CORSO DI BOTANICA SISTEMATICA

LEZIONE 52

Radiocontaminazione di funghi, piante vascolari e muschi dopo l'incidente di Chernobyl

2nd Caesium Workshop: meeting challenges for Fukushima recovery

LA CONTAMINAZIONE DA CESIO-134 E CESIO-137 NEI MACROMICETI DEL FRIULI-VENEZIA GIULIA NEL 1986

P.L. NIMIS, C. GIOVANI, R. PADOVANI *

Keywords: Chernobyl, Fungi, Radioactivity, Friuli-Venezia Giulia.

Abstract: This study is based on the measure of the ^{134}Cs and ^{137}Cs content in 298 samples belonging to 120 species of macromicetes, collected in 37 stations throughout the Friuli-Venezia Giulia Region (north eastern Italy) in September-October 1986. Significant differences in contamination have been recorded both among species collected in the same station, and among average values of the stations themselves. The differences among species of the same stations seem to depend on the depth of the mycelium in the soil: contamination is highest in the fungi with superficial mycelium, lowest in those that are in symbiosis with deep-rooting deciduous trees. This is related to the fact that most of the radionuclides are presently concentrated in the upper horizon of the forest soil, as demonstrated by the analysis of 59 soil samples collected in the 37 stations. The differences among stations are well correlated to the amount of precipitation in the days following the Chernobyl disaster. This allowed the elaboration of a contamination map of the Friuli-Venezia Giulia Region based on precipitation and contamination data: the most polluted areas are located in the Carnian and Julian Pre-Alps, whereas the lowland has been but little affected by radioactive deposition. The average ratio $^{137}Cs/^{134}Cs$ in mushrooms is 2.7, which is probably due to the presence in the material of ^{137}Cs deriving from nuclear tests.

RADIOCESIUM IN PLANTS OF FOREST ECOSYSTEMS

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Keywords: Forests, Radiocesium, Radioecology, Vegetation.

Abstract: This paper presents a review of the behaviour of radiocesium in plants of forest ecosystems, based on a screening of 375 articles. Particular stress is given to those factors which affect data variability in plants, such as vertical and horizontal patterns of radioactivity in soils due to interception, resuspension, wash-off, litter fall etc. The behaviour of radiocesium in different horizons of forest soils is discussed. The paper summarizes the main uptake mechanisms in fungi, lichens, bryophytes and higher plants, and the possible use of these organisms as bioaccumulators of radioactive deposition. For higher plants, the effects of several factors on root uptake are considered, such as pH, organic matter and clay content of different soil horizons, the concentrations of other ions in the soil solution, rooting depths, mycorrhiza, etc. Finally, the paper includes a discussion of translocation phenomena inside plants, of seasonal variation of radionuclide concentrations, and of the expression of radiocontamination of plant material. The expression of radiocesium concentrations on a water basis is suggested as being more appropriate than the usual expression on a dry weight basis for the solution of several radioecological problems.

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Bryophytes as indicators of radiocesium deposition in northeastern Italy

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Abstract

Samples of moss carpets growing in forest vegetation have been used to map radioactive fallout in northeastern Italy. The main factors affecting data variability are the inclination of the carpets, water absorbing power, and their thickness. The best suited bioindicator proved to be *Ctenidium molluscum*. The results indicate that these carpets were able to intercept most of the radiocesium deposited after the Chernobyl accident, and that the removal half-time in the survey area is of ~46 months.

2nd Caesium Workshop:
meeting challenges for Fukushima recovery

Assessing radiocontamination in forest ecosystems

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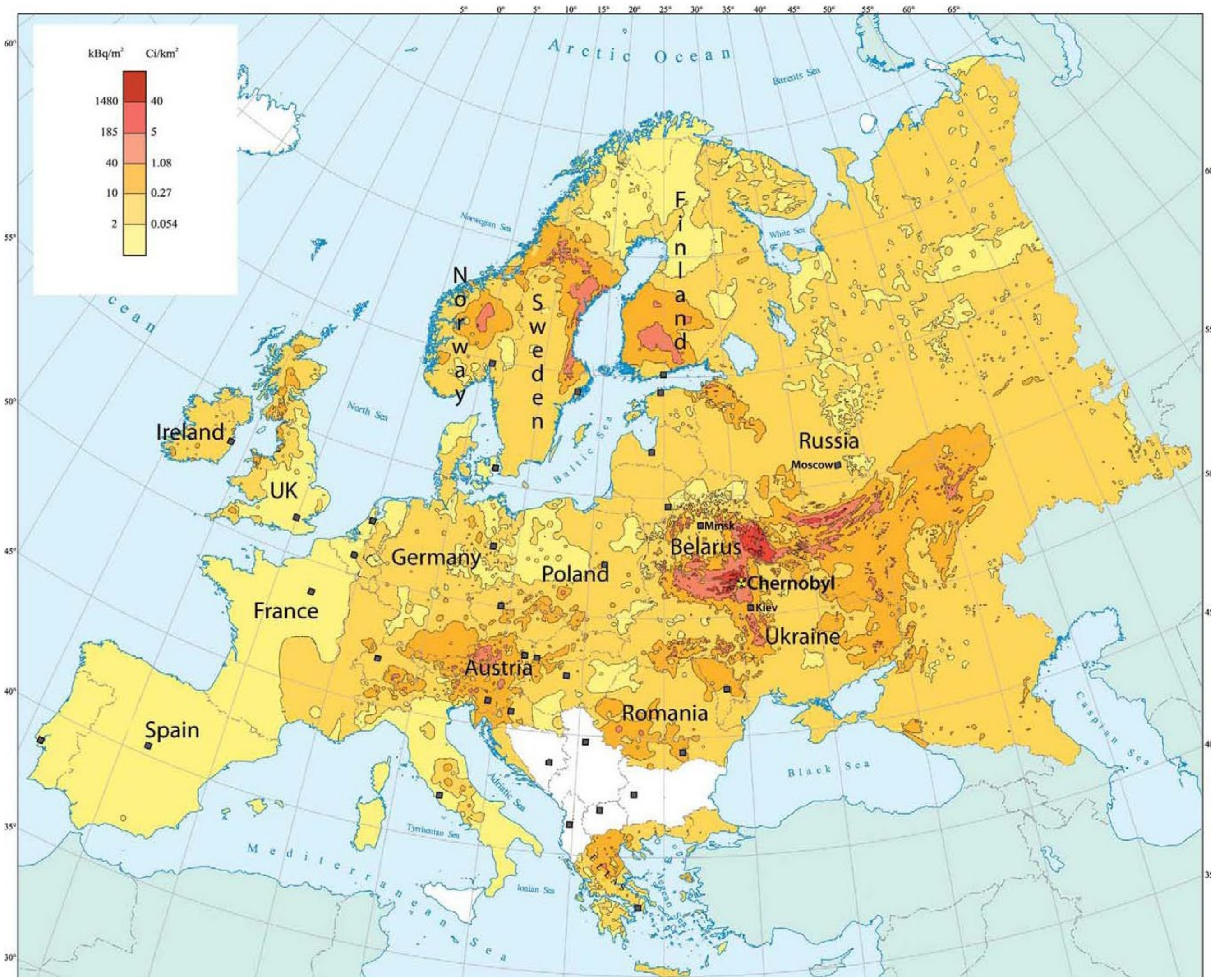


Radiocontamination patterns in Europe after the Chernobyl accident (April, 26th, 1986)

In Italy the highest deposition was in the eastern Alps…

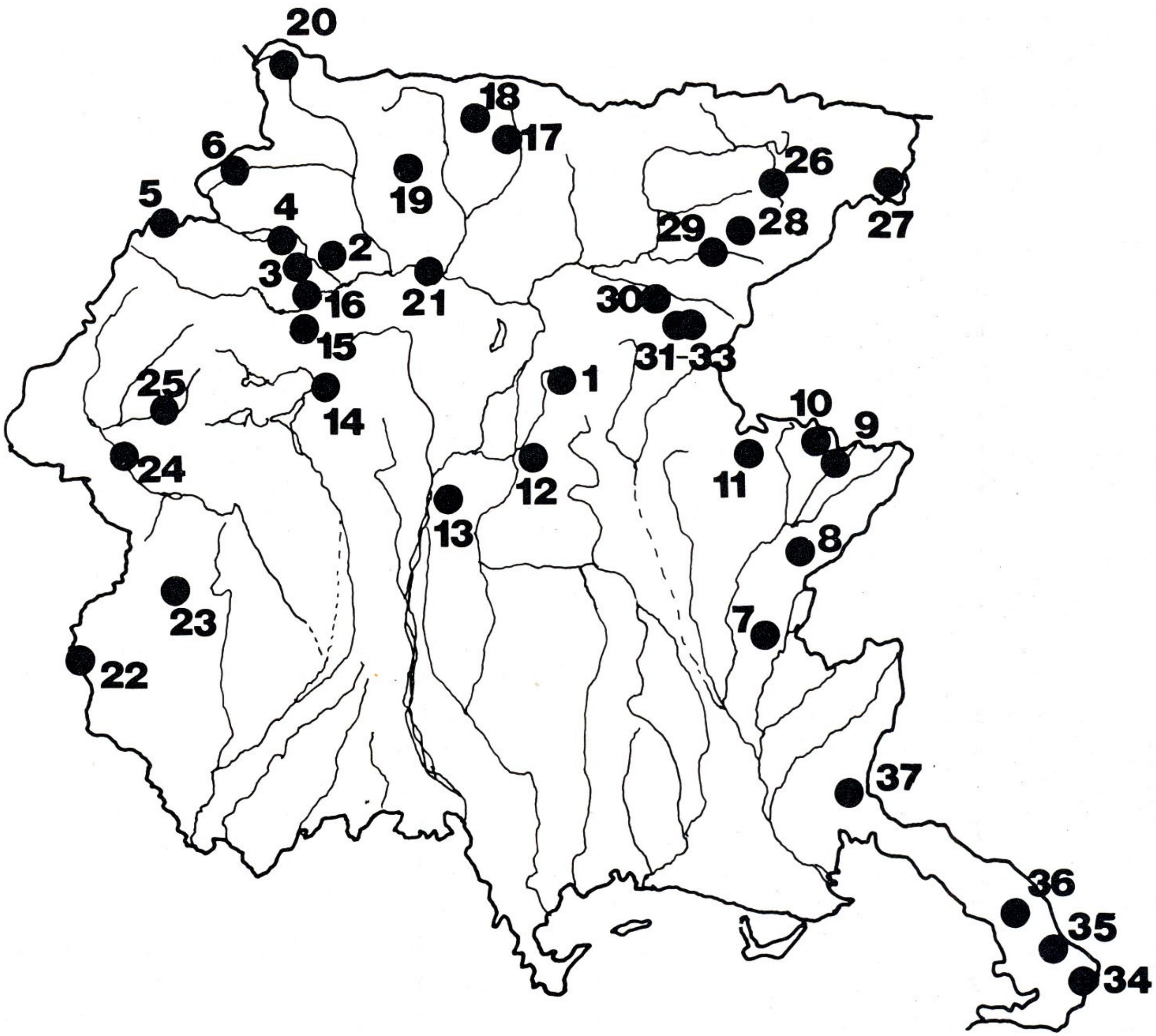
…in an area corresponding to the administrative region of Friuli Venezia Giulia…

…where the Regional Authorities set up a
Radioprotection Committee a few days after the accident

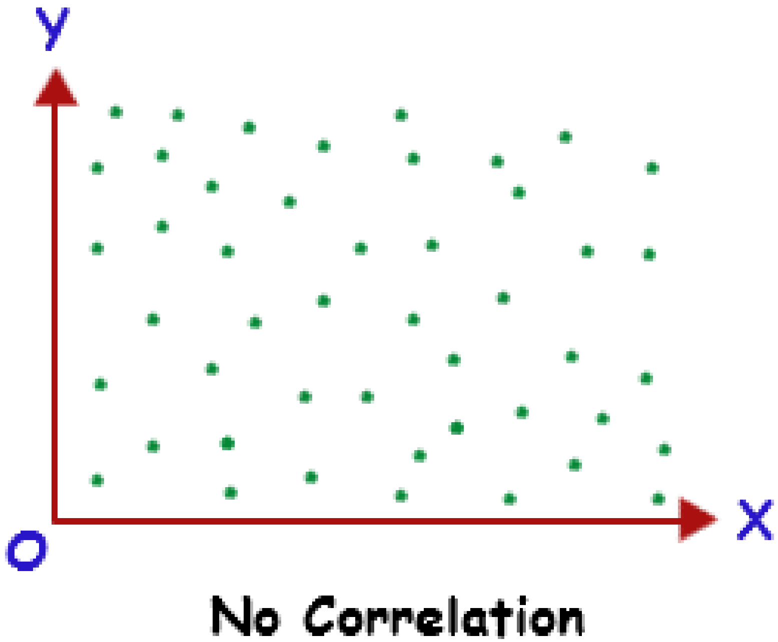
1 - mushrooms are complex

The first data showed high contamination levels in wild mushrooms.
No geographic pattern, just a rise of radiocontamination values in August

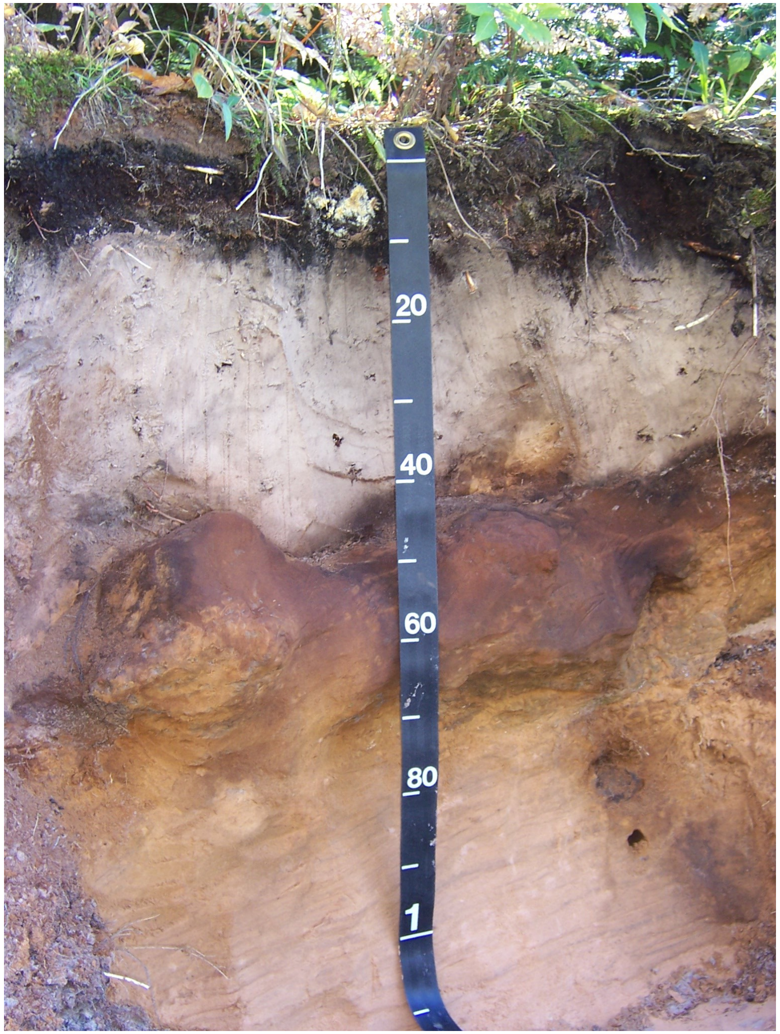
Measures were expressed in Bq/kg **fresh weight**! This makes sense for radioprotection, not for radioecology. The higher values in August were due to dehydration of carpophores due to low precipitations



