

## **Towards a better understanding of $\gamma$ -ray for soil mapping – analysis of $\gamma$ -ray measurements at field sites across Europe**

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### **Abstract**

Radionuclide concentration in soils depends on soil parameters, geological origin and exogenous conditions (e.g. weather, moisture). For usage of  $\gamma$ -ray data spectrometry in Digital Soil Mapping a translation by geophysical transfer-functions into soil parameters is needed. A prerequisite to develop such functions is a reliable comparison between measurements at different field sites and times. This can be done by (1) using quantifiable field data or (2) usage of additional lab  $\gamma$ -ray data. In our study we took soil samples for analysis of  $\gamma$ -ray concentration in laboratory. In this way we compared point  $\gamma$ -ray measurement with lab  $\gamma$ -ray data from two different field sites.

**Keywords:** airborne  $\gamma$ -ray spectrometry,  $\gamma$ -ray lab measurements, soil mapping

### **Introduction**

Airborne  $\gamma$ -ray spectrometry is used more and more for spatial mapping of soil parameters. The measured isotope concentration of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  in soils depends on different soil parameters, which are the result of composition and properties of parent rock and processes during soil genesis under different climatic conditions. Grain size distribution, type of clay minerals and organic matter are soil parameters which directly influence the  $\gamma$ -ray concentration. A general comparison between grain size and nuclide concentration is described by Megumi and Mamuro (1977). During laboratory analyses, they found an increase in concentration of  $^{238}\text{U}$  and  $^{230}\text{Th}$  with decrease in particle size below 0.15 mm, which can be explained by an increase in surface adsorption at decreasing grain sizes. Schön (1996) reports the influence of clay content as one parameter for radionuclide concentration in unconsolidated sediments. Taylor (2002) shows poor correlation between clay content and ground  $\gamma$ -ray measurements during high-resolution mapping survey in Western Australia. However airborne  $\gamma$ -ray measurements seem to correlate more strongly to particle size than ground measurements. Such relationship for airborne  $\gamma$ -ray measurements were also reported by Purvis and Buckmeier (1969). They found that sand has lower  $^{40}\text{K}$  concentrations than clay. It was confirmed by Kiss et al (1988), who stated that this effect depends on soil genesis.

All these studies were site specific. With respect to the geological background and pedogenesis it might be possible to develop a more regional approach for  $\gamma$ -ray interpretation, e.g. geophysical transfer-functions at the landscape scale.

Therefore it is necessary to compare  $\gamma$ -ray data from different field sites and different times. This can be done by (1) using reliable comparable field data or (2) usage of additional lab  $\gamma$ -ray data. One challenge for producing reliable data to compare between different field sites is exogenous conditions during the measurements, like soil moisture or rain. An increase in soil moisture will attenuate and decrease the  $\gamma$ -ray signal (Cook, 1996, Corner et al. 1996, IAEA 2003). Rain can also have effects on U estimation. Radon, one daughter product of the U decay series will be enriched in soil caused by precipitation and soil moisture (Grasty 1997). Such influences of exogenous parameters are important to observe and to prevent. We recommend the usage of

reference profiles and detailed field protocols. However we will not focus on that topic in this presentation.

Here, we will describe our investigation for the integration of  $\gamma$ -ray measurements in the laboratory to establish geophysical transfer functions. We performed field measurements and took soil samples for analysis of  $\gamma$ -ray concentration in laboratory for better comparison between measurements at different field sites and times.

## **Methods**

To validate field and lab data we compared data from two different field sites. They are located in different regions of middle Europe and are characterized by different geological origin. First is located in middle Germany and is characterized by fluvial sediments. The second field site is located in the north of Czech Republic. Here we can find autochthonous soil with parent material from carboniferous. The area was not influenced by glaciers during the ice ages. Data acquisition was performed as follows:

### Field measurements and probing

A portable  $\gamma$ -ray spectrometer (4l NaI(Tl) – crystal, automatic peak-stabilization) by company GF Instruments with 512 channels and an energy range between 100 keV and 3 MeV was used for all field measurements. The detector is placed on sledges including GPS positioning, which can be dragged by four-wheel vehicles or a tractor across the field site. We use a 5 s sampling interval for  $\gamma$ -ray measurements. Data quality of calculated concentration in the statistical process of radioactive decay will raise with measuring time at a point (Duivenstijn and Ververloo 1964). Thus measuring speed is an important parameter for  $\gamma$ -ray measurements. Our towed data were recorded at a speed of 5 km/h. Furthermore we did static  $\gamma$ -ray point measurements placing the instrument for 15 minutes at the same position. The measured cps were converted for each data point into the concentration of K (in %), U and Th (in ppm) and the dose rate (in nGy/h) with a software and calibration provided by the manufacturer. Round point measurement location we did intensive towed measurements with a profile distance of 1 m at 5 homogeneous subplots of a size of 30m by 70m. Point measurements were placed in the middle of these subplots. We compared towed data close to the point with point measurements. Soil samples from different depths (0-10 cm, 10-30 cm, 30-70 cm) were taken by a hand auger at  $\gamma$ -ray point measurement locations.

