3.4 Philippines

Soil Redistribution Studies Using Fallout $^{137}$Cs
Elvira Sombrito, Philippine Nuclear Research Institute

A) Introduction to the use of the technique in the soil erosion and sedimentation studies of the region; Background info; Framework of reference for the study; Objectives; Scales of work; Evaluation of available resources

A.1) Introduction

The Philippines consists of 7107 islands in Southeast Asia, with only 2000 of them inhabited. The land area is 300,000 sq. m. (30 million ha), with about 6 % irrigated land. The populated, mountainous islands are divided into four groups. Luzon is the largest and northernmost island whereas to the south is Mindanao, the second largest island. Together, Luzon and Mindanao account for 65% of the land mass.

About two-thirds of the population make their living from fishing, agriculture, and forestry. Most of the country's rain forests are lost due to tree-felling and slash-and-burn agriculture. The country has a volcanic topography, with eighteen of its 37 volcanoes active.

The Philippines has a tropical marine climate with relatively high humidity year-round, mild temperature and abundant rainfall. There are three main seasons: the wet season (June to October), the cool dry season (November to February) and the hot dry season (March to May). The average annual temperature is 25°C (77°F). The northeast monsoon is from November to April while the southwest monsoon happens from May to October.

Environmental issues of concern for the country are uncontrolled deforestation in watershed areas; soil erosion and sediment deposition; air and water pollution in Manila and increasing pollution of coastal mangrove swamps which are important fish breeding grounds. At the beginning of the century, forests cover 70%. From 1970 to 1990, forests declined from about one third to one-fifth of land area.

A.2) Extent of Soil Erosion in the Philippines

The major agent of erosion in the Philippines is water especially during heavy rainfall which results in flooding. During erosion, the topsoil and everything else on the land surface within the packed energy of the flowing water is carried away.

Sloping lands occupy about 9.4 million ha or one-third of the country’s total land area of 30 million ha. The sloping topography and the high rainfall subject the cultivated sloping lands to various degrees of erosion and other forms of land degradation.

With increasing population and limited arable land, agricultural production activities are now being carried out on hilly and mountainous lands. Recent trends show that more and more of the sloping lands are being used for agriculture to support the needs of the burgeoning population.
About forty five percent of the arable lands on the country have been moderately to severely eroded, a phenomenon that causes abandonment of farms and migrating into marginal lands. Approximately 5.2 million hectares are now seriously eroded and their productivity reduced by at least 30-50 percent. The water retention capacity of these eroded soils is reduced significantly, making them very vulnerable to recurrent drought and prolonged dry spell attributed to El Niño. Approximately 74 percent of sloping uplands are actively used for subsistence farming and these phenomena certainly aggravates land degradation and predisposed these lands to the processes of desertification. The increasing population and subsequent increasing demand for human settlement and other non-agricultural uses have contributed to the great loss of prime lands for the production of food, fiber, and in supporting various forms of biodiversity. These losses result into opening of ecologically fragile lands and destruction of natural vegetation and loss of habitat for many endangered plants and animal species. At a replacement value of 1.3 – 4 hectares of replacement between alluvial lands and uplands, some 60,000 to 80,000 hectares of suitable uplands must be converted and used for agriculture to replace an annual loss of rate of 20,000 has of prime lands.

Field experiments conducted in the IBSRAM ASIALAND Management of Sloping Lands network sites in the Philippines showed that up-and-down slope cultivation resulted in annual erosion rates averaging about 100 t ha⁻¹, depending on the rainfall and kind of soil. It was estimated by the Bureau of Soils and Water Management (BSWM) that about 623 million metric tons of soil are lost annually from 28 million ha of land in the country. Between 63% and 77% of the country's total land area is estimated to be affected by erosion. There are reports that 13 of the country's 73 provinces have over half of their land area affected by moderate to severe erosion.

An associated problem concurrent with soil erosion is the increased amount of sediment deposited in downstream reservoirs and other infrastructures. Sedimentation has reduced the storage capacity of the country's major reservoir. These situations caused considerable reduction in the productivity of the forests, agricultural lands and fisheries, and decreased returns from major investments in domestic, hydroelectric power generation and irrigation systems.