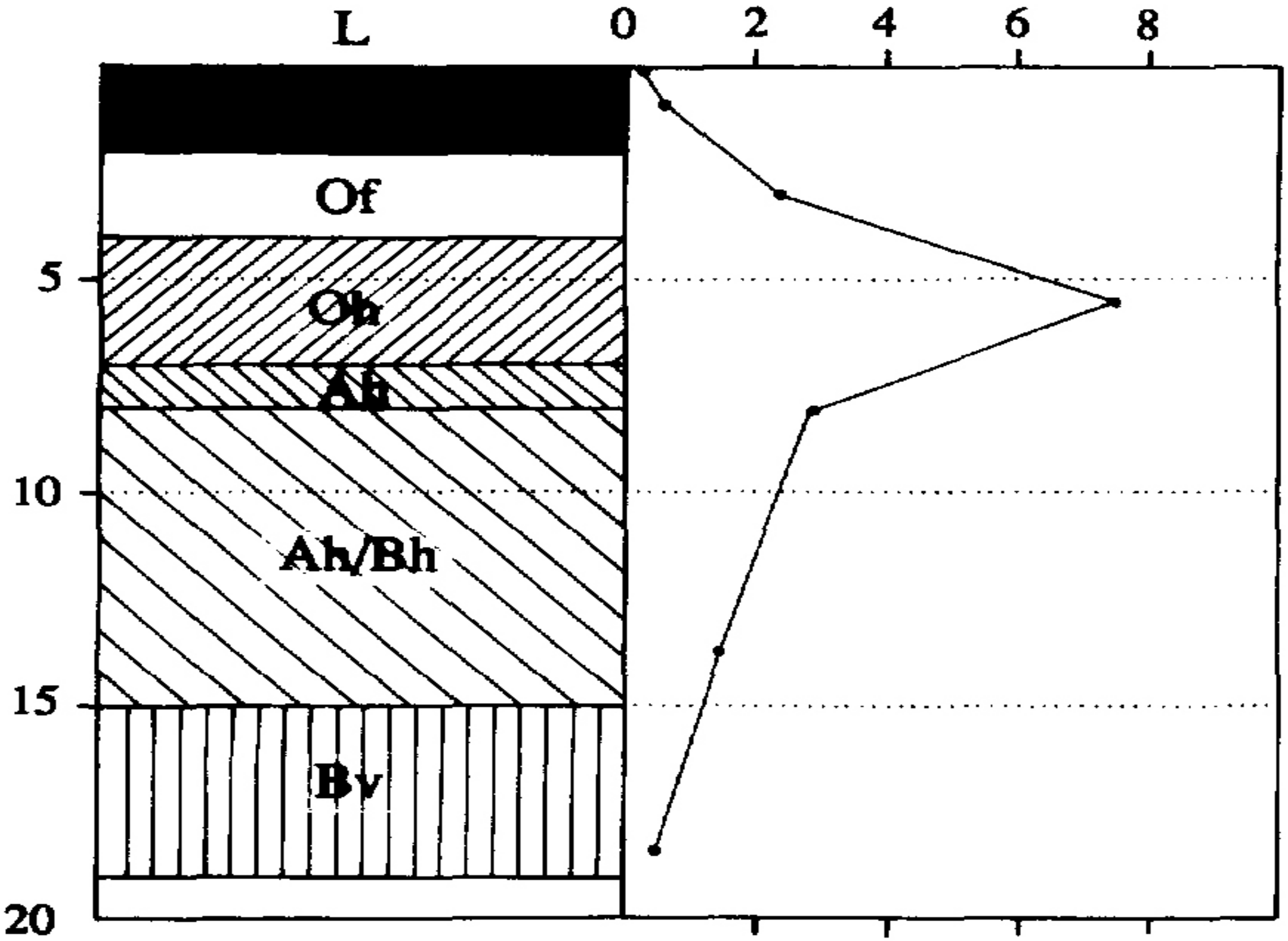
Location of the 37 sampling stations (mushrooms)
in forest areas (late summer 1986): 298 samples, 120 species



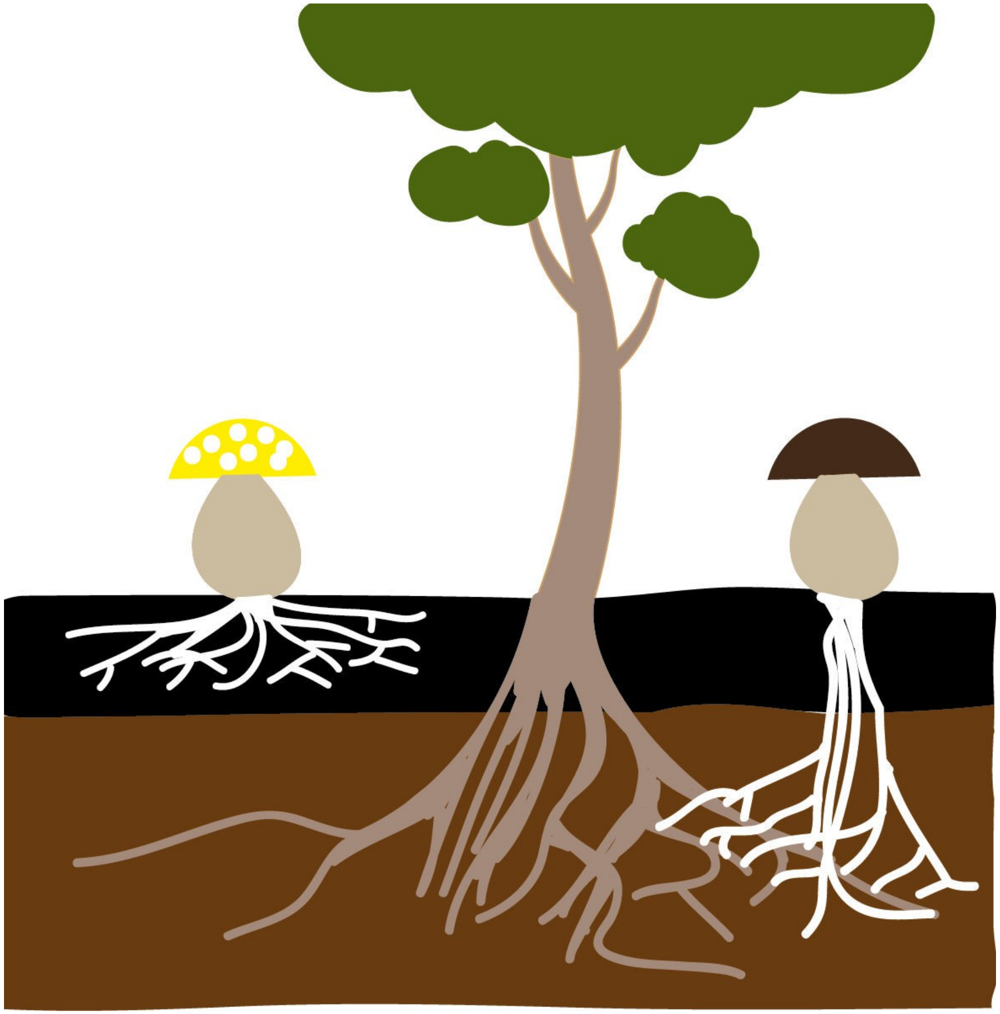
The analysis of all data revealed no geographic pattern,
while differences among species of the same site were considerable



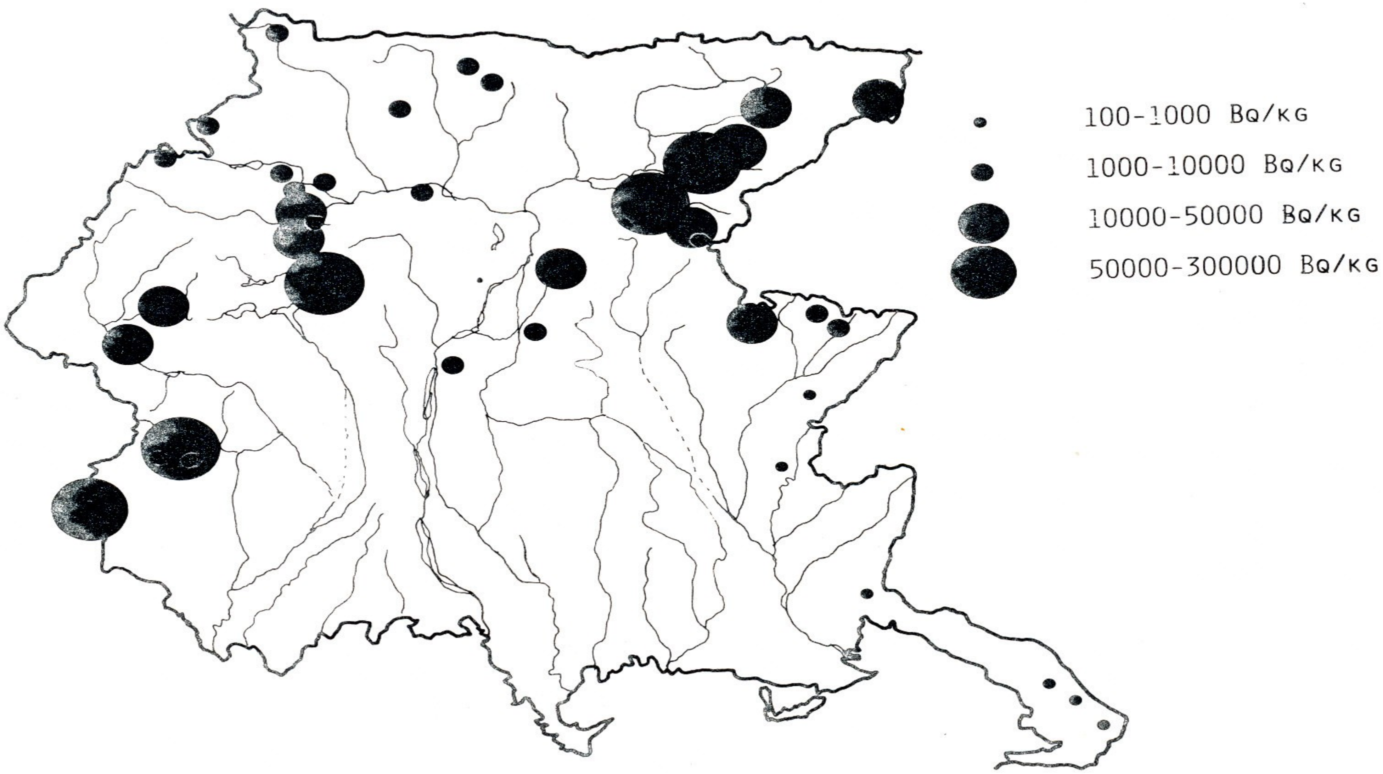
Compared with agricultural soils,
forest soils are much more structured



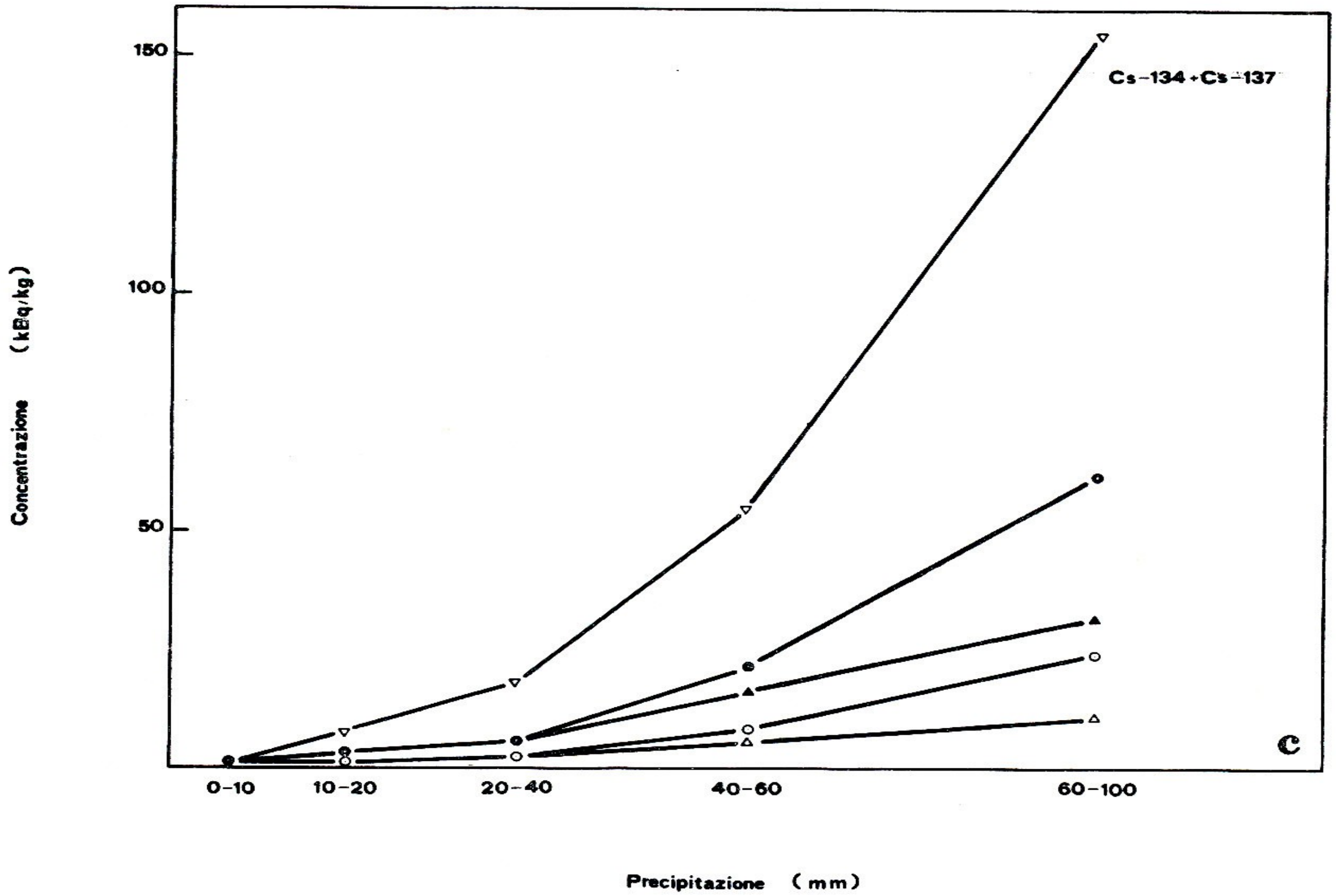
In 1986 most of the **radiocesium was concentrated in the upper (organic) soil layers**



