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Assessment of ^{137}Cs inventories in agricultural landscapes: soil sampling of actual ploughed horizon or standardized layers?

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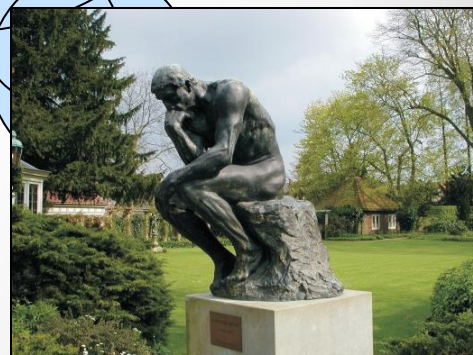
Outline

- Assessment of ^{137}Cs inventories in soil is the key factor for elaboration of land use strategy. Most of uncertainties in this assessment derived from soil sampling procedure, in particular, from a chosen depth of soil collection. Sampling of fixed 0-10(15) cm surface layer for soils with undisturbed profile and sampling of ploughed horizon (Ap) for arable soils is recommended and common (*Soil Sampling for Environmental Contaminants*, IAEA-TECDOC, no. 1415, IAEA, Vienna, Austria, 2004).
- But different crops of field rotation are cultivated nowadays with different depth of tillage. Thus, considerable uncertainties in assessment of ^{137}Cs inventory in soil can occur while sampling only current Ap horizon.

Objectives:

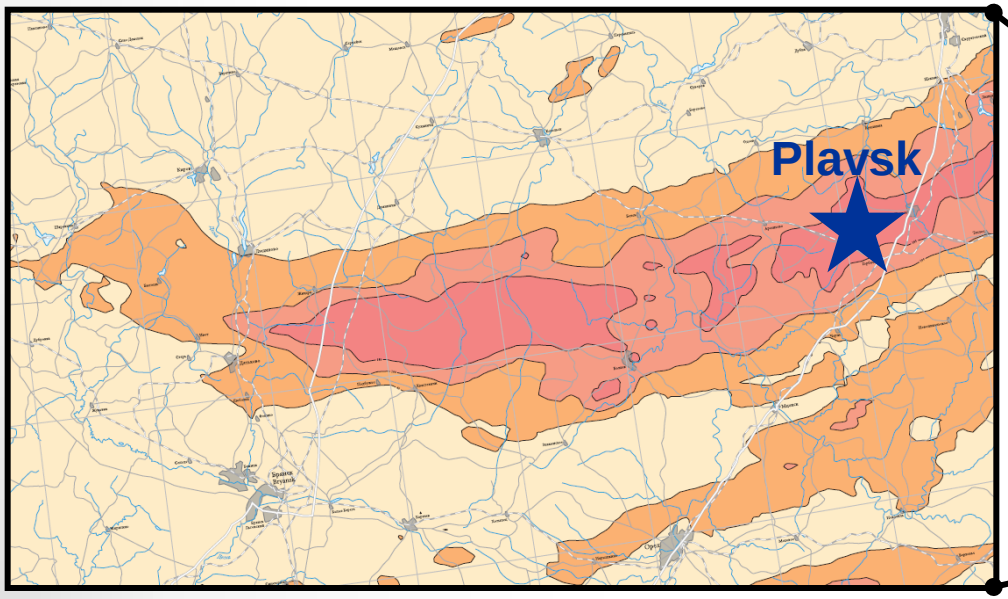
- The main purpose of the present study was to clear the accuracy of soil sampling from current Ap horizon for the precise determination of ^{137}Cs inventory in cultivated chernozems in the area of European Russia strongly contaminated by the Chernobyl fallout with 3 decades passed since the contamination event.



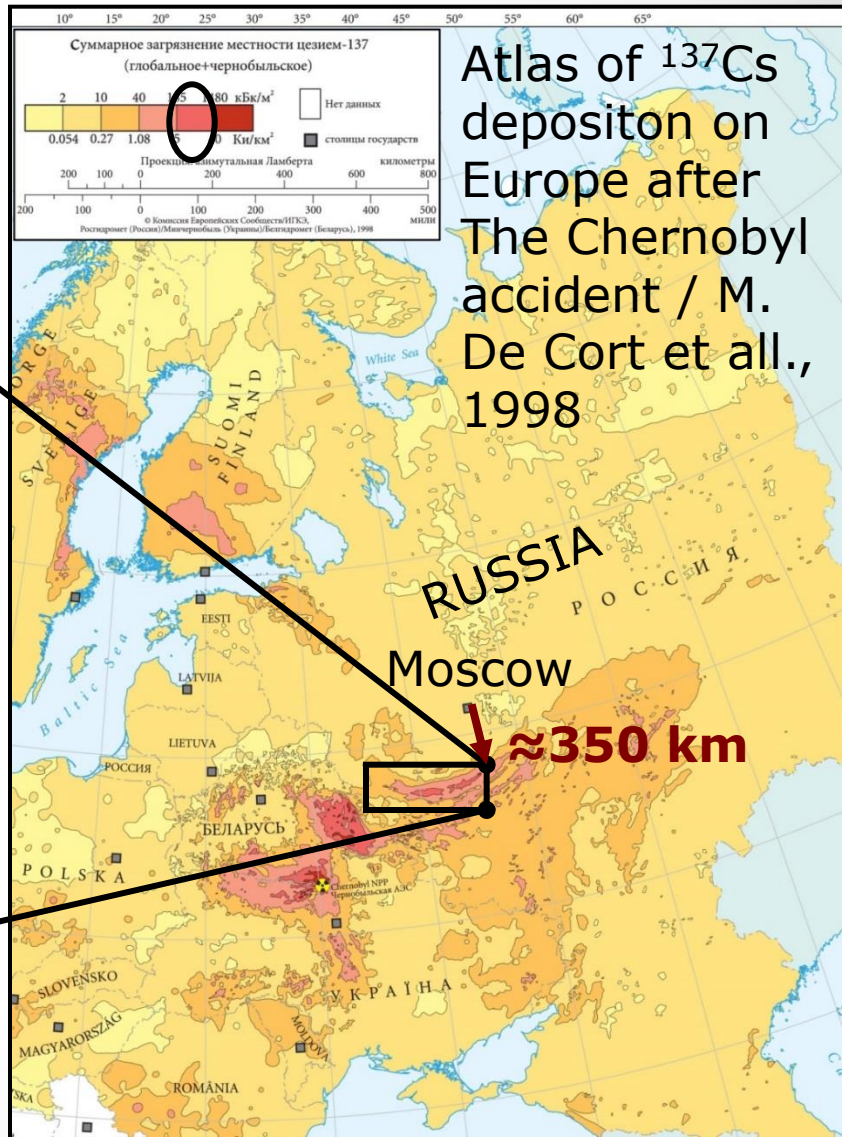
The Plavsk radioactive hotspot, Tula region