A.3) Application of $^{137}$Cs technique in soil erosion studies

The use Cesium-137 ($^{137}$Cs) as tracer in soil erosion and soil redistribution studies has been demonstrated in many areas of the world, including the tropical areas of Thailand and Africa (1). However, in the Philippines, the technique has not been used yet for the quantification of erosion rate. There is also no quantitative data on long-term erosion rate in the country. A quantitative representation of the erosion problem is often very difficult to obtain because of the problems associated with data collection, and the diversity of analytical methods used. Although several methods have been used for predicting and quantifying soil erosion, the use of isotopes for the reconstruction of the erosional records, including the dating of sediment and studying topsoil movement has not been explored locally yet.

Under the IAEA RCA 5/039 project Part 2. Measuring Soil Erosion/Sedimentation and Associated Pesticide Contamination, exploratory studies were made to determine the potential of $^{137}$Cs and $^{210}$Pb as tracers of soil redistribution in agricultural areas.
A.4) Resources available for the study

The study makes use of one dedicated coaxial HPGe detector with relative efficiency of 20% (ORTEC), coupled to NIMBIN amplifier and high voltage power supply for 662 keV-gamma measurement of $^{137}$Cs.

For $^{210}$Pb measurements, the alpha activity of $^{210}$Po is separated by spontaneous deposition and measured using a silicon surface barrier detector. There are four alpha detectors, one of which can be dedicated for erosion studies.

Soil analyses are done at PNRI and BSWM. Pesticide analysis can be obtained for a fee from the Bureau of Plant Industries and from other analytical service providers.

Manual soil sampling tools are also available for this study.

There are two trained staff on soil sampling, alpha and gamma measurements and application of conversion models in calculating soil loss/gain. Counterpart institute is the Bureau of Soils and Water Management under the Department of Agriculture, whose staff has extensive experience in soil erosion studies.

B) Field reconnaissance, field sampling design, reference sites and sample collection and processing

B.1) Study site

Bukidnon is a landlocked province and occupies a wide plateau in the North Central part of Mindanao Island. It lies between the latitudes 7°22 to 8°35 north, and longitudes 124°33 to 125°26” east. It has a total land area of 829,378 ha accounting for 2.7% of the Philippines’ total land area. Being relatively elevated and centrally located, Bukidnon is in itself a “watershed” for most of North-Central Mindanao, comprising the headwaters and substantial portion of seven major river catchments originating in the Province. These are the Pulangi River watershed, Tagoloan River watershed, Cagayan River watershed, Muleta River watershed, Maradugao River watershed, Salug River watershed, and the Cugman-Agusan River watershed.

Bukidnon is the country’s eighth largest province. About 49% of its total land area consists of rugged hills and mountains. Mts. Kitanglad and Kalatungan are the second and the third highest mountains in the country, rising to 2,938 m and 2,836 m, respectively. The province’s land classification shows that 336,412 ha (40.56%) are classified as alienable and disposable while 492,966 ha are forestland. The vegetative covers of the forestland reveal that only 227,062 ha are forested while the remaining 265,904 ha are brush lands and open or cultivated areas. Furthermore, analysis of the forestland shows that 213,330 ha are utilized as production forests.
Bukidnon is basically an agricultural province. The major economic activities include farming and livestock production. Principal crops cultivated are corn and rice. Commercial crops include sugarcane, pineapple, banana, coffee, rubber and other high value vegetable crops grown extensively in the upland areas.
The last three official population surveys of the National Statistics Office showed that the province had a reported population of 631,634 (1980); 843,891 (1990); and 1,060,415 (2000). This suggests an average population growth rate of 3.46 % (1975-1980) to 2.94 % (1980-1990) and 2.31% (1990-2000).

The province faces numerous issues and concerns related to promoting watershed conservation and management. These include the

1. Conversion from Forest Land Use to Agricultural and Other Land Uses
Development brings about a lot of changes not only on the social and economic side but also more on the physical view of the environment. Development of upland areas for high value crops and the attractiveness of the province’s low lands for plantation crops such as pineapples and bananas, and the establishment of poultry and piggery farms have further pushed the local population to the uplands.