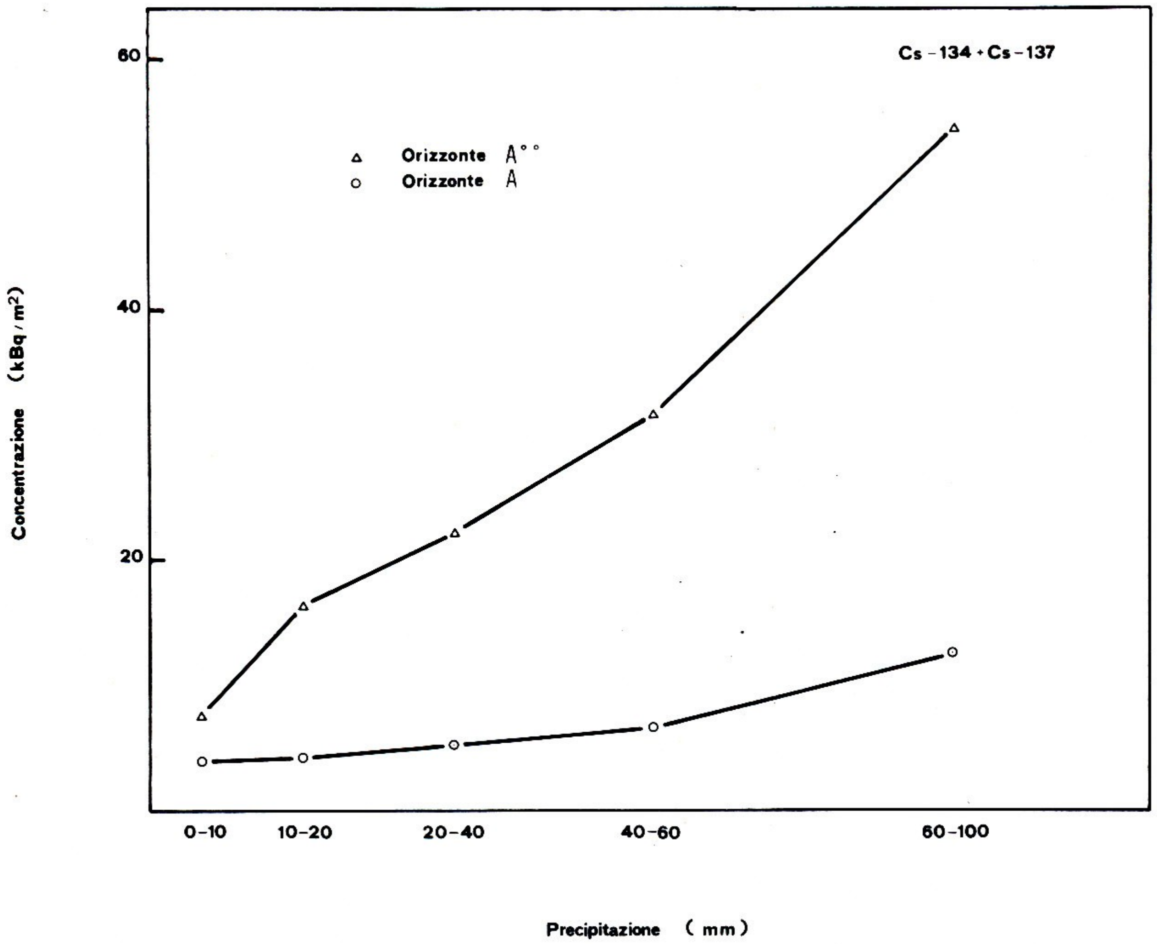
Introducing the difference between **mycorrhizal** and **saprophytic** fungi: the mycelium of the former occupies much deeper soil layers



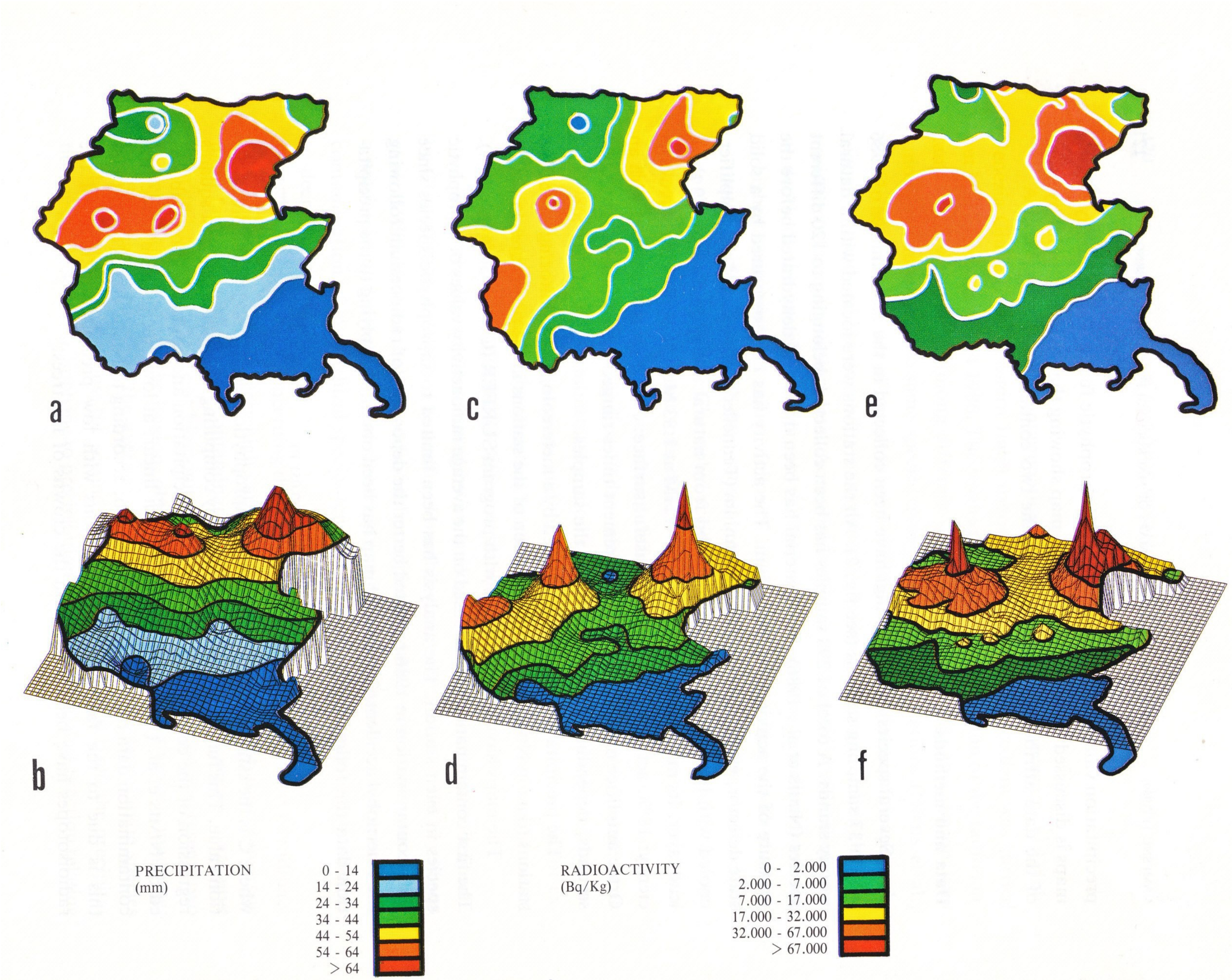
By using saprophytic fungi alone (i.e. those with a superficial mycelium), a **clear geographic pattern** appears



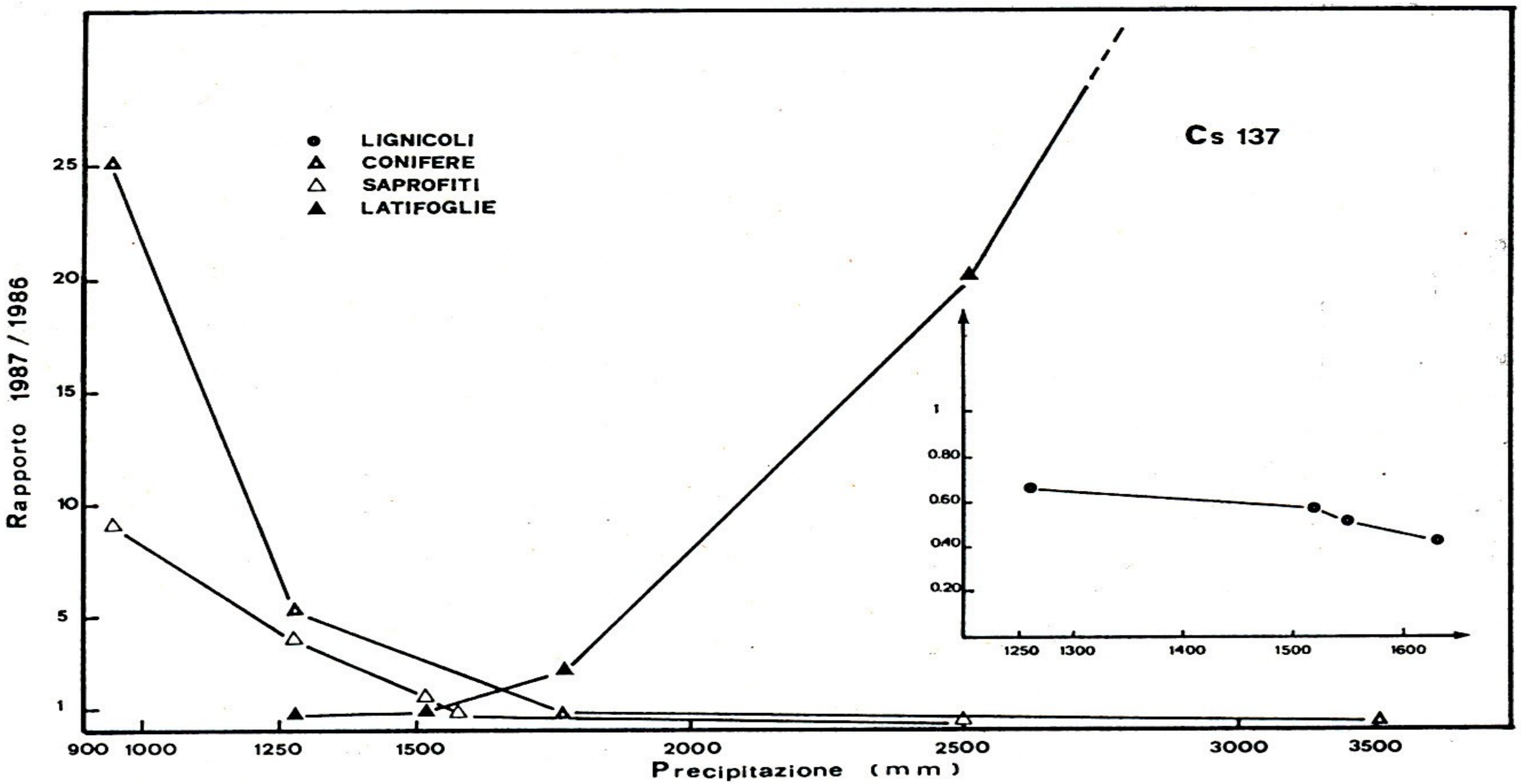
Radiocontamination of saprophytic fungi was correlated with the amount of precipitation in the 7 days following the Chernobyl accident



The same pattern applies to the most superficial (organic) soil layer, where most of the radiocesium was concentrated



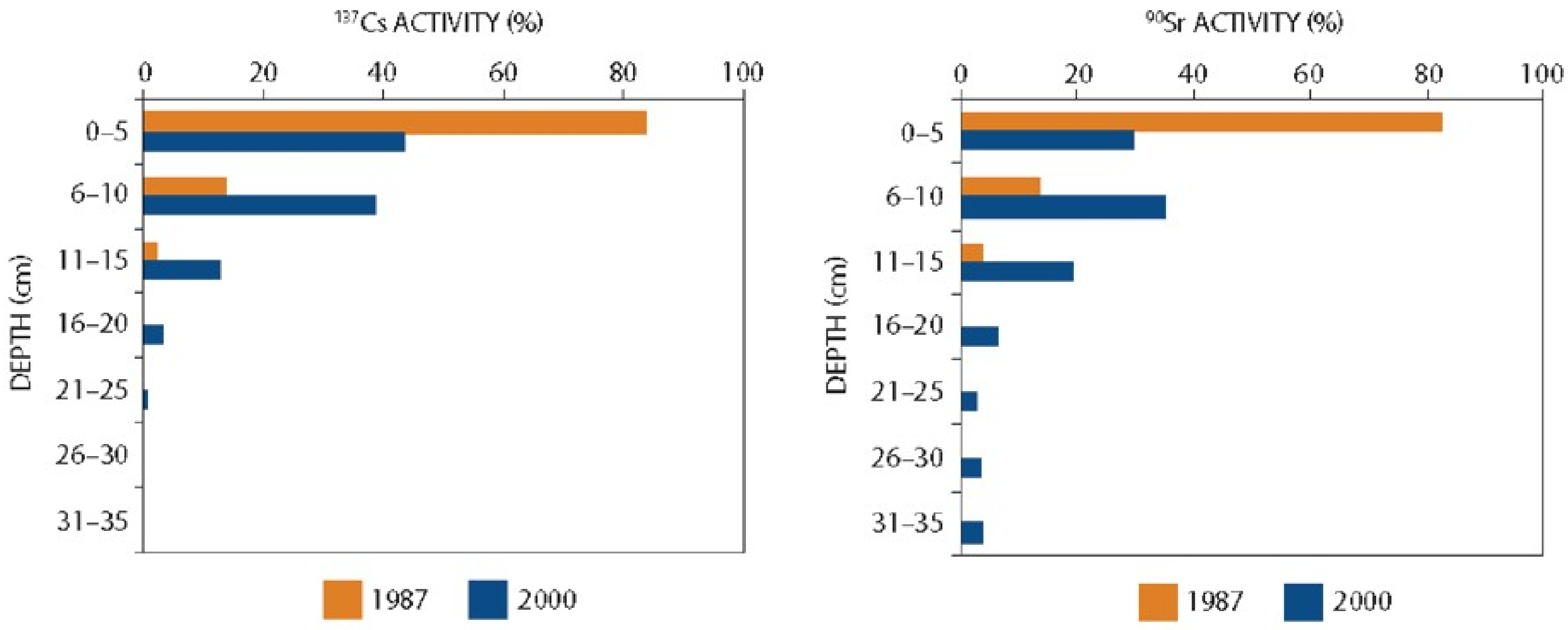
Radiocontamination data of mushrooms and precipitation data were used to construct a **spatial model of the radiocontamination** of mushrooms over the entire region



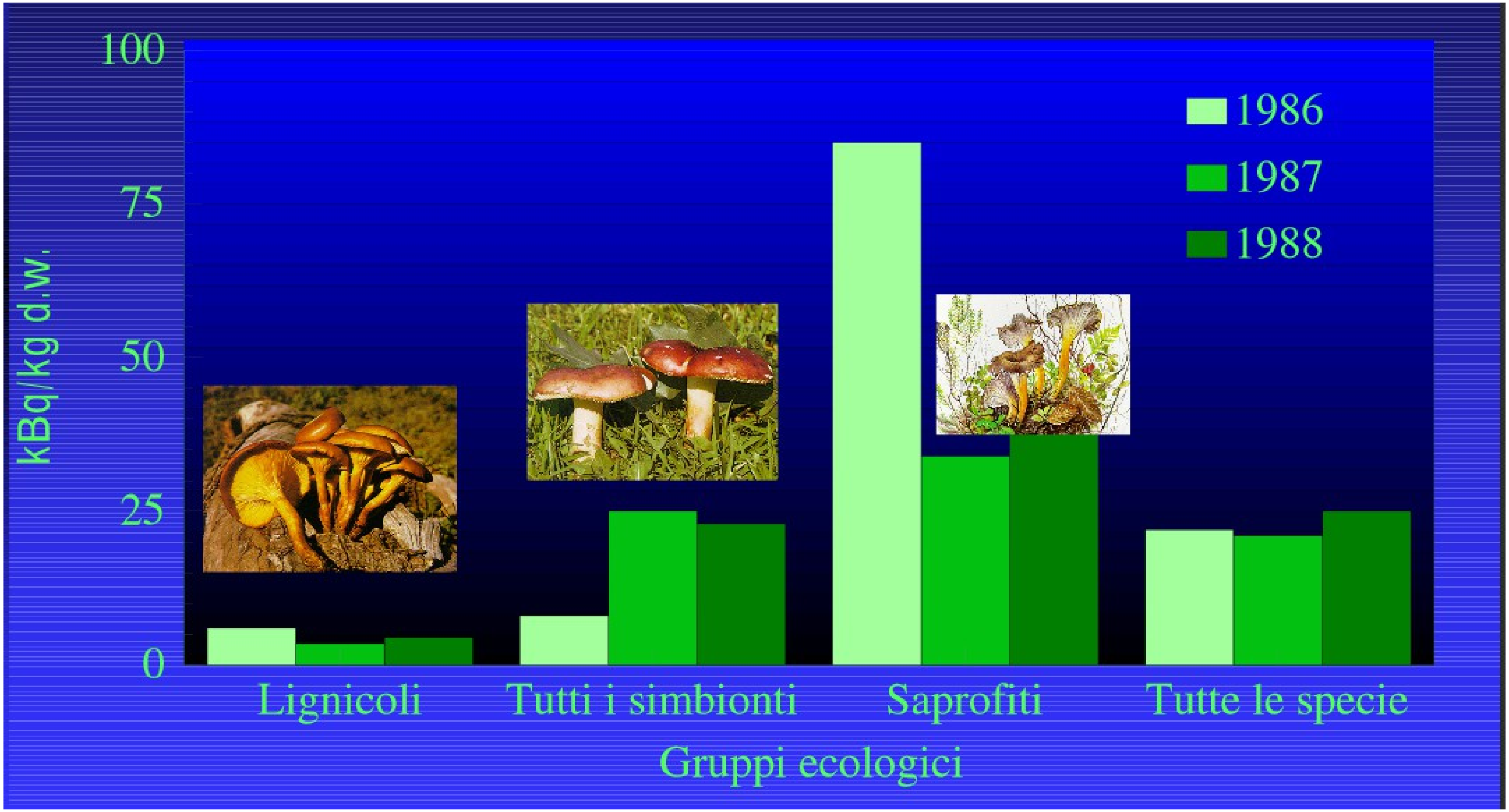
Monitoring the situation one year later:

1) in low-precipitation areas the radiocontamination of mushrooms with superficial mycelium increased (input from tree crowns in autumn 1986)

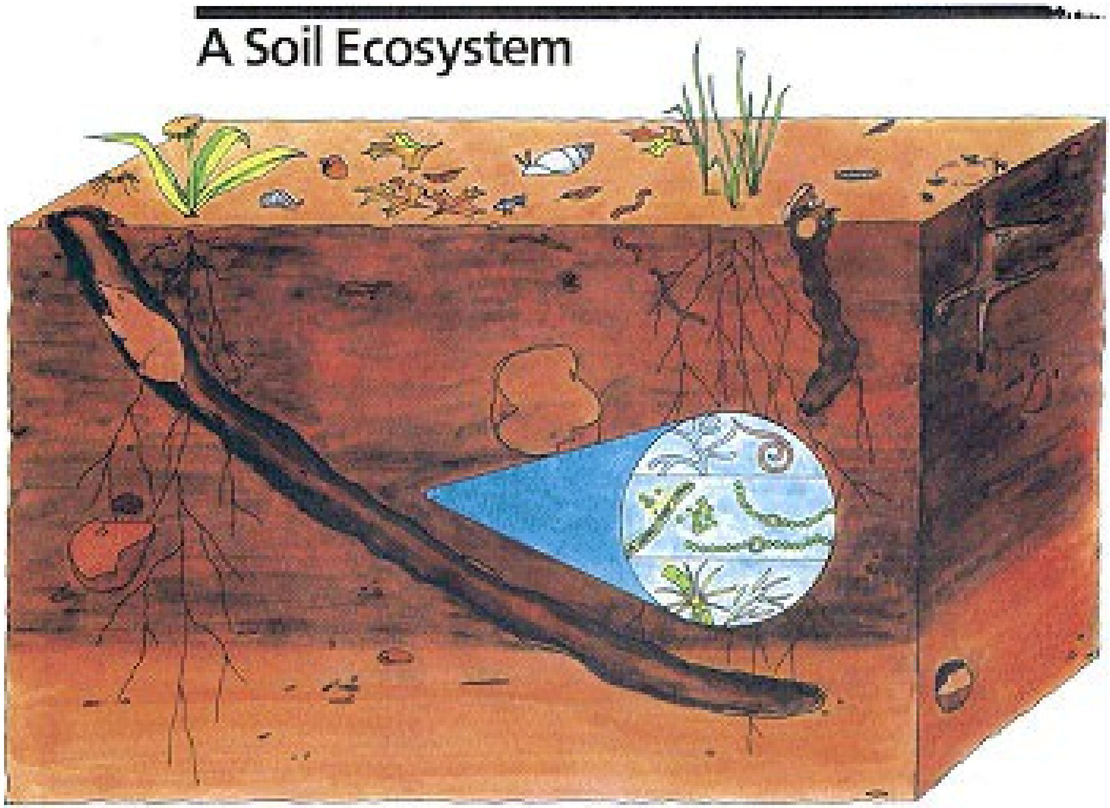
2) In high-precipitation areas the radiocontamination of mycorrhizal mushrooms increased (higher migration into deeper soil layers)



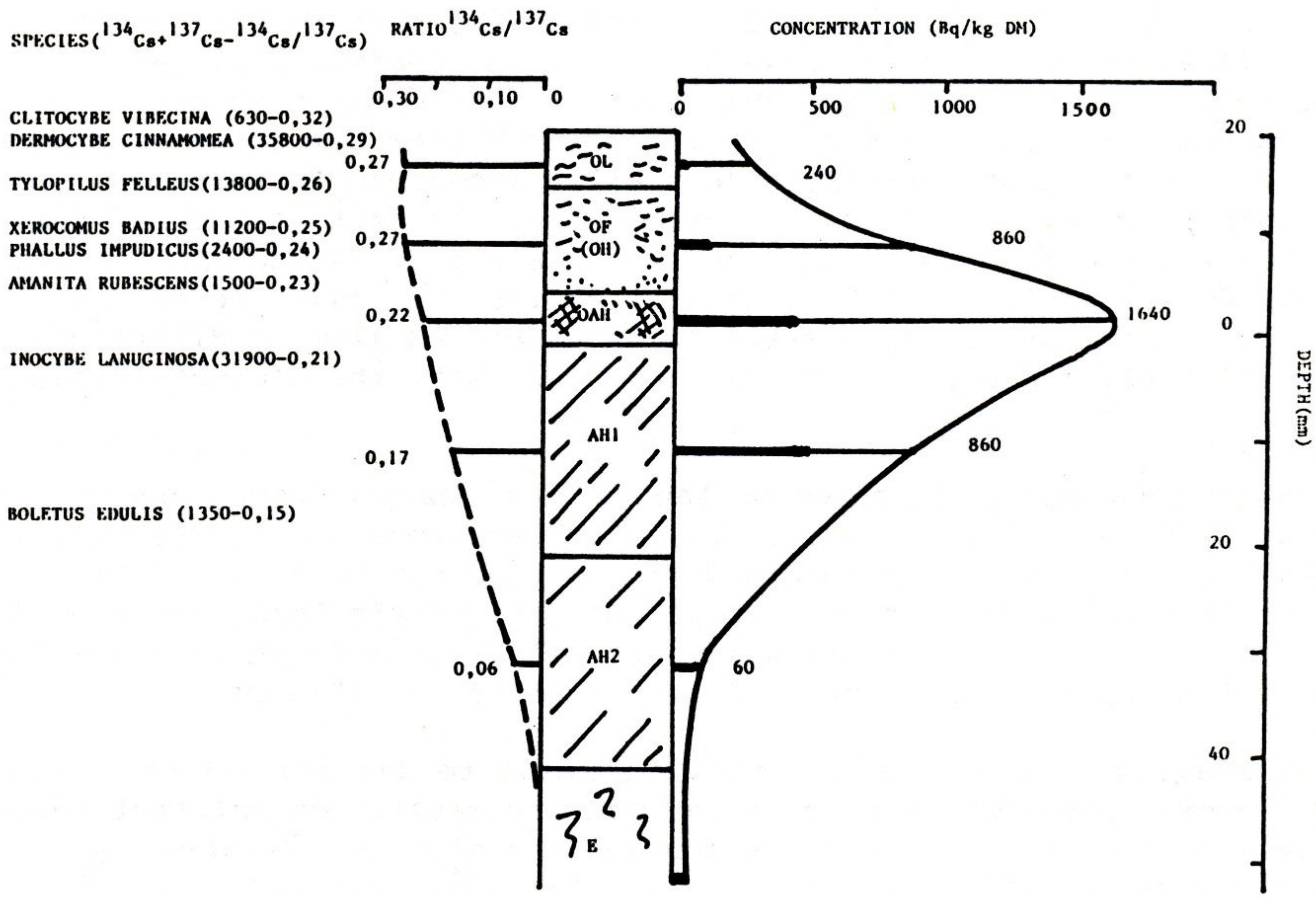
Monitoring the situation 4 years later: most of the radiocesium is still retained in the upper (organic) soil layers…



…and saprophytic fungi still have the highest radiocontamination



Biological retention of radiocaesium in the organic soil layers is high, considerably slowing down its migration into deeper soil layers



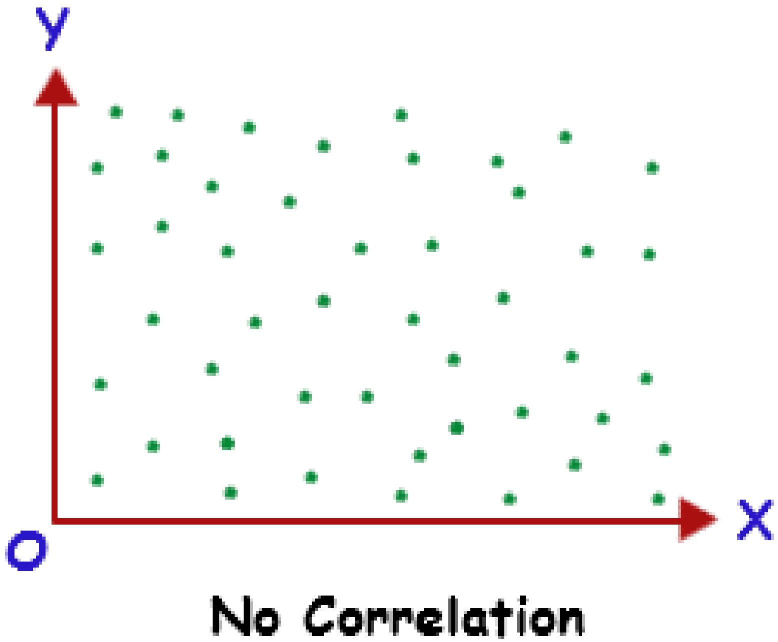
The **ratio Cs134/Cs137** (0.27 at the time of the Chernobyl accident) clearly decreased with mycelium depth…

(from Guillitte et al., 1990)

…likely showing the **pre-Chernobyl contamination**
due to the nuclear tests of the ’60s

2 The radioecology of vascular plants in forest ecosystems is complex as well

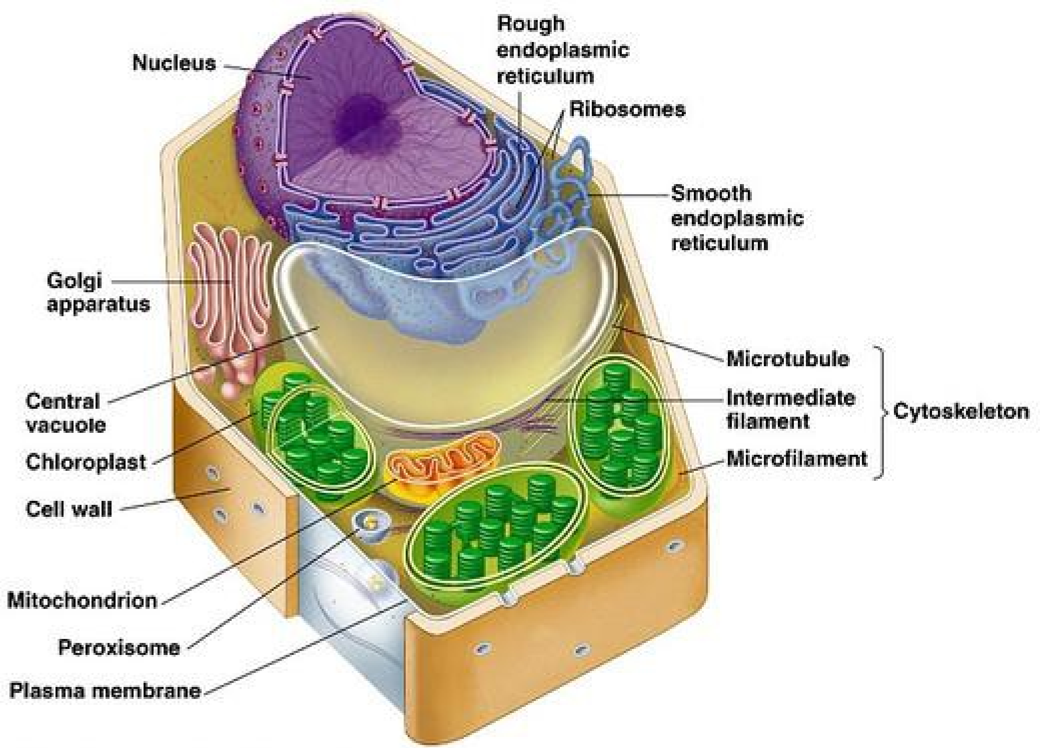
A case study: radiocontamination of leaves, stems and roots of the total flora in a beech forest (48 species)



The analysis of data (expressed in Bq/kg) showed no correlation with any ecological parameter…

Only clear result: leaves were much more contaminated than roots

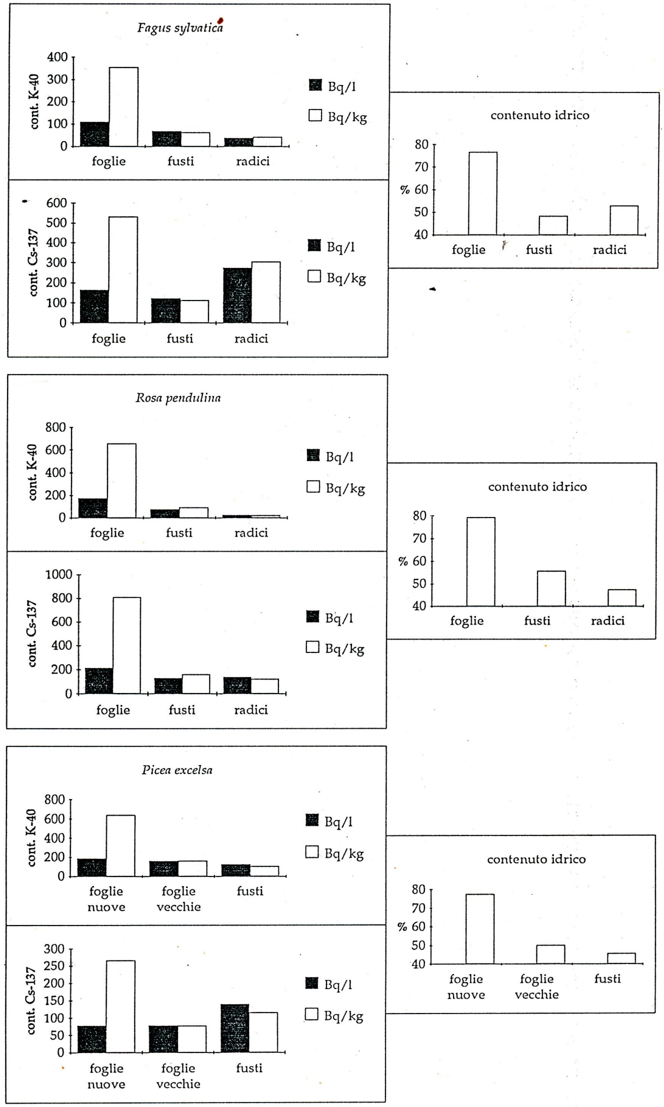
Except in an outlier: a plant with fleshy roots with very high radiocontamination leves!

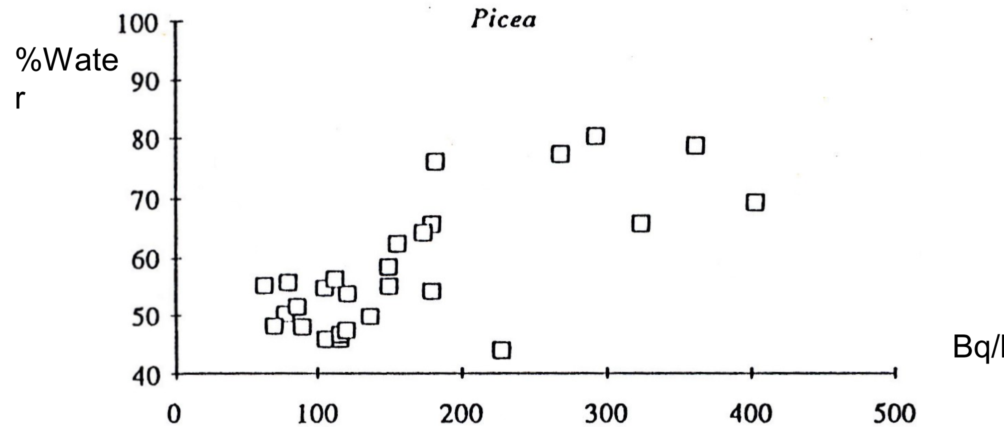


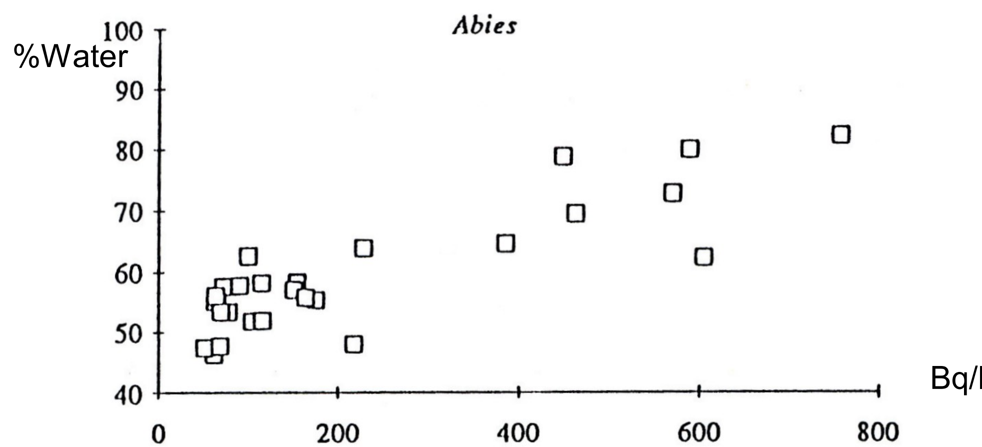
A basic difference between animal and plant cells: **the wall**

Bq/kg or Bq/l ? – An example by analogy

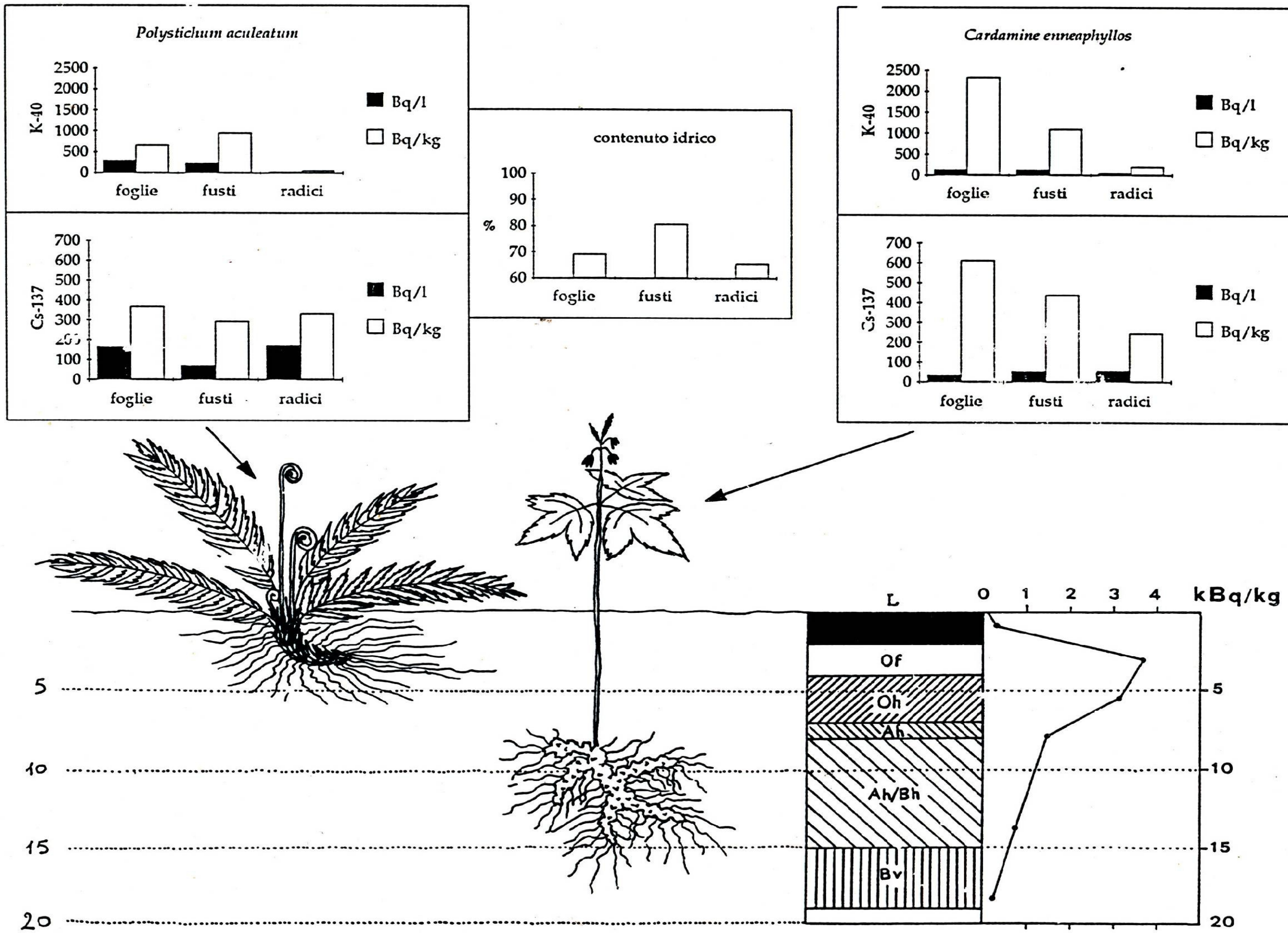
Bq/kg or Bq/l ? – An example by analogy



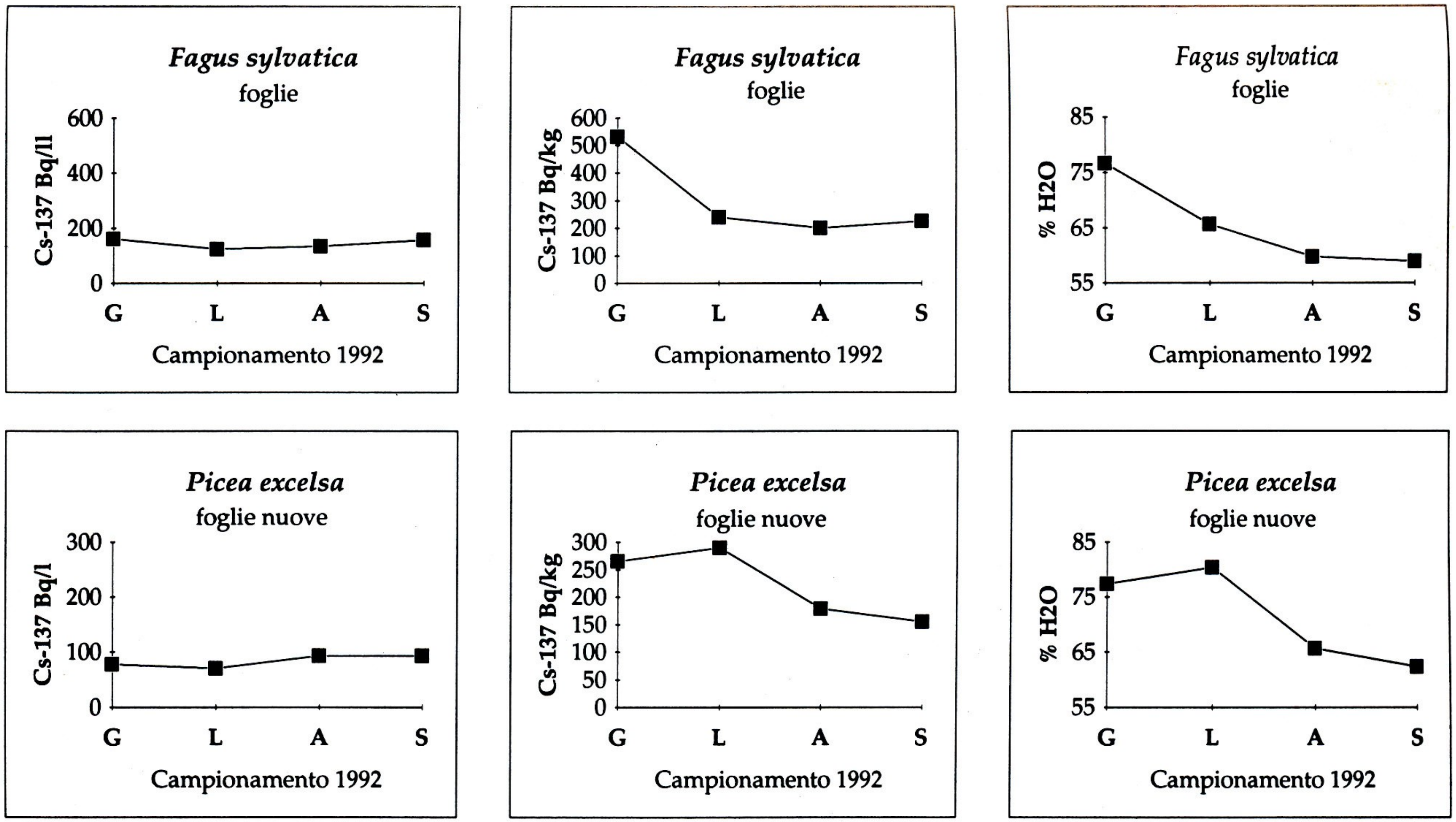




The expression of data in Bq/kg (dry weight) mainly reflects the **amount of water** present in the plant material…



…introducing a **consistent source of bias** in radioecological research



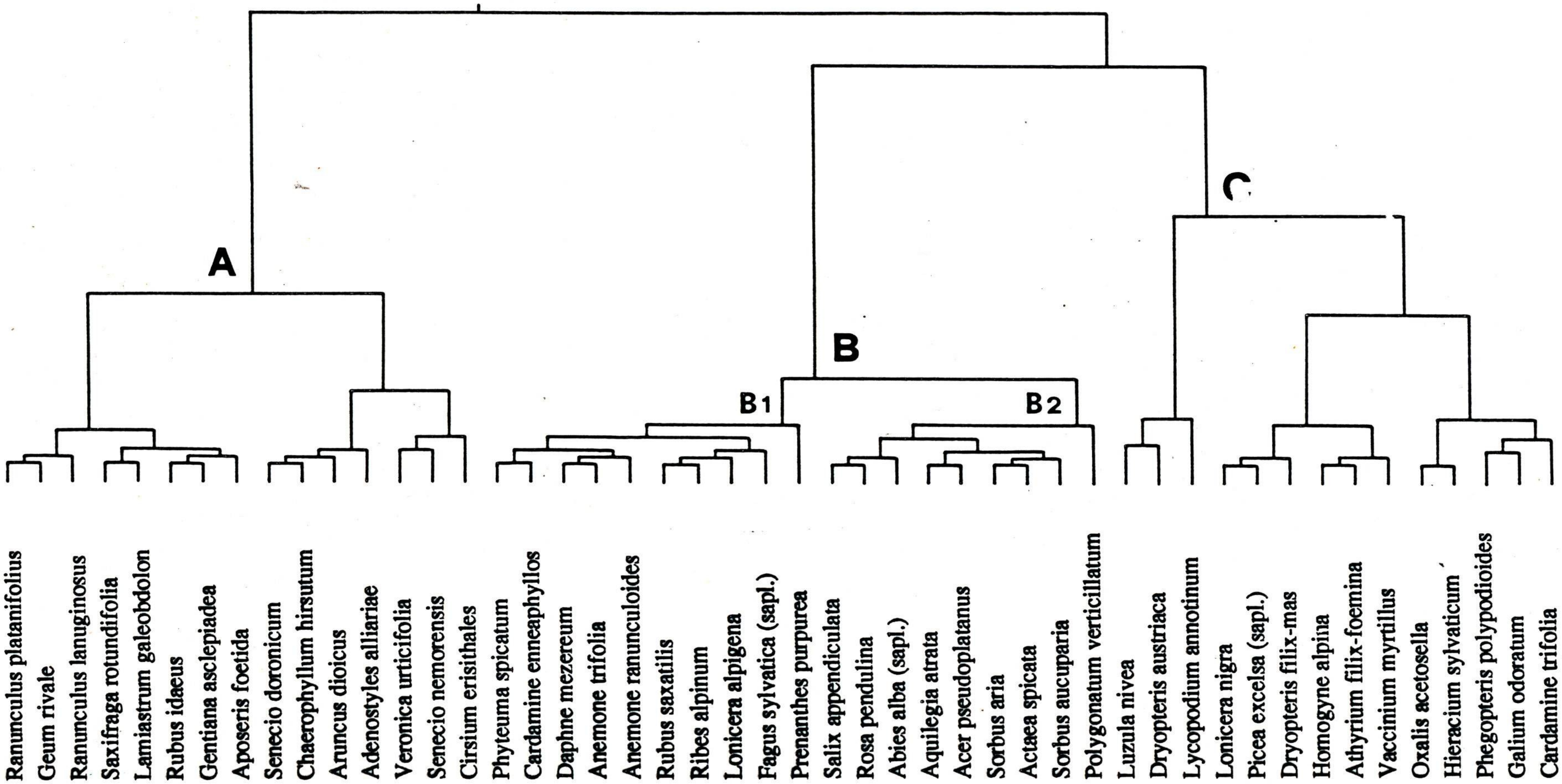
…which can bring to **false results**
(e.g. translocation of radiocaesium within different parts of a plant)

Radioecological variables of the 48 vascular plant species

	$^{137}Cs/^{134}Cs$	Cs_r/Cs_l	Cs_{tot} (Bq/l)	^{40}K(Bq/l)	$^{40}K_r/^{40}K_l$	Root depth (cm)
Ranunculus platanifolius	4.83	2.62	97	96	0.76	5.8
Geum rivale	4.66	2.73	73	89	0.56	5.3
Ranunculus lanuginosus	6.19	2.58	52	185	0.60	5.5
Saxifraga rotundifolia	6.07	3.11	218	78	0.93	6.6
Lamiastrum galaeobdolon	5.35	3.31	180	245	0.46	7.0
Rubus idaeus	5.51	4.08	98	112	0.98	5.0
Gentiana asclepiadaea	4.98	3.79	103	94	0.57	—
Aposeris foetida	5.22	4.39	232	99	0.85	5.3
Senecio doronicum	4.90	5.48	65	174	1.52	—
Chaerophyllum hirsutum	4.88	5.25	106	227	0.87	6.6
Aruncus dioicus	5.47	5.39	83	219	0.37	8.3
Adenostyles alliariae	4.63	6.12	71	133	0.78	9.2
Veronica urticifolia	5.49	8.99	339	159	0.90	5.6
Senecio nemorensis	4.49	7.50	114	273	0.38	–
Cirsium erisithales	5.46	13.11	52	138	2.73	42.0
Phyteuma spicatum	4.88	1.29	102	161	0.33	19.3
Cardamine enneaphyllos	5.05	1.31	109	157	0.55	6.6
Daphne mezereum	5.44	1.62	54	101	0.56	50.0
Anemone trifolia	5.48	1.57	65	164	0.42	4.7
Anemone ranunculoides	5.33	1.80	76	166	0.89	4.7
Rubus saxatilis	5.01	1.56	173	105	0.38	4.6
Ribes alpinum	5.40	1.36	188	143	0.96	50.0
Lonicera alpigena	4.81	2.33	148	183	0.58	50.0
Fagus sylvatica (sapl.)	5.23	2.07	227	147	0.99	20.0
Prenanthes purpurea	5.46	0.91	271	148	0.52	14.3
Salix appendiculata	7.95	0.82	69	84	0.28	50.0
Rosa pendulina	7.62	0.71	142	132	1.11	50.0
Abies alba (sapl.)	6.26	0.45	95	105	0.90	20.0
Aquileegia atrata	7.45	1.61	50	169	0.65	35.0
Acer pseudoplatanus	7.43	1.71	86	202	0.38	60.0
Sorbus aria	6.22	1.32	89	110	0.41	60.0
Actaea spicata	6.45	1.46	152	189	0.99	—
Sorbus aucuparia	7.08	1.69	221	152	0.51	60.0
Polygonatum verticillatum	11.33	0.65	24	116	0.36	25.0
Luzula nivea	4.57	3.89	1215	295	0.53	4.6
Dryopteris austriaca	5.36	0.58	1301	151	0.20	8.0
Lycopodium annotinum	4.82	2.89	2291	114	0.81	1.0
Lonicera nigra	5.28	0.63	256	199	0.19	50.0
Picea excelsa (sapl.)	5.55	0.97	340	116	1.11	20.0
Dryopteris filix-mas	6.27	0.55	332	163	0.29	9.5
Homogyne alpina	4.56	0.93	467	146	0.56	1.0
Athyrium filix-foemina	5.38	0.72	450	152	0.16	10.2
Vaccinium myrtillus	5.64	1.60	376	179	0.63	3.6
Oxalis acetosella	4.66	4.91	556	137	1.98	1.0
Hieracium sylvaticum	4.89	4.71	462	148	1.73	5.2
Phegoperis polypodioides	4.63	3.05	330	150	0.76	4.0
Galium odoratum	4.40	2.39	461	176	0.73	1.5
Cardamine trifolia	4.65	2.33	674	156	0.87	1.1

