Potential Application of Thorium Isotopes in Upland Maize Soils for Assessment of Soil Erosion

W Kulawat\textsuperscript{1, 2} and N Kaewchuay\textsuperscript{2} *  
\textsuperscript{1} Thailand Institute of Nuclear Technology (Public Organization), 9/9 Moo 7, Ongkharak District, Nakhon-Nayok 26120, Thailand  
\textsuperscript{2} Rajamangala University of Technology Thanyaburi, 39 Moo1 Klong 6, Khlong Luang, Phathum Thani 12110  

*E-mail: netnapit_k@rmutt.ac.th  

Abstract. Soil core samples from upland maize field at Mae Ramah district, Tak province were analysed for thorium isotopes using the modified method. The measures Th\textsuperscript{-232}, Th\textsuperscript{-230} and Th\textsuperscript{-228} revealed that the rock parent material is the dominant source at these sites while fertilizer is an important supplement. Migration behaviour of Thorium isotopes varying with seasonal and human activities during cultivation period such as ploughing, harrowing, and applying fertilizer resulted in different distribution of Thorium isotopes in soils. It was observed the descending and ascending of Th\textsuperscript{-232}, Th\textsuperscript{-230} and Th\textsuperscript{-228} concentrations in maize soils along the 250 meters line transect sampling. The highest Th\textsuperscript{-232} found in the upland maize soils was 11.7597 Bq/kg or 5344.56 Bq/m\textsuperscript{2} while the lowest was 1.8772 Bq/kg or 289.40 Bq/m\textsuperscript{2}. Erosion and deposition of topsoil in the site should be the most possible reason for the significantly lower thorium isotopes values and vice versa along downhill soils. These results demonstrated that Thorium isotopes could be applied as an ideal substitute of Cs\textsuperscript{-137} for soil erosion study in the future. Further study is to collect additional line transect sampling including increase with the distance.

1. Introduction  
Soil is considered as a non-renewable resources. Time for soil forming processes is relatively long; however, degradation rate is rapid. Soil degradation is increasing worldwide and threatens sustainable land use. Major source of soil degradation mainly linked to water erosion which impacts on nutrient loss, siltation load, reservoir sedimentation, and groundwater pollution. Sediment delivery to streams and rivers can cause flooding and decreases soil fertility. Soil erosion induce socioeconomic problems, lower household incomes, food insecurity and poverty. The earth surface of 23\% or approximately 5\texttimes 10\textsuperscript{11} hectares has been affected by soil erosion each year [1]. The highest degraded land occurs in Asia due to rapid population growth, land-use changes, inadequate land-use planning and regulations to control soil erosion [2].  

Erosion is a serious problem for productive agricultural land and for water quality concerns. Controlling the sediment must be an integral part of any soil management system to improve water and soil quality. Eroded topsoil can be transported by wind or water into streams and other waterways. Sediment is a product of land erosion and derives largely from sheet and rill erosion from upland areas, and to a lesser degree, from cyclic erosion activity in gullies and drainage ways [1, 2].
The Northern region of Thailand is vulnerable to soil erosion due to its undulating topography, steep slopes, high rainfall and land use change from forests to agriculture or to urbanization. Erosion of soils is a gradual process which passes mostly unseen especially on upland-cultivated sites but may be responsible for high sediment loss. Conservation method on soil erosion monitoring needs regular and long term period sampling to detect trends. Thus, the alternative methods for estimating soil erosion by using naturally radionuclides in the soil, sampling survey including geo-statistics have been proposed [3, 4]. However, Thorium isotopes as a soil erosion tracer for assessing soil erosion rates is scarce in Thailand.

Thorium (Th) is abundant in the Earth’s crust, being almost three times more abundant than uranium. Thorium is found in small amounts in most rocks and soils. Thorium occurs in several minerals, the most common being the rare earth–thorium–phosphate mineral, monazite, which contains up to 12% of thorium oxide. Granitite contains up to 80 mg/kg of Th. In the environment, thorium exists in various combinations with other minerals, such as silica. It is commonly accepted that most Thorium compounds found in the environment do not dissolve easily in water and do not evaporate from soil or water into the air. Thorium is a typical lithophilic element, and its geochemical behavior is very similar to that of rare earth elements. The geochemistry of Thorium is simplified by the existence of just one valence state, +4. Since Thorium is commonly found in phosphate rock, the raw material of phosphate fertilizer. Therefore, applications of phosphate fertilizer in the cultivated soil would eventually enhanced Thorium level in the soil [5, 6].