2. Unsustainable Agricultural Practices
Modern farming involves the extensive use of inorganic fertilizers and chemical pesticides, some of which have been proven to pollute land and water resources and hazardous to people’s health. As farmers apply more and more chemicals to their crops, the higher the soil acidity becomes, and the lesser the soil’s potential to produce abundant harvests. Further, since the great majority (about 84%) of present agricultural areas are in the uplands, the inappropriate farming technologies have contributed to the degradation of upland areas.

Land-degrading patterns of agricultural growth are often taken to be promoted by adverse economic conditions -- poverty -- and malfunctioning institutions -- tenure insecurity or open access to land without restraints on the uses to which it is put. The combination may cause land managers (such as small farmers) to discount the future very heavily, or to adopt very short planning horizons, thereby introducing a bias in favor of short-term land uses. Rates of return to long-term investments in perennial crops and soil-conserving structures are also reduced by high capital costs in ‘thin’ local credit markets. For these reasons and more, farmers in steeply sloping upland areas close to the frontier of cultivation or in the buffer zones of forested areas are frequently observed to engage in land-degrading agricultural practices, even when they are clearly aware of the long-term consequences of their actions.

The development of the province is guided by its vision to make Bukidnon a “province of self-reliant people enjoying a full life in an atmosphere of justice and harmony, and as an agricultural-based industrial center with an optimally developed agricultural economy and ecologically balanced environment” (RDC 1999: 2). Specific to conservation and management of watersheds and other natural resources of the province, the approved Provincial Physical Framework Plan (PPFP) and the Bukidnon Watershed Development and Protection Plan provide guidance as to how the vision statement is to be implemented.

The PPFP translates provincial policies and development goals and objectives into a general land use plan indicating the manner in which land shall be put into use within the planning period (in this case from 1993 to 2002). Further, it delineates the direction and extent of expansion of urban and other built-up areas of cities and municipalities in the province, the alignment of
transportation networks, the location of major infrastructure projects and facilities and all major land development proposals that have provincial, regional, or national impact and significance. The provincial legislative body officially adopted this plan in 1996.

The Bukidnon Watershed Management Framework Plan (1996) provides the provincial government with the basis to coordinate and supervise all programs and projects relating to water management in Bukidnon. The plan aims to document the common understanding reached by the range of institutions and interest groups concerning the current environmental and socio-economic situation in the province. It also outlined the general principles and approaches that the province believes should be followed to most effectively address the situation, and to have a commonly agreed framework for coordination and supervision of subsequent programs, projects and activities on behalf of the Provincial Government.

B.2) Specific Study area: Dalwangan, Malay Balay, Bukidnon in Mindanao (Southern Philippines)

Malaybalay is within the grid coordinates between 8 and 9 degrees North latitude and 125 degrees East longitude. It is strategically located at the eastern side of Bukidnon. It is bounded on the east by the Pantaron Range separating Bukidnon from the Provinces of Agusan del Sur and Davao del Norte, on the west by the municipality of Lantapan and Mount Kitanglad, on the north by the municipality of Impasug-ong and on the south by the municipalities of Valencia and San Fernando. It is 91 kilometers south of Cagayan de Oro City.

The climate classification of Malaybalay falls under the fourth type or intermediate B type, that is, with no very pronounced maximum rain during and dry season. The climate of the city is relatively cool throughout the year. The mean annual temperature is 23°C with a mean annual maximum of 29°C and a mean annual minimum of 18.5°C. Based on records from the 34-year period ending in 1995, the average annual rainfall in Malaybalay is about 2,500 mm or 210 mm per month. November to April are the relatively dry months, with rainfall less than or about the same as the monthly average, while May to October are mostly wet months.

The 1995 Census registered a total household of 20,529 with a total population of 112,277. It is projected to reach 216,983 in the year 2007 with a growth rate of 5.61% the end of planning period. About 31.65% of its population occupies the urban and urbanizable areas from barangays Dalwangan to Bangcud (21 barangays). The trend of urbanization is very fast when it became a city. Based on the 1990 and 1995 census year, the city has a 3.43% growth rate.