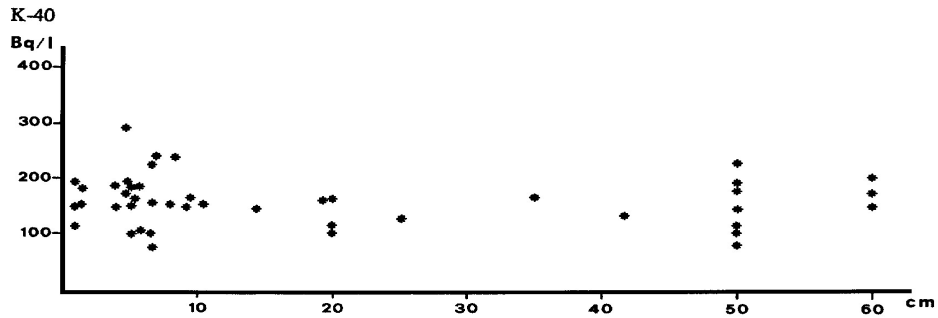
Variables: (1) cesium-137/cesium-134; (2) ratio of cesium-137 roots/leaves; (3) total average radiocesium contamination (Bq/l); (4) total average potassium-40 contamination (Bq/l), (5) ratio of potassium-40 roots/leaves; (6) average root depth (cm).

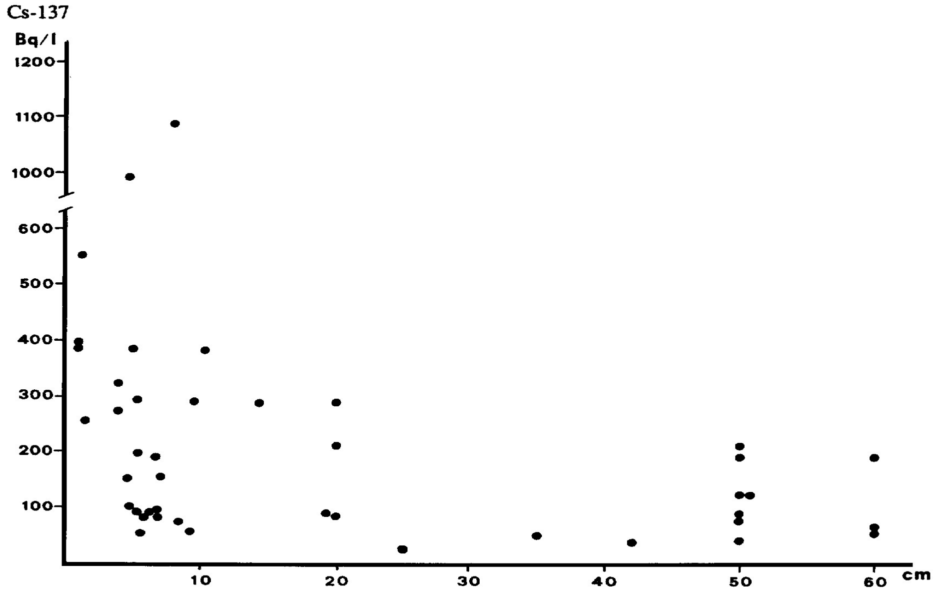
By expressing the data in **Bq/l**
(i.e. on the difference between fresh and dry weight…)



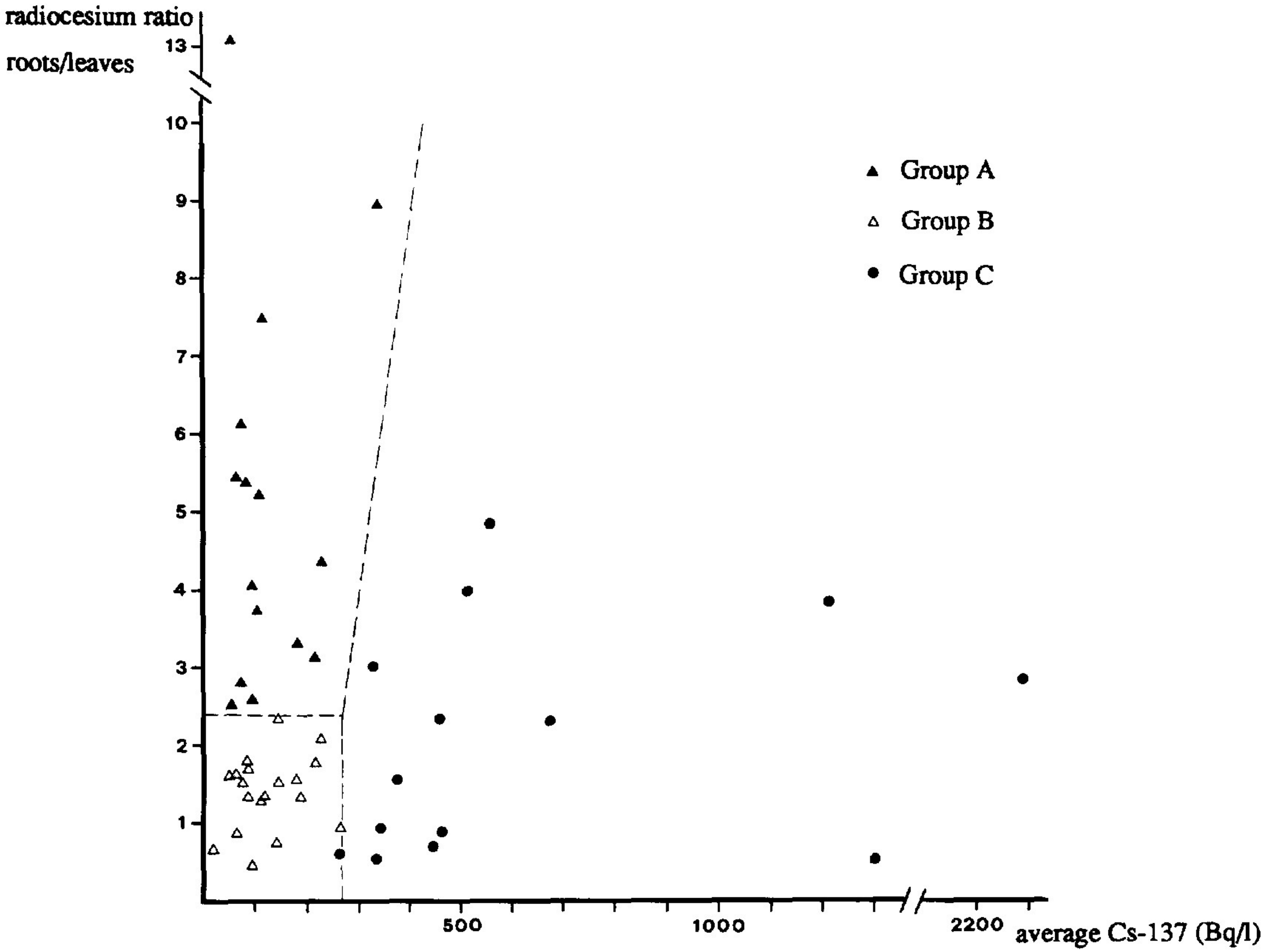
The species are subdivided into 3 clusters

corresponding to 3 well-known ecological groups



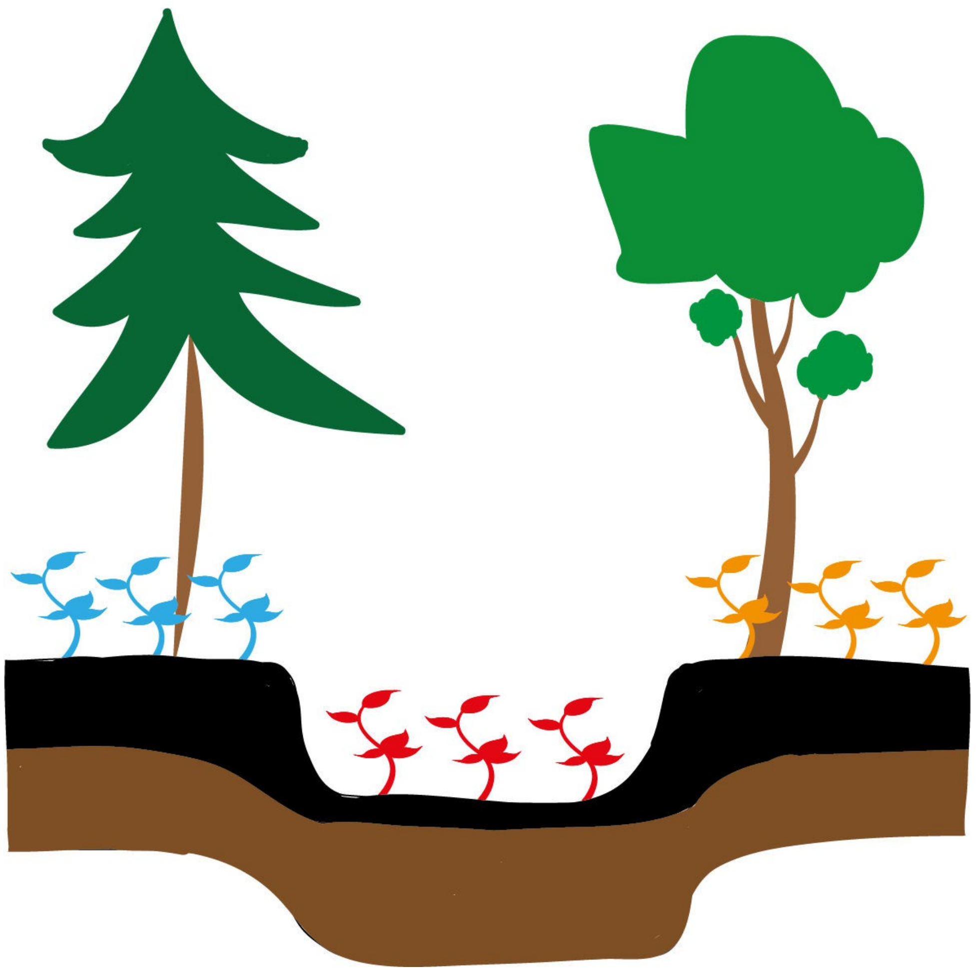


The radiocontamination of plants is **well correlated** with the average depth of their rooting systems…



…and the 3 groups of species are **neatly separated by some radioecological variables**

Gr.A
Gr.B
Gr.C



Lessons learnt: 1) radiocontamination patterns in forest ecosystems may be very complex. 2) Expressing radiocaesium data in Bq/l permits to disentangle this complexity.

3 – With mosses it's easier!

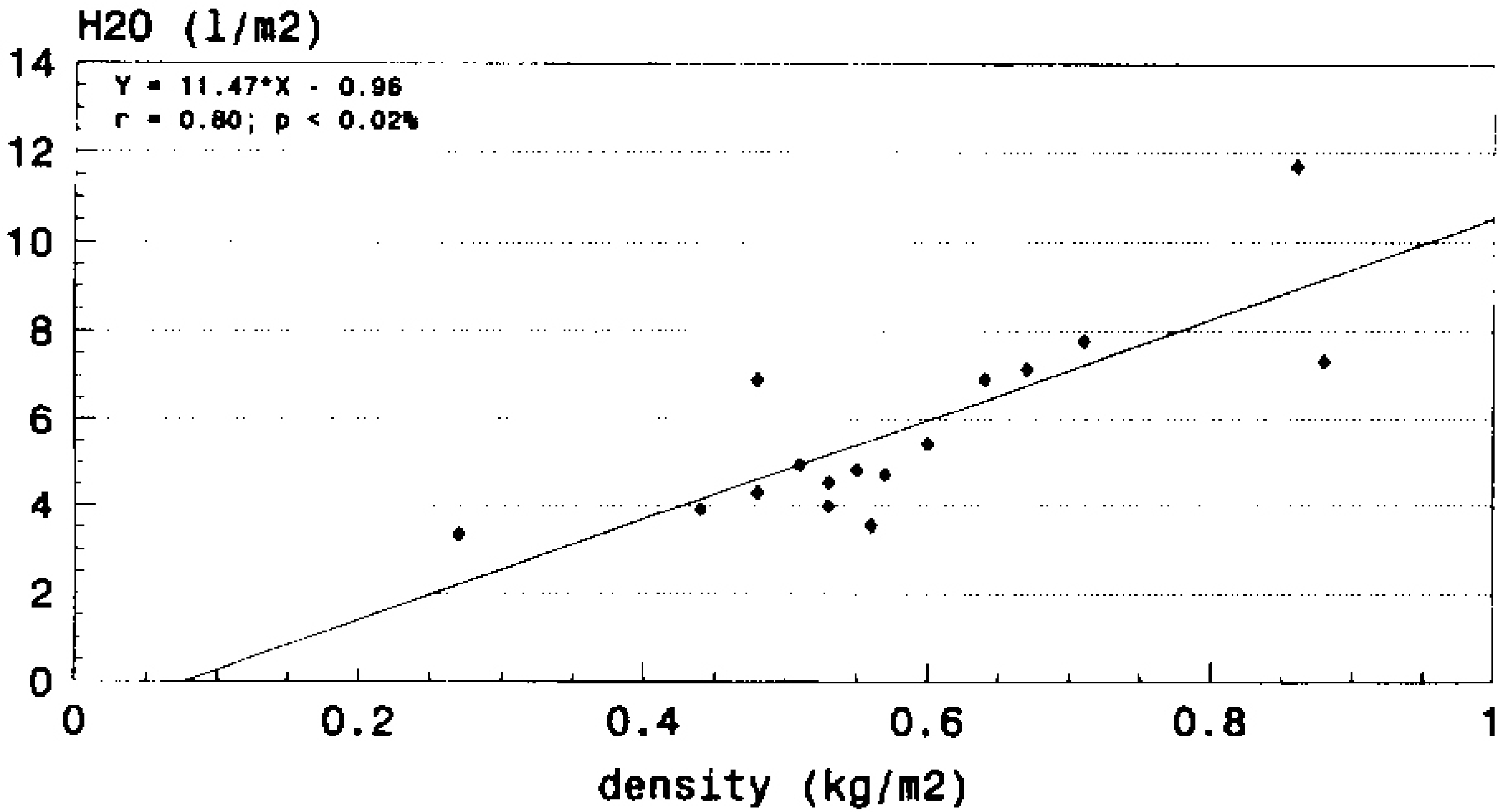
The regional authorities wanted a **bioaccumulator** to rapidly map the extent of radiocontamination all over the region