Objects

^{137}Cs deposition 185-555 kBq/m^2



Russian radiation safety standard for ^{137}Cs - 37 kBq/m^2



Agricultural landscapes of the Plavsk radioactive hotspot

Objects

Soil cover of the Plavsk radioactive hotspot

A+AB ~60-80 cm

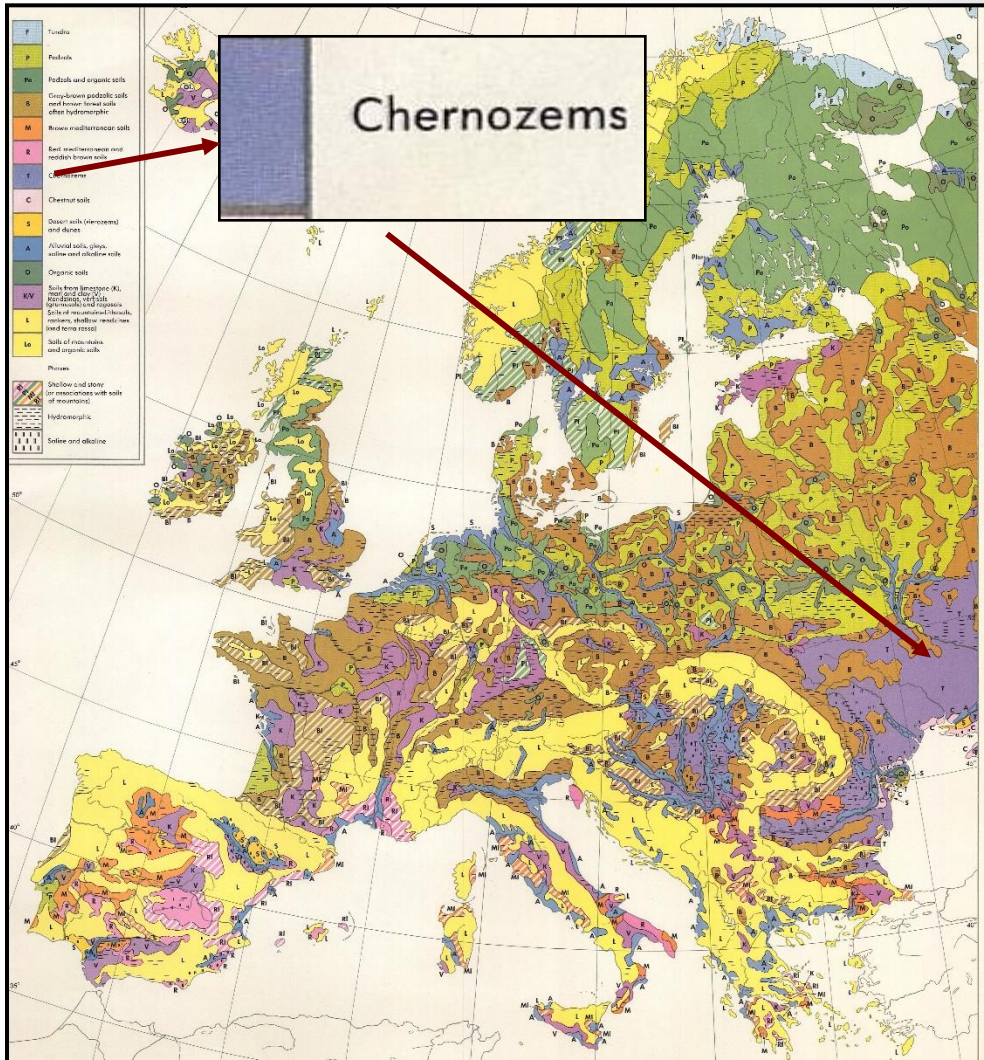
C_{org} 4.9-7.3%

pH_w 6.2-6.7

d_V1.1-1.2 g/cm^3

loamy texture

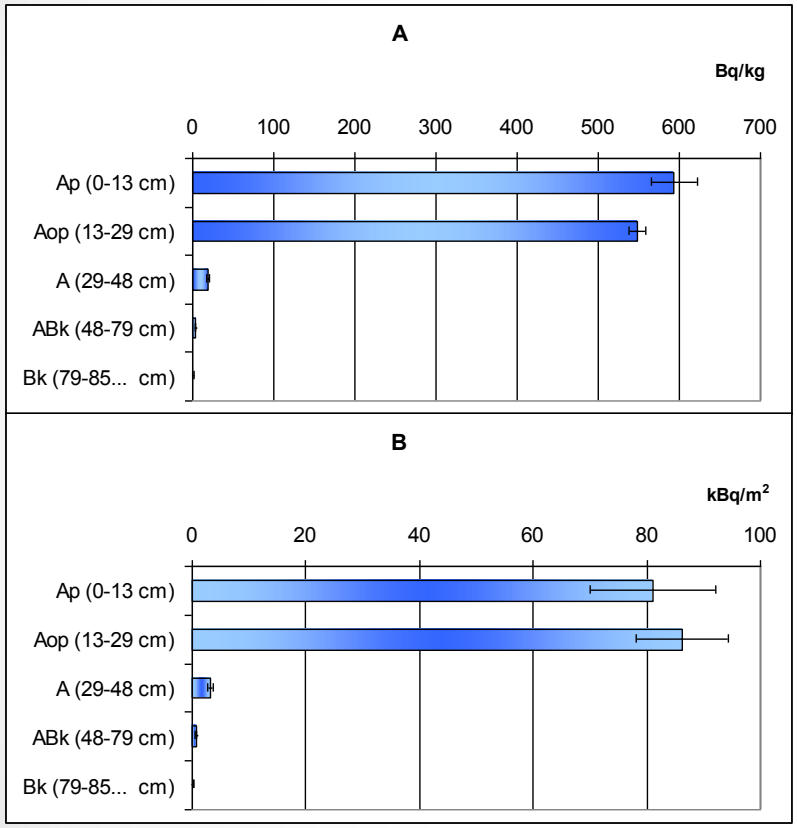
EU Soil Map by Prof.Dr.H.E. Stremme



Methodology

- Soil samples were taken in triple replications:
  - from sample's strata 0-10 cm, 10-20 cm, and 20-30 cm (within a uniform elementary soil areal 5-15 m from each other),
  - from top current Ap and old- ploughed (Aop) genetic horizons (from front and side walls of a single soil section)
    - The depth of Ap horizon varied from 10 cm (wheat, barley) to 20 cm (buckwheat, amaranth, white mustard), and to 25-28 cm (maize, soybean, potatoes). There is no annual agrogenic turbation for the grass mixture.

