops were affected by direct deposition of radionuclides.
- Implications for agriculture and trade remained relatively little.

Large-scale depositions during the peak growing season could have much larger radiological implications

- Activity levels in crops would be much larger
- Areas potentially affected by restrictions would be much larger (if the radiological criteria are applied)
- Implications may need to be explored to elaborate solid grounds for contingency planning.

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