Advantages of using moss carpets:

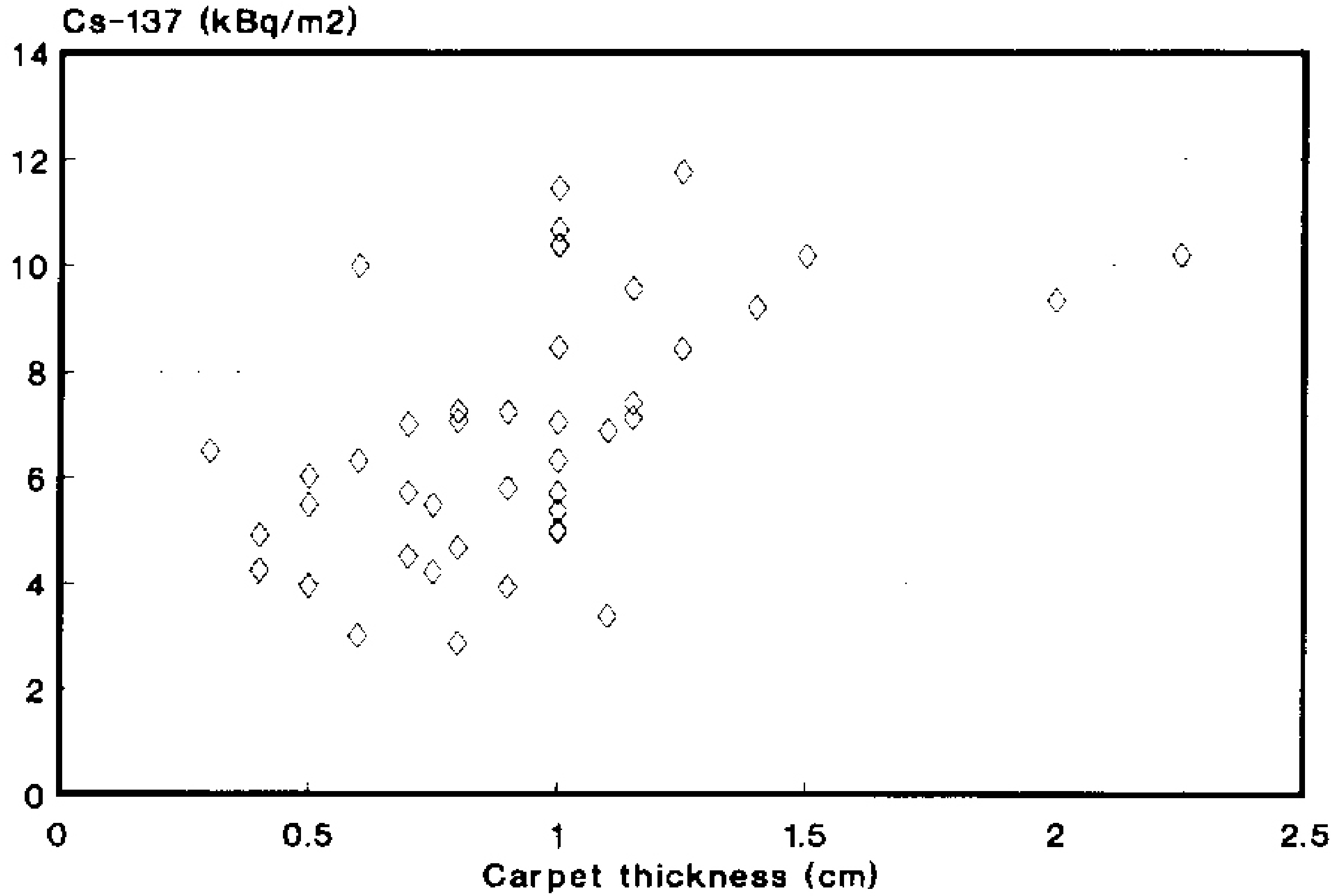
1) They produce a very homogeneous soil, withour mineral inclusions

Advantages of using moss carpets:

2) They can be easily cut into geometrical forms (assessing radiocontamination per unit area)



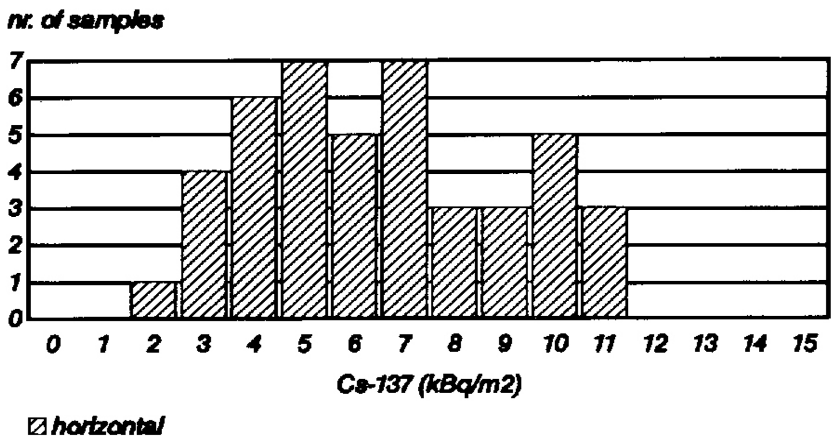
Developing a sampling protocol, **1st step**: assessing the absorbing power of moss carpets (in terms of density): moss carpet can absorb up to 12 l of water per square meter

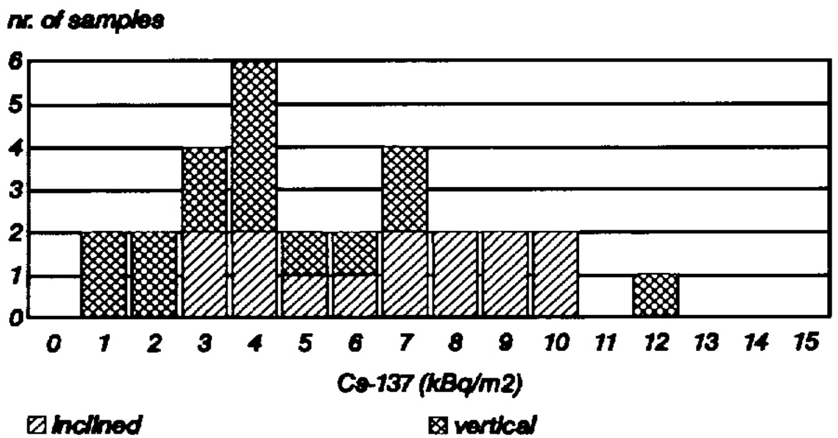


Developing a sampling protocol, **2nd step**:
assessing the absorbing power of moss carpets: the absorbing power **is related to carpet thickness**

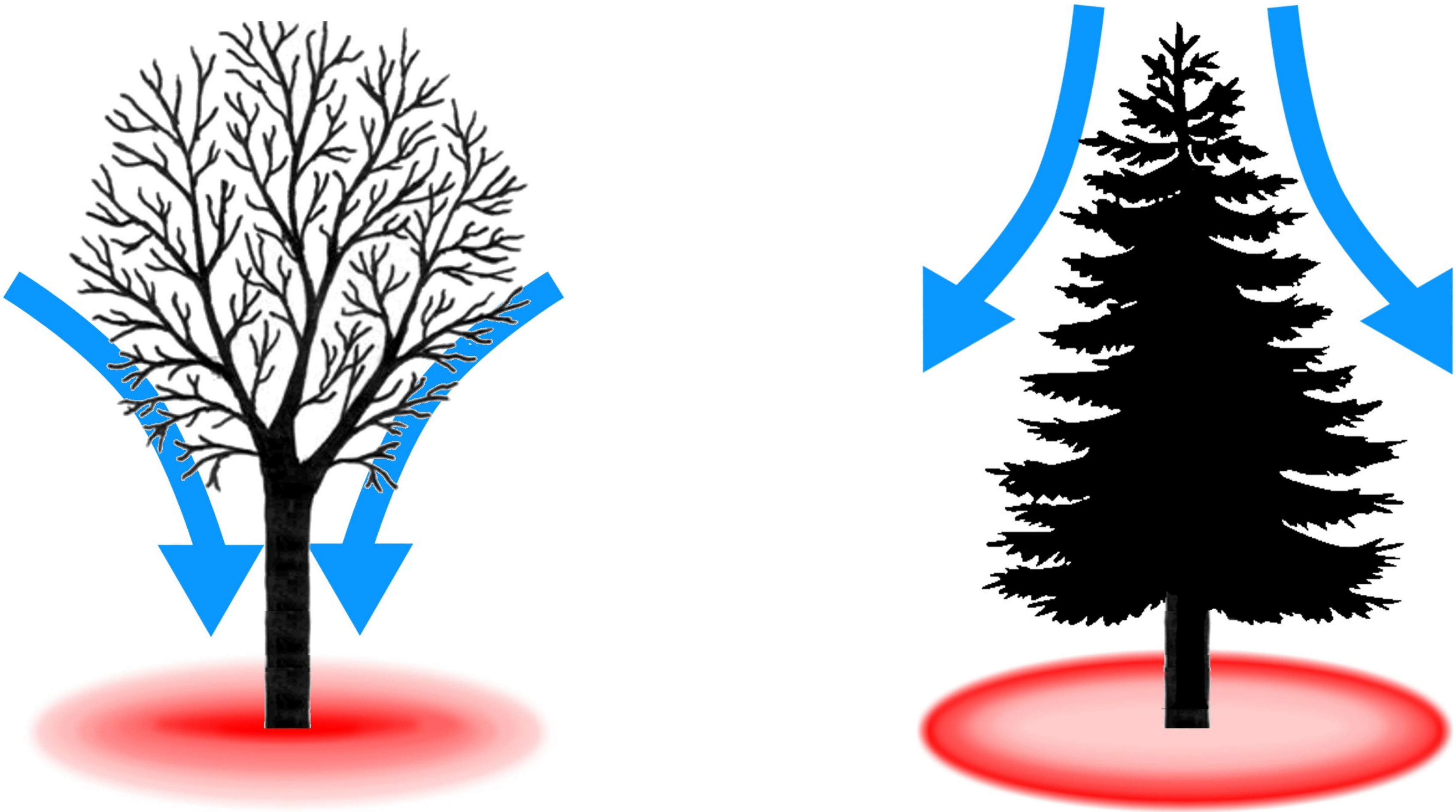
The selected bioaccumulator: ***Ctenidium molluscum***
(high absorbing power, widespread and common in forests ecosystems)

Reducing data variability: inclination has an effect on radiocontamination values

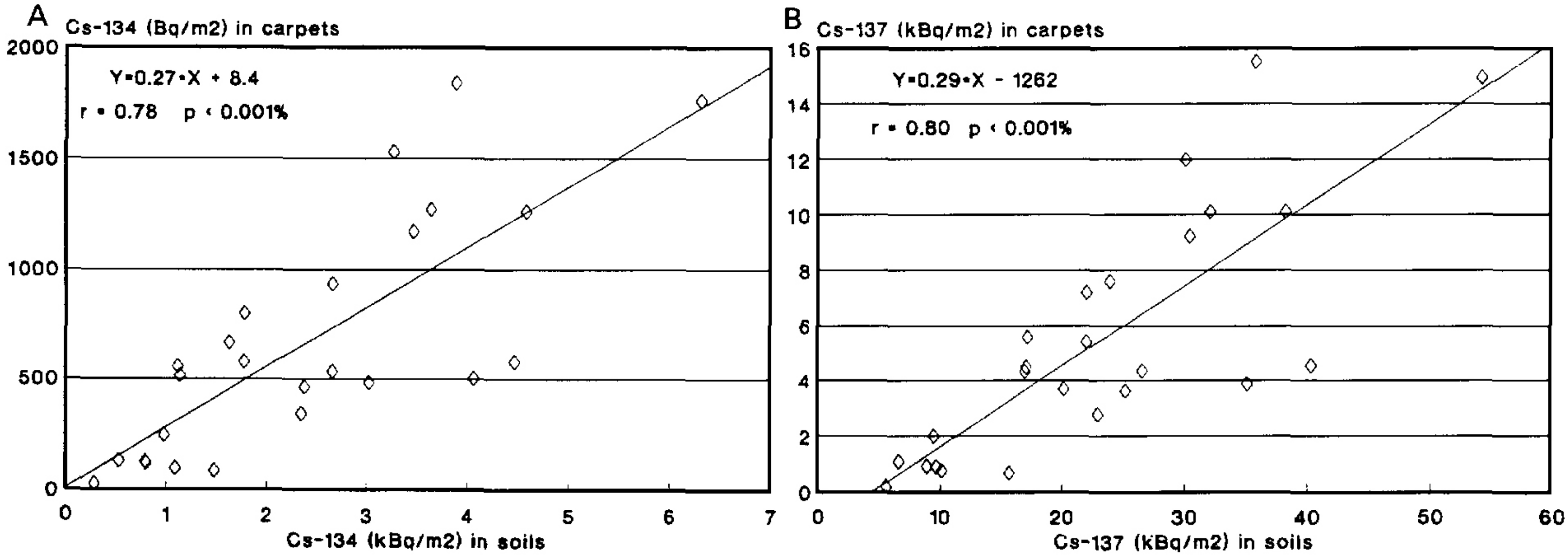




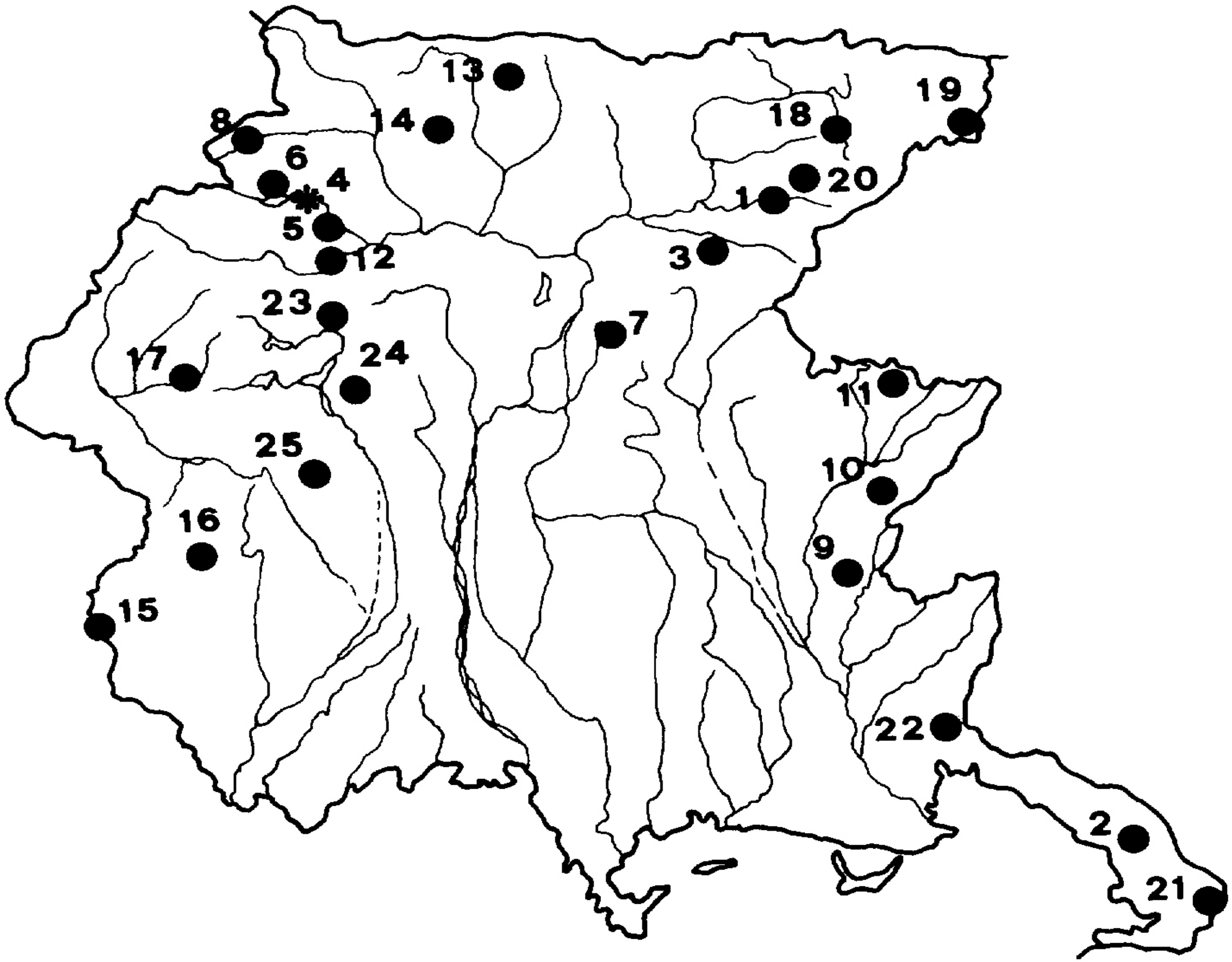
Developing a sampling protocol, **3rd step**:
assessing the influence of inclination
on the radiocontamination of moss carpets



