Creating soil degradation maps using gamma-ray signatures

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Abstract
The uplands of northwestern Thailand are highly susceptible to soil erosion. The high degree of soil degradation originates mainly from unsustainable farming practices on steep terrain. The situation could be improved by sustainable land use planning. Therefore information is needed about the location of erosion-prone areas and the state of soil degradation. Our study aims to provide decision makers with maps containing these informations. As the determination of actual soil erosion rates can be time consuming, we tested if radio signatures (K, eTh) can be used as proxies. Therefore, we compared the data of topsoil thickness and erosion measurements by Gerlach troughs with the gamma-ray signatures of these sites in an upland rice field in Mae Hong Son province. The results show a significant correlation between the erosion measurements and the K/eTh ratio. As next step an interpolated erosion map will be created using the data collected from the Gerlach troughs. This map will be overlain with the interpolated radiometry map in order to calculate the goodness of their fitting. If the fitting is significant, such gamma-ray interpolation maps can be used to pinpoint erosion hot spots on field scale and give information about the actual state of soil degradation.

Key Words
Erosion hazard zones, sloping land, rainfed rice field, northern Thailand, radiometry

Introduction
The livelihoods of farmers in northwestern Thailand depend on the quality of the soils on which they cultivate their crops. Unfortunately the erosion on these already due to their steepness (mostly >25 degrees) highly endangered soils is further expedited by unsustainable land use practices, like shortening of the traditional fallow period or the intensive cultivation of upland rice and maize (Schuler 2008). These practices result in strongly eroded soils, leaving in certain areas less than 10 cm of topsoil thickness. The further deterioration of the sloped farmland could be avoided by sustainable land use planning. Our study aims to provide decision makers with maps indicating the location of high risk erosion spots within the fields and the state of actual soil degradation. These soil degradation maps would enable them to plan and implement adapted anti-erosion measures like vetiver grass strips (Mattiga and Nareuban 2005) or convince farmers to change the land use for such fields altogether.

For the production of such soil degradation maps detailed information about the specific erosion rates of each field would be needed. As this is a time consuming process, we tested if radio signatures, which are more rapidly measured, can be used as proxies for soil erosion. The basis for this approach is the fact that illuviation type soils are dominant in Northern Thailand and that in these soils the Bt-horizon contains a higher concentration of K-rich clay minerals than the overlying eluviated topsoil. Hence, when the topsoil is eroded, the K-rich Bt-horizon is closer to the surface enhancing the K-radio signature (Wilford 1995; Tyler 2008; Schuler *et al.* 2009).

Material & Methods
For this study we selected an obviously highly eroded upland rice field near the village Bor Krai in Phang Ma Pha District, Mae Hong Son Province, northwestern Thailand. The soil of the rice field is classified according to WRB 2006 (IUSS Working Group 2006) as Alisol. The parent material is claystone (Schuler 2008). On this field 21 Gerlach troughs (=GT, in 6 rows, each containing 2-4 GTs, distributed over the slope in a W-shape) are installed, which are used to measure the soil loss and deposition along the slope taking each Gerlach trough's catchment area and the discharge of the respective upslope row into account. At all GT locations the radio signatures of potassium (K) and thorium equivalent (eTh) were measured once in the dry season using a GRM-260 handheld radiometric device (Gf Instruments, s.r.o. Geophysical Equipment and Services, Czech Republic). Additionally inclination and topsoil thickness were measured at the Gerlach trough positions as well as in between once at the end of the rainy season. In order to test radio signatures as

potential proxies for erosion the correlation was calculated for the radio signatures (especially K, K/eTh) with GT-erosion measurements as well as topsoil thickness using SPSS 17. Therefore the erosion/deposition data of each GT was summed up over one rainy season (April – July 2009).

Results

Data with relevance to soil erosion measured on the sloped rice field show the following ranges:

Table 1. Descriptive statistics for erosion relevant data on the experimental rice field.