Malaybalay has an urban population of 18,537 which represent 16.51% of the total population. The population is denser in the Poblacion and in big urbanizable areas. It will reach 31,087 in 2007 following the growth rate of 3.43%.

Dalwangan, the barangay where the study area is located, has a population of 3,227 accounting for 2.43% of the city’s population (1995). It has an area of 6,825 ha.

Location: Barangay Dalwangan, Malaybalay, Bukidnon
Coordinates: 8°12'42.7" - 8°12'44.3" N
Elevation (m asl): 900
Mean Annual Rainfall: 2650 mm/yr
Classification: Ultisols (Typic Kanhapludults)
Parent Materials: Andesitic and basaltic rocks
General Description: These soils found on plateau with undulating to rolling landscapes, are reddish brown to yellowish red clay loam and well-drained.
Major Land Use: Corn is the major land use. Pineapple and sugarcane are also grown in the site.
From 1960 to 1980 guayabano (Annona muricata) and citrus spp. with corn (Zea mays) were grown in the area. Contour strips were established in early 80’s.

Soil Management Options: These are acid upland soils. Liming is highly recommended.

B.3) Reference Site

One major concern in the project is finding a suitable reference value for \(^{137}\)Cs deposition. The accuracy of soil loss estimates using the \(^{137}\)Cs method depends upon obtaining reliable estimates of the \(^{137}\)Cs pool in soils of reference sites that have experienced no soil redistribution since the time of fallout. Accurate reference values may be difficult to obtain in the mountainous terrain of the country. There is varying precipitation levels complicated by factors of windward and leeward slopes, thus fallout levels can be variable.

In the Philippine agricultural landscapes, oftentimes, there are few available undisturbed grasslands or pastures and the forested areas may be the only alternative. Tree canopies may enhance fallout deposition and cause high spatial variation because of canopy interception and stem flow. Presently, human activities have expanded deep into forested areas, that it is also difficult to locate an undisturbed area for use as reference site.

Thus, in the first year of the study, we collected samples from three different areas in the country in an effort to demonstrate the applicability of \(^{137}\)Cs in measuring erosion rate, soil movement and deposition in the Philippines.

In the study area described herein, the reference samples were collected from a forest area with no visible events of accelerated erosion and is presumably an undisturbed area.

Two sampling methods were used: pit method for incremental depth measurement and bulk coring method for total inventory measurement. After the expert’s visit of Dr. Robert Loughran, a scraper method is now in use for collecting reference samples.

Figure 2 a-c show the depth profile of \(^{137}\)Cs inventory in these three samples.
Figure 2. Depth Profile of $^{137}$Cs inventories of reference sites

Although there were only three samples, it is quite evident from these profiles that the area has variable $^{137}$Cs inventory:

- Reference 1- 690 Bq/m$^2$
- Reference 2- 210 Bq/m$^2$
- Reference 3- 260 Bq/m$^2$

$^{137}$Cs penetration depth is also variable:

- Reference 1- 45-50 cm
- Reference 2- 30-35 cm
- Reference 3- 20-25 cm

Reconnaissance of the site upon return to the area shows that site 1 was at the foot of a sloping area. The area from which the samples were collected was on a slope and the site where sample 1
was taken may be a depositional area. This second visit allowed the collection of samples from as nearly flat area as possible. The samples were collected by bulk core sampling.

The samples gave the following $^{137}$Cs inventory:

- Reference 4- 220 Bq/m$^2$
- Reference 5- 200 Bq/m$^2$
- Reference 6- 240 Bq/m$^2$
- Reference 7- 200 Bq/m$^2$

These reference values are considerably lower than the values expected from computed value based on rainfall data in the area (600 Bq/m$^2$). However, there is little dispersion in the values obtained. Some erosional process could have occurred from the period of $^{137}$Cs deposition to the present time or the conditions at the time of deposition could have resulted in low deposition because of forest cover in the area. Extrapolation of the linear exponential plot to 600 Bq/m$^2$ would mean that a soil layer of 20 cm could have been eroded from the area. A very simplistic calculation will translate this depth to an erosion rate of 50 t/ha/yr.

It is reasