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Rapid Soil Resource Survey Using Radiometric Signatures

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Introduction

The three principal radioactive elements in the earth's crust potassium (K), uranium (U) and thorium (Th) are bequeathed from the parent rock to the respective soil (Wilford et al., 1997). The radiation signatures of the parent rock as well as the soils can easily be measured using gamma-radiometry. So far, in soil science gamma-radiometry was mostly used to differentiate between areas of different soil properties (Taylor et al., 2002, Tyler, 2004). Also its application for the detection of different weathering states (e.g. regolith) was explored comprehensively (Schwarzer et al., 1971; Wilford et al., 1997; Roberts et al., 2004; Chan et al., 2007; Wilford, 2007; Wilford & Minty, 2007). Nevertheless, the utilization of gamma-radiometry in soil science is still in its infancy, especially as its use for differentiation of WRB soil reference groups has not been evaluated yet. The aim of the present study is to measure the radioelement distribution in weathering sequences on the most important parent rocks of NW-Thailand and to evaluate its predictive potential for the resulting WRB soil reference groups.

Study Area & Methods

The study area comprised Northwestern Thailand with special focus on three different petrographic study sites, which represent the major petrographic units of the region (Schuler, 2008). The focus area Bor Krai is dominated by limestone, Huai Bong by sandstone, while in Mae Sa Mai mostly migmatitic granite-gneiss complex is found. Soil chemical and physical analyses followed the manuals of Herrmann, 2005, Blume et al., 2000, VDLUFA, 1991, Klute, 1986. Subsequently the soils were classified according to WRB 2006 (IUSS Working Group WRB, 2006). The radiometric measurements of the radioelements K, eTh and eU were conducted using a "Geophysical Gamma-Ray Spectrometer GRM-260" and a "Gamma Surveyor" (Gf Instruments, s.r.o. Geophysical Equipment and Services, Czech Republic). Measurements were done repeatedly in each horizon and from the soil surface or at the surface of the selected parent rocks limestone, claystone, sandstone and granite/gneiss. The prediction of the WRB soil reference group by radio signature indices (eTh/K & eU*eTh) in combination with the respective parent rock units was calculated using classification trees (CART algorithm) (Breiman et al., 1984) in SPSS 17.0. Additionally, the usefulness of airborne gamma-ray measurements was evaluated. Therefore, these were compared with the above described ground-based gamma-ray data and a classical soil map (based on transect information of auger and profile data) from a previous study (Schuler, 2008). The airborne gamma-ray measurements were acquired from the Thai Department of Mineral Resources, which conducted an airborne geophysical survey of entire Thailand in 1989 (DMR, 1989).

Results

Radiometric measurements, especially of potassium, show clear differences between parent rock domains as well as in the weathering sequence (fig. 1). The general rule is that as weathering proceeds in terrestrial environments potassium is lost from the profile and also transported to subsoil horizons by clay illuviation. This differentiation allows by using ratios with the thorium concentration the distinction between i.e. Alisol and Acrisol soil reference groups (fig. 2). Also a high correlation exists between proximal and remotely sensed values (fig. 3), though a shift of absolute values can be observed due to changing sensor distance and coverage.

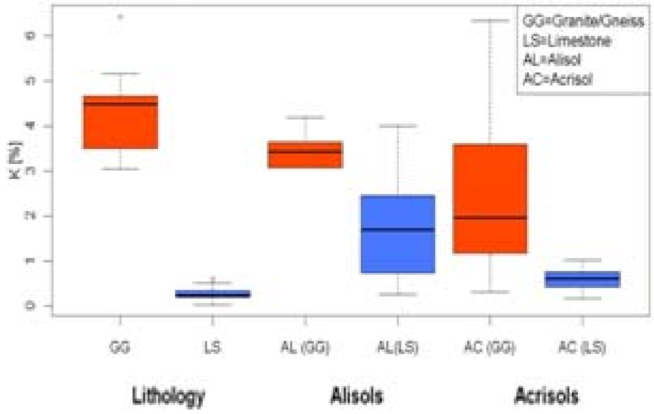

Fig. 1. K-signature of Alisols and Acrisols on granite and limestone.

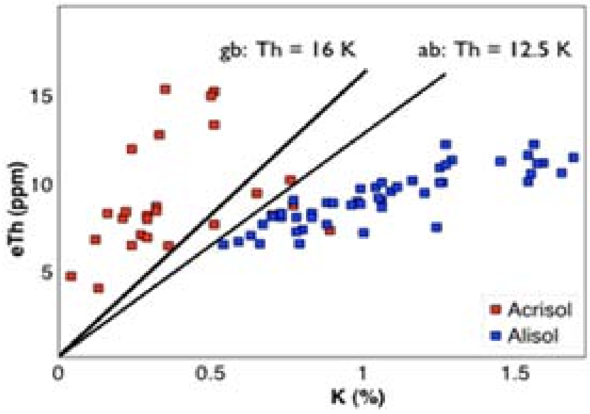

Fig. 2. Differentiation of Acrisols (AC) and Alisols (AL) by ground-based data (gb), for airborne data (ab) only separation line included.

The prediction accuracy of the final classification tree for entire NW-Thailand is very high for Acrisols, Alisol Chernozems, and Ferralsols, high for Umbrisols and Cambisols, but low for Luvisols. Gleysols cannot be predicted based on radiometric data alone, but inclusion of topographic information may improve the situation. The overall predictability for the study area is 84% and thus higher than for traditional soil maps (tab. 1).

Tab. 1: Classification Tree predictability using radio-signatures and lithology in the study area.