Why did we examine the soils of the Plavsk radioactive hotspot up to depth 30 cm?



- Typical profile distribution of ^{137}Cs in cultivated chernozems of the Plavsk radioactive hotspot:
  - A - ^{137}Cs specific activity, Bq/kg
  - B - ^{137}Cs inventory, kBq/m^2

* Homo/heterogeneity of Cs-137 distribution within ploughed horizon of arable chernozems, 30 years after Chernobyl accident / Paramonova T., Belyaev V., Komissarova O., Ivanov M. // Radiation and Applications. — 2017. — Vol. 2, no. 3. — P. 192–199.

- Considerable radioactive contamination detected in the 20-30 cm layer clearly demonstrates deep ploughing up to 30 cm for the remediation of lands of the Plavsk radioactive hotspot after Chernobyl accident in 1986.

Sampling area and plots

Soil sampling has been conducted on 8 test plots with main crops occupying the investigated space: wheat, barley, maize, potatoes, soybean, rape, amaranth, and legume-cereal grass mixture.

Soil sampling









Results

- The range of total ^{137}Cs inventories in top 30-cm layer of arable chernozems of the Plavsk radioactive hotspot varied from 106 to 196 kBq/m^2 reflecting primary spatial heterogeneity of Chernobyl fallout and secondary translocation of the radionuclide due to erosion process.
- Arithmetic mean and median values of total ^{137}Cs inventories in soil patterns were quit similar (155-156 kBq/m^2); variation coefficient (Cv) was equal to 20%.

^{137}Cs inventories in standardized incremental 10-cm layers of arable chernozems up to depth 30 cm, kBq/m^2

Soil depth	wheat	barley	maize	potatoes	soybean	rape	ama-ranth	grass mixture
ridge				38,2				
0-10 cm	47,3	42,2	66,6	36,1	64,1	55,3	54,2	32,9
10-20 cm	51,8	51,9	78,7	45,0	68,8	85,5	50,6	37,0
20-30 cm	40,9	33,2	28,4	34,3	55,6	55,4	54,0	36,3

Variability of ^{137}Cs inventories in incremental 10-cm layers of arable chernozems up to depth 30 cm, kBq/m^2

Soil depth	Mean	Median	Confidence limits, ±	Range	Cv, %
0-10 cm	49,8	50,7	8,6	32,9 - 66,6	25
10-20 cm	58,7	51,8	11,8	37,0 - 85,5	29
20-30 cm	42,3	38,6	7,7	28,4 - 55,6	26

Results

- Assessment of total ^{137}Cs inventories by incremental 10-cm layers of arable chernozems up to depth 30 cm has revealed the heritage of deep ploughing of contaminated fields after the event of Chernobyl radioactive fallout in 1986, as well as demonstrated comparable data of testing different crops of field rotation.

^{137}Cs inventories in current Ap horizon of arable chernozems under different crops of field rotation

Crop	wheat	barley	maize	potatoes	soybean	rape	ama-ranth	grass mixture
Ap thickness, cm	10	10	27	30	25	20	25	no tillage
^{137}Cs, kBq/m^2	47,3	42,2	155,3	153,6	145,9	140,8	124,8	106,2

	Mean	Median	Confidence limits, ±	Range	Cv, %
^{137}Cs, kBq/m^2	114,5	132,8	31,9	42,2 – 155.3	40