The aim of this study is to apply nuclear technique to 75 upland maize soils in Mae Ramah district, Tak province with the purpose to use $^{228}$Th, $^{230}$Th, and $^{232}$Th as indicator for soil disturbance.

2. Method
2.1. Study area
The study area Mae Ramah district is situated in the Tak province (Figure 1). The bedrock mostly consists of rocks range in age from Precambrian to Quaternary. The common lithologic associations of these rocks are mainly granitic to granodiorite para-gneisses, mica schist, hornblende schist or amphibolite, calc-silicate and marble of the Almandine Amphibolite Facies with frequent collaboration of orthogenesis, migmatite, pegmatite, aplite and granites [7].

![Figure 1 Location of the study area](image_url)
the Mae Ramah district is 1,476 km². Mountainous with evergreen and pine forest covers 80% of Mae Ramah district. Within 81 km contains large variations in elevation (~207 meters). The area within 3 km of Mae Ramah is covered by trees (100%), within 16 km by trees (85%), and within 81 km by trees (69%) and cropland (17%). Agriculture is a major part of the Tak economy. The province of Tak produces rice, corn, vegetables, fruit, beef, tilapia and other foods. Industries in Tak include granite quarrying and jewelry.

In Mae Ramah, the wet season is oppressive and overcast, the dry season is humid and partly cloudy, and it is hot year round. Over the course of the year, the temperature typically varies from 16°C to 36°C and is rarely below 12°C or above 38°C. Mae Ramah experiences extreme seasonal variation in monthly rainfall with average annual rainfall of 1540 mm The Köppen-Geiger climate classification is Aw [8].

2.2 Sample collection and preparation

Three transects of 250 m length were established in the transition zone of fragment forest to maize agricultural land. Soil cores were taken at 25 sampling points separated by consecutive sampling intervals of 10 m along each transect from up-slope to down-slope. Each transect were 20 meters intervals.

The samples were taken by soil corer (Eijkelkamp, Netherland) at depth level of 0-30 cm during 2018-2019. All fresh soil samples were air-dried, crushed and sieved through a 125 micron mesh sieve, homogenized and stored in zip lock plastic bag for chemical analysis. In each sampling point, five grams of dried finely grounded soil sample was processed.

2.3 Thorium isotopes determination

Thorium determination in this study was based on the modified technique [9]. Briefly, thorium radionuclide analysis was performed using 3 g of dried homogenized soil sample together with 0.12 Bq ²²⁹Th as internal isotopic tracer. The sample was digested with concentrated HNO₃. It was slowly heated on a hot-plate until the reaction started. The solution was evaporated to foaming to destroy the organic matter until the incipient dryness was obtained. Due to foaming, the reaction rate was controlled by cooling or lowering the temperature. The sample residue was subsequently digested with HClO₄, HF, and then HCl. The dry residue was finally dissolved in 9 M HCl and passed through ion-exchange resin. There are many kinds of ion-exchange resin. Most of them are typically organic polymers onto which functional groups are attached. 90% of the polymers are polystyrene matric. In this study, cation chloride form (AG 5X8, 200 mesh) exchange resin (Bio-Rad Lab) was used. Then, the thorium isotopes contained in the solution were electroplated onto a stainless steel disc and simultaneously measured by alpha-spectrometer. Measurements of thorium alpha particles emitted by the disc was performed with low background 450 mm² ion implant detector from ORTEC EG&G connected to an Octete Plus alpha spectrometer.

Quality assurance of analytical results was ensured by analysis of IAEA certified reference materials (IAEA-375 soil) with good results.

3. Results and Discussion

As the maximum depth of cultivation at the site is 20 cm, it was initially considered that a sampling depth of 35 cm would be sufficient to include all the Thorium isotopes within a soil profile. This was found to be the case where the point inventory was less than the up-slope level, indicating that erosion had taken place. With this approach, it is possible to identify a clear pattern of erosion on the upper parts and deposition in the lower zones of all the sloping fields. Slope gradient is a very important factor affecting soil erosion intensity. In this study slope gradient was approximately 17%.

The measures ²³²Th, ²⁰²Th, and ²²⁸Th revealed that the rock parent material is the dominant source at these sites. It was observed that phosphate fertilizer were applied at the actual growth period of maize. Thus, trace of Thorium isotopes in phosphate fertilizer would be enhanced naturally Thorium levels the soil [5, 6]. It was observed the descending and ascending of ²³²Th, ²⁰²Th, and ²²⁸Th
concentrations in maize soils along the 250 metres line transect sampling (Figure 2). The values of $^{232}$Th associated with the 75 sampling points indicated the highest $^{232}$Th found in the upland maize soils was 11.7597 Bq/kg or 5344.56 Bq/m$^2$ while the lowest was 1.8772 Bq/kg or 289.40 Bq/m$^2$.