	Minimum	Maximum	Mean	Coefficient of variation (%)
Inclination (°)	17	32	24.86	14.6
Topsoil depth (cm)	3	19	8	43.97
Cumulative annual erosion/GT (kg ha-1)	-12926.80	14730.81	-172.961	-2797.43
K (%)	0.83	1.54	1.23	15.04
eTh (%)	5.05	11.29	9.52	14.46

No significant correlation was found between the topsoil thickness and the single nuclide specific radiometric measurements. Also no significant correlation was found between K alone and the erosion data. Nevertheless the K/eTh ratio and the total cumulative erosion data over one rainy season per GT showed a highly significant negative correlation with a Pearsons Correlation Coefficient of $r = -0.629$ at $p < 0.05$ (exactly 0.003).

Linear Regression: $R^2 = 0.395$, $F=11.772$, $p<0.05$, $y=1834.942 x – 895528.1$ (Figure 1).

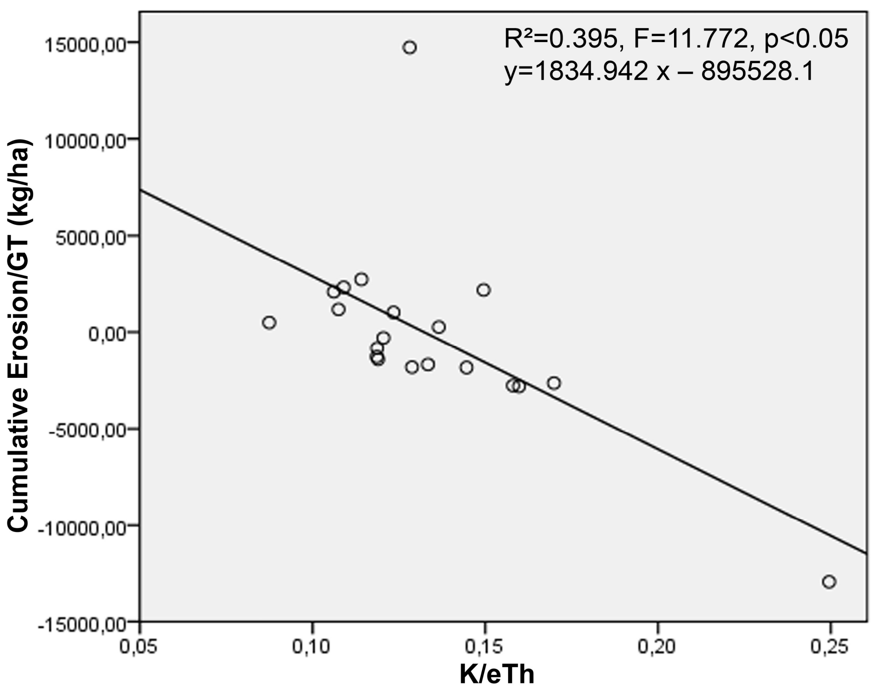

Figure 1. Linear regression of K/eTh and annual cumulative soil erosion as measured by GTs.

Discussion

Contrary to our initial hypothesis no significant correlation between the topsoil thickness and the single nuclide specific radiometric measurements (K) was found, which is at first glance surprising, but some reasons come to mind:

1. The topsoil thickness along the measured section shows only minimal variations as the rice field comprises only a part of the middle slope, but neither upper nor base slope areas.
2. The soil material is not homogenous due to small scale rill erosion (see outlier in Figure 1), landslides, land use history and variability within the parent mudstone, leading to different radioelement levels.
3. The number of measurements, both radiometric (N = 21) and topsoil thickness (N = 58), might be too low

to produce significant statistical proof.
A significant negative correlation was found between the erosion rate measurements and the ratio of K/eTh radiation. This might be explained by the assumption that during increased erosion a preferential transport of K-rich particles, which are of a certain grain size (further research is needed to determine the exact particle size), takes place, while Th is abundant in a different particle size, which is not as easily translocated.
It seams not sufficient to measure only a single nucleide radiation signature as erosion proxy, but rather a ratio of several (in this case K/eTh) or even an entire spectrum, which has to be proven in further studies.

Outlook
As the results indicate a certain potential of radiometric measurements as erosion proxies, in a next step interpolation maps of the gamma-ray signatures, GT data, as well as topsoil thickness and inclination will be created (using GeoSoft and/or ArcGis 9.2). These maps will be laid over each other and their fitting will be calculated. If the goodness of the fitting is significant, such gamma-ray interpolation maps can be used to pinpoint erosion hot spots on field scale in the given environment (petrography) and give information about the state of soil degradation. The final step of this study will be the upscaling to watershed level.

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