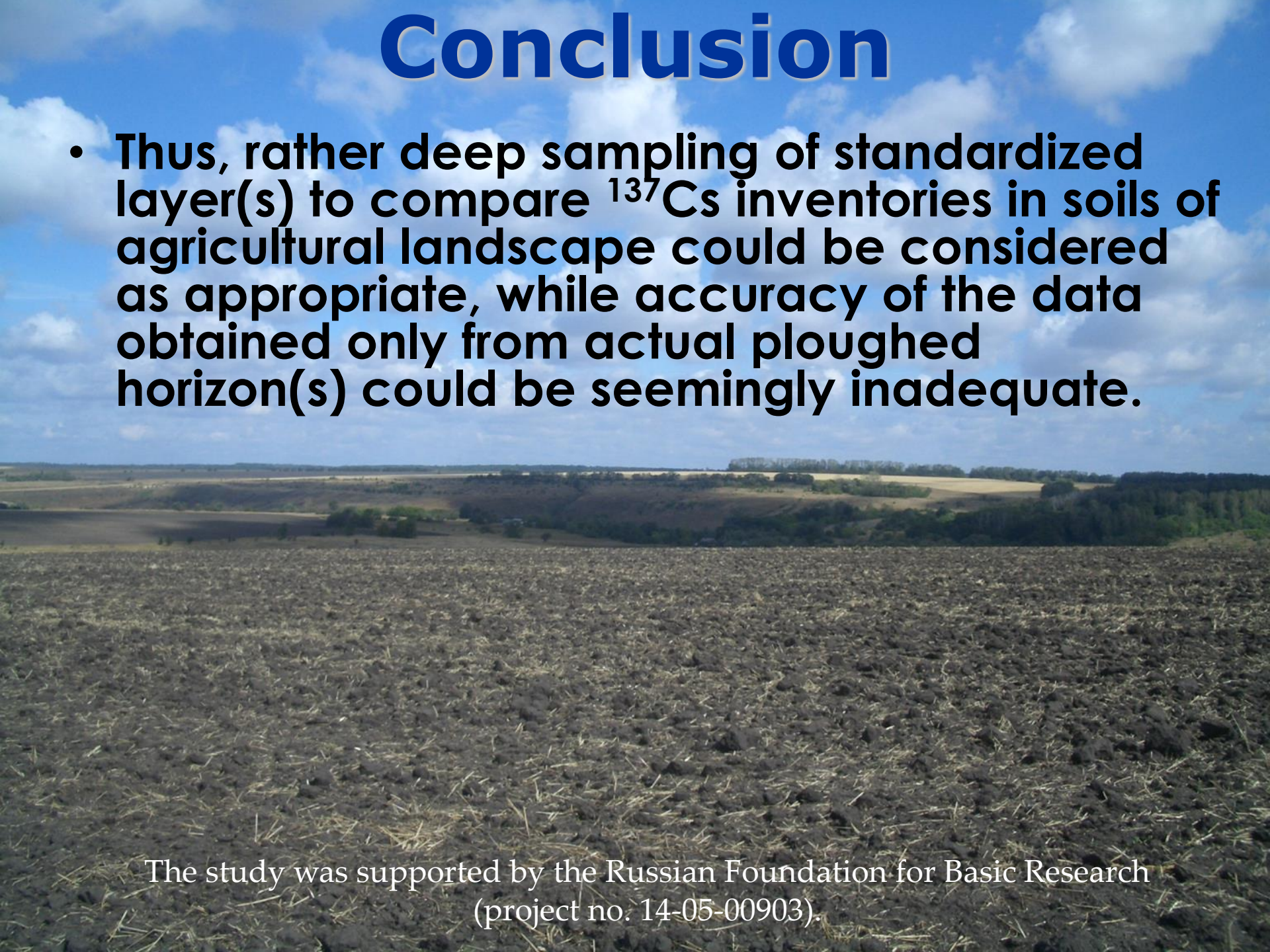
Results

- When comparing ^{137}Cs inventories using the samples of current Ap the rise of uncertainties is obvious: the density of soil radioactive contamination seems to be 42-47 kBq/m^2 for cereals, 106-155 kBq/m^2 for row crops, and 154 kBq/m^2 for potatoes. Median is shifted relative to arithmetic mean, and Cv builds up to 40%.

- In addition, soil sampling limited by actual Ap prevents the assigning of ^{137}Cs inventories in old Ap that is unlikely reasonable.

Conclusion

- Thus, rather deep sampling of standardized layer(s) to compare ^{137}Cs inventories in soils of agricultural landscape could be considered as appropriate, while accuracy of the data obtained only from actual ploughed horizon(s) could be seemingly inadequate.



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