In this study case, the change from erosion to deposition occurred near the mid-point of the field. In the sloping area, the lower Thorium isotopes trace from soil surface at the upland area could be caused by slowly removal of the topsoil where the Thorium isotopes were normally accumulated in the flat or in the depression area, enhancing soil particles with Thorium isotopes trace. Area with lower values of Thorium isotopes; therefore, was an erosion site and the higher values was a deposition site.

Since radionuclide on earth surface is fixed particularly at fine size soil particles. In the higher annual rainfall, spreading by fine soil particles transport proceed faster [5]. The rainfall totals associated with the different erosive events in the study area ranged from a minimum of 5.4 mm to a maximum of 98.4 mm. with a mean of 32.7 mm. Previous studies have been revealed the probable impact of climate change on soil erosion. Below about 320 mm of rainfall, soil aggregate stability was uniformly low because of the influence of high levels of water soluble salts; above 320 mm aggregate stability varied according to the way in which temperature influenced organic matter dynamics.

Considering the slope and response unit scales and the relationships of climate to aggregate stability, the results showed that the important factor influencing aggregate stability was the degree of shading. Under vegetated or litter covered areas high values of aggregate stability were found. Just as at the humid sites at the landscape scale, favorable organic matter dynamics resulting from a large turnover of organic matter and production of soil stabilizing substances and roots, gave uniformly high levels of aggregate stability. Conversely, areas of soil not covered, had a uniformly low level of aggregate stability, sometimes as a result of dispersive conditions resulting from small amounts of water soluble salts. This is why the areas of low biological activity are the most vulnerable to erosion under intensive disturbance regimes. The more resilient areas are subject to the most disturbance. The relationship of climate to erosion will therefore depend on the effect of climate at different scales. Over a period of months or a few years erosion will be related to the actual amount of rainfall that occurs along transects and to the aggregation (erodibility) status of the soil. Over a period of 15–30 years it will be dependent on the stability and resilience of the soil and vegetation and the frequency and severity of disturbance (fire and grazing) in combination with the amount of erosive rainfall [10].
The study demonstrated the potential for using Thorium isotopes measurements to obtain information on soil erosion and soil redistribution within upland cultivated maize. Further study is to collect additional line transect sampling including increase with the distance.

4. Conclusion

Soil samples were collected from the upland farm cultivated with maize situated at Mae Ramah district, Tak province during 2018-2019. $^{232}$Th, $^{208}$Th, and $^{228}$Th technique for assessments of soil erosion has been applied in the upland maize soil. The soil at the sloping area contained less Thorium radioactivity than those of low-lying area due to the topsoil removal by rate of erosion process. The study demonstrated the potential for using Thorium isotopes measurements to obtain information on soil erosion and soil redistribution within upland cultivated maize. Further study is to collect additional line transect sampling including increase with the distance.

5. References

[1] Stavi I and Lal R 2015 J. Arid Environ. 112 44
[2] Phuong TT, Thong CVT, Ngoc NB, Chuong HV 2014 Resources and Environment 4(3) 139
[3] Emil Fulajtar E, Mabit L, Chris S. Renschler CS, Lee Zhi Yi A 2017 Food and Agriculture Organization of the United Nations, Rome, Italy. 64 p.
[4] Yin S, Zhu Z, Wang L, Liu B, Xie Y, Wang G, Li Y 2018 Hydrol. Earth Syst. Sci. 22 1695
[5] Shtangeeva I Chapter 14 Uranium and Thorium Accumulation in Cultivated Plants in Trace Elements as Contaminants and Nutrients: Consequences in Ecosystems and Human Health, Edited by M. N. V. Prasad 2008 John Wiley & Sons, Inc. 344 p.
[6] Bramki A, Ramdhane M, Benrachi F 2018 J Rad Res Applied Sci 11 49
[7] Information on http://www.dmr.go.th/main.php?filename=GeoThai_En
[8] Information on https://th.wikipedia.org/wiki/Mae_Ramat/Tak
[9] Kulsawat W, Porntepkasemsan B, Kaewchuay N 2020 Proceeding of the 7th Burapha University International Conference Chonburi Thailand.
[10] Imeson AC, Lavee H 1998 Geomorphology 23 219