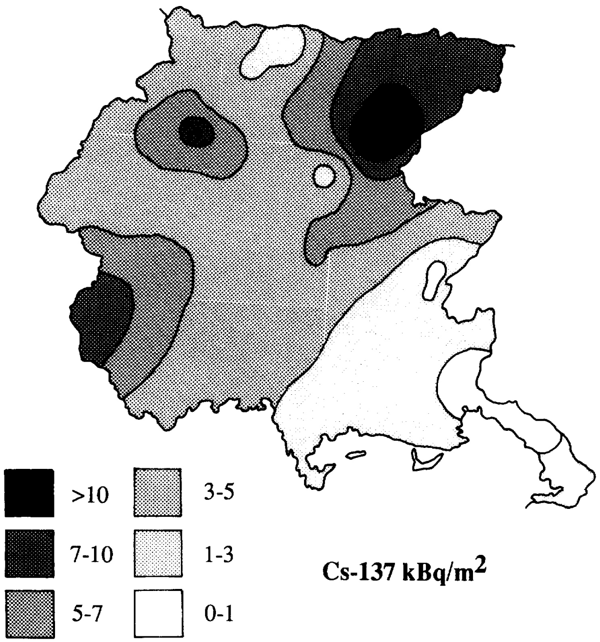
Developing a sampling protocol, **4th step**:
assessing the effect of tree crown geometry on radiodeposition

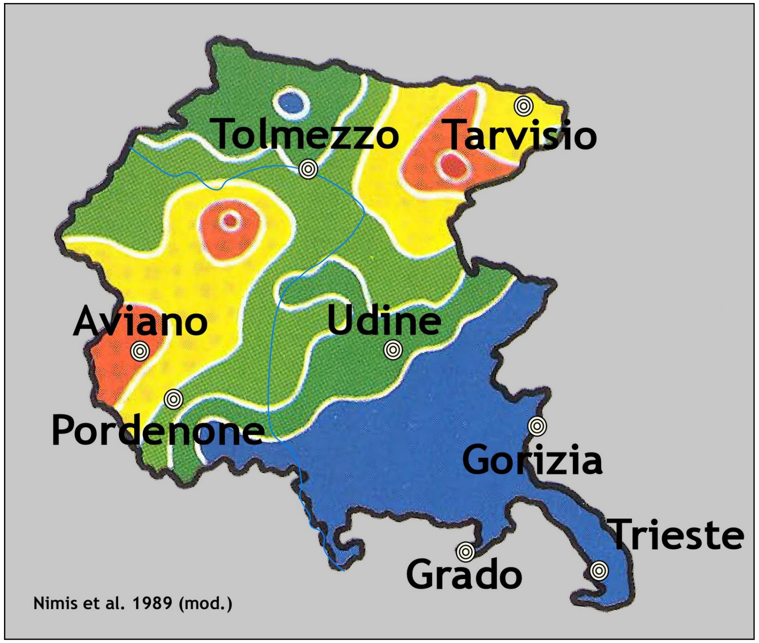


Testing the sampling protocol: **predictive value** of moss data versus soil data



Testing the sampling protocol: the 1990 campaign

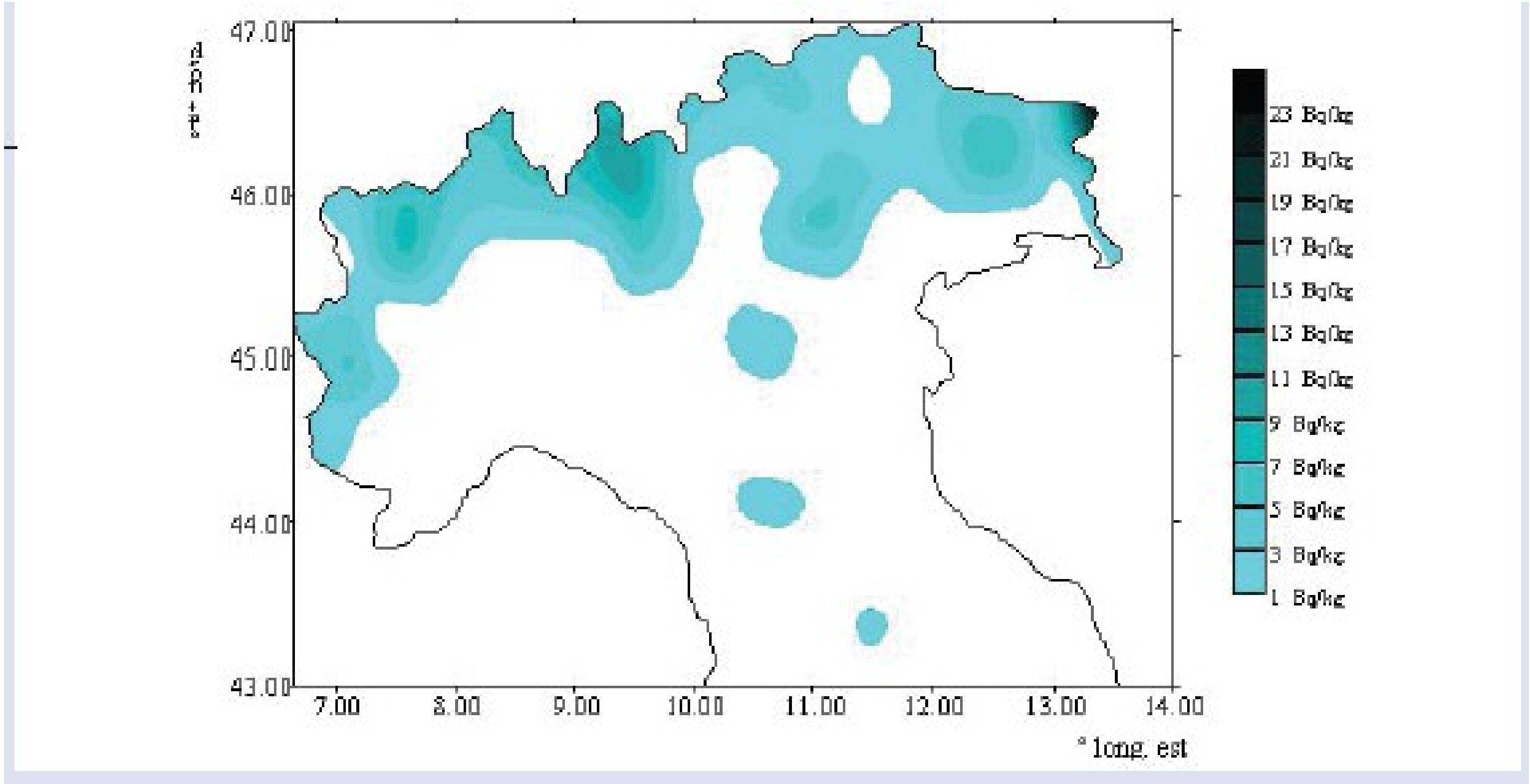




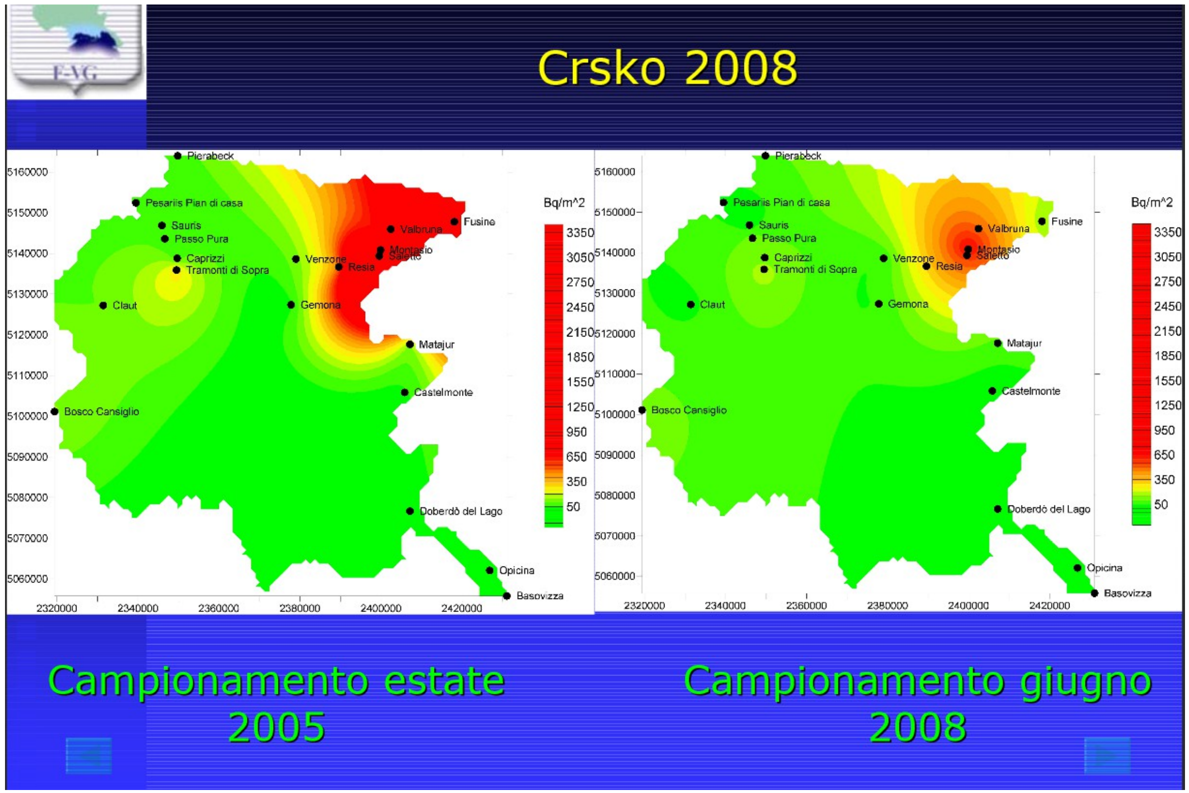
Mosses 1990 (Bq/m²)

Mushrooms 1986 (Bq/kg)

The results of the 1990 campaign (less than a week):
mosses are optimal bioaccumulators!

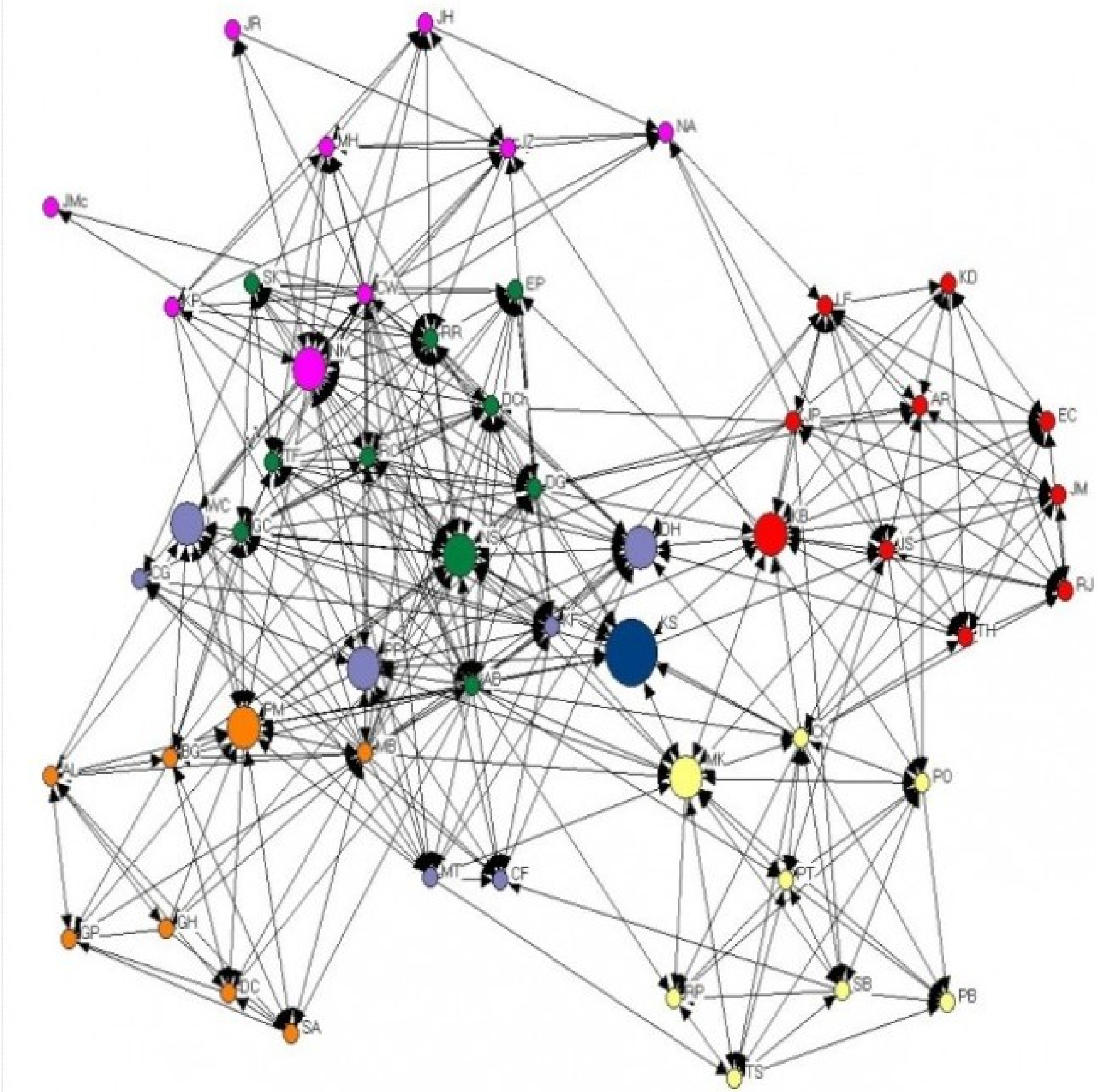


Our protocol was **adopted at the National level** to monitor radiodeposition in forest ecosystems…



...and proved to be useful for the **rapid assessment of radiocontamination** after an accident (Crsko, Slovenia, 2008)

4 - Final remarks: the complexity of forest ecosystems



Final remarks: historically, radioecoloogy developed from radioprotection: the first studies and models were mainly carried out in simple agroecosystems.

Final remarks: however, agroecosystems and forest ecosystems are widely different

1) In forests, plants avoid root competition by exploring different soil layers with different biological, chemical and physical characteristics,
2) many plant species are in mycorrhizal symbiosis with fungi,
3) Microgeomorphological variation may induce sharp micropatterns in soil radiocontamination.
4) Thus, **spatially contiguous plants might root in widely different soil types**.

Final remarks: in complex forest ecosystems **the aims of radioecology and radioprotection do not always coincide**.

Different approaches are often needed for different aims.
However, radioecology is fundamental to develop predictive models which are of basic importance for radioprotection.


Thank you for the attention !