### Laboratory measurements

Soil samples (10-30cm) were dried at air temperature and sieved to 2 mm grain size. To analyze radionuclide concentration in lab dried and sieved samples were filled into flat plastic boxes with volume of 108 cm<sup>3</sup>. The samples were stored for 24h into a calibrated high-resolution Germanium-detector. The detector measures within an energy range between 3 keV and 2 MeV. The concentrations of radionuclides were analyzed by determination of integrals at nuclide specific peaks at different energies. To minimize errors, the activity at different peaks of decay series were determined and compared, requiring decay products are in equilibrium. In the case of Uranium series this could pose a problem. One of the daughter products is Radon, which is a gas and leaks into the atmosphere (IAEA 2003). To establish the equilibrium the soil samples are stored for 5 times the half life period of Radon (min. 21 days) after preparation in sealed boxes.

## Results

Field data of towed and point measurements show good conformance (Figure 1). The range and means are comparable for all three nuclides. The point measurements are closer to normal distribution because of higher frequencies.

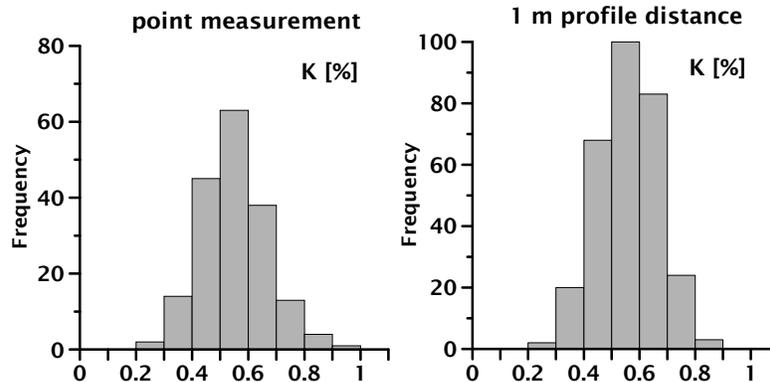


Figure 1. Histograms of K with different measuring set-ups at point measurement location.

The correlation between lab and field data for two gamma emitters is presented in Figure 2. Lab values for all nuclides generally show higher values than field data. This can be explained by soil moisture, which attenuates the radiation under field conditions (Hussein 2003). There is a large correlation for K. On the other hand no correlation in U values is found. This can be explained by equilibrium of U decay series in lab measured soil samples. Degassing of Radon was stopped during storage in small boxes. Equilibrium was restored.

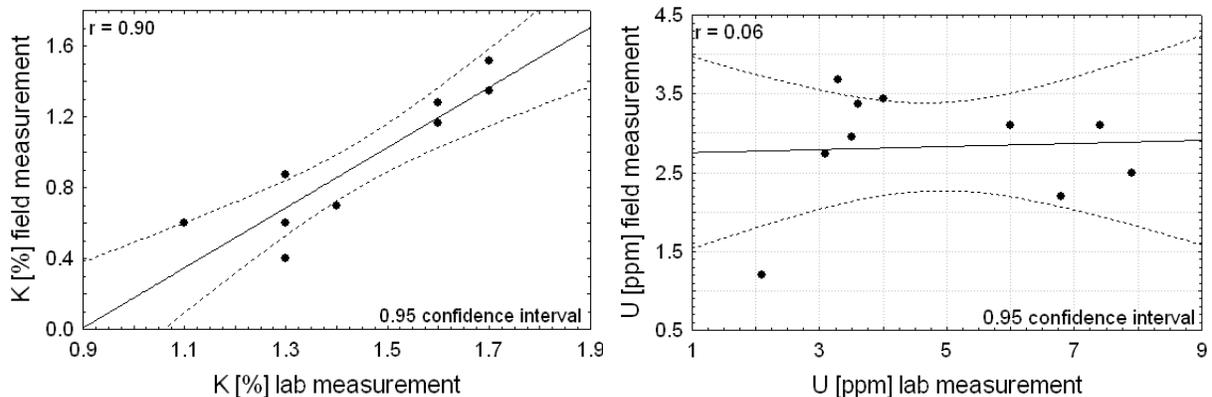


Figure 2. Correlation between point values measured with a field detector and lab values for K and U concentration. The data show two field sites with different geology (different signatures).

## Conclusion

The comparison between point and towed field measurements with our devices shows identical results. There is no need for detailed time consuming point measurements when using data for further investigations concerning the development of geophysical transferfunctions and for (soil) mapping of nuclide concentration.

Using lab  $\gamma$ -ray data for systematic investigation of parameter relationships is only possible for K. Thus lab analysis is a useful tool to compare K values between different sites. However lab analysis is time consuming and one has to take soil samples at field sites carefully. The

correlation of U values from field and lab is poor. Thus using lab measurements for comparison between different field sites is not possible. All studies concerning U values at field sites must base on field results. A special attention should be put on high quality data collection including proper documentation of boundary conditions.

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