Observed	Predicted								
	Acrisol	Alisol	Cambisol	Chern.	Ferral.	Gleysol	Luvisol	Umbrisol	Correct
Acrisols	103	2	0	3	1	0	0	0	94.5%
Alisol	5	77	0	0	0	0	0	3	90.6%
Cambisol	0	0	7	0	0	0	4	0	63.6%
Chernozem	0	0	0	4	0	0	0	0	100.0%
Ferralsol	0	0	0	0	6	0	0	0	100.0%
Gleysol	0	0	0	1	0	0	0	0	0.0%
Luvisol	0	19	0	0	0	0	8	0	29.6%
Umbrisol	1	3	0	0	0	0	0	13	76.5%
Overall %	41.9%	38.8%	2.7%	3.1%	2.7%	0.0%	4.6%	6.2%	83.8%

An independent validation in another catchment is ongoing. With respect to the comparison with the traditional soil map, only in a small area in the southeastern part an aberration of the radiometric data (both airborne and ground-based) could be detected (fig. 3). Here, the traditional soil map postulated occurrences of Acrisols based on reference soil profiles supported by geomorphological characteristics. Further soil sample analyses of the area in question proved that the radiometric data provide a more precise prognosis. Other minor deviations (fig. 1, NE-area) can be explained by the interference of locally occurring iron ore.

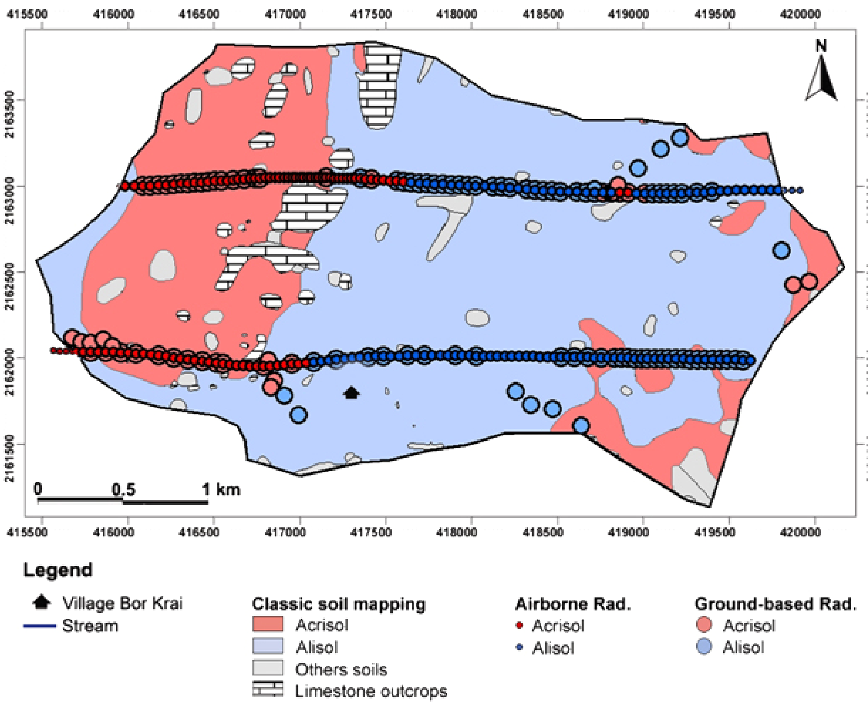

Fig. 3. Comparison of airborne and ground-based radiometric data with a previously created classical soil map (Acrisol & Alisol) of the limestone area Bor Krai.

Discussion

The spread of radiometric signatures across different environments and its differentiation with weathering clearly show that soil forming processes have an influence on the radiometric signal at the soil/landscape surface. Though dominated by the parent rock influence and starting from this point, soil formation influences the concentration of radioactive elements via solute leaching, particle transport or residual accumulation. Going further than Schuler et al. (2011) who successfully differentiated Alisols and Acrisols in an earlier study, the present study shows the successful differentiation of the major soil types of NW-Thailand using classification trees (CART algorithm). Prediction problems only occur for soil types with low sample numbers as in the case of Gleysols.

The evaluation of airborne gamma-radiation data in comparison to ground-based data and a traditional soil map based on field augering (Schuler, 2008) shows an excellent fit for the selected karst area. The traditional soil map could even be improved using the more objective radiation signatures.

The study has shown that pedogenic processes like decarbonatisation, desilification, base leaching, clay illuviation, and clay and sesquioxide neoformation definitely change the radiometric signal at the surface as well as within the soil profile. Therefore, it is to be expected that also pedogenic enrichment processes like carbonatisation and silification have a significant effect. Consequently, the radiometric signal can be used as one information parameter in soil mapping.

As the CART application shows, combined with other easily available or measurable data like pH, a digital elevation model or a petrographic map, a high soil reference group prediction accuracy can be achieved, which would otherwise not be that easy with any other approach in areas dominated by clay illuviation type soils.

Given the discrimination potential for Alisols and Acrisols gamma-ray spectrometry might also have a potential to predict dominant clay minerals, and categorised cation exchange capacity.

Conclusion & Outlook

Gamma-radiometry is a promising tool for modern soil science, which unfathomed potential has yet to be tested. The acquisition of a portable radiometer is worthwhile, even though these devices are quite expensive, as costly laboratory analyses (especially for CEC_{clay}) can be greatly reduced for the identification of WRB Soil Reference Groups (IUSS Working Group WRB, 2006). Airborne radiometric data – in so far available for the respective area – could be a more inexpensive alternative, which could allow supraregional, multi-temporal mapping without time consuming field and laboratory work. However, the correlation between airborne and ground-based gamma-ray data requires further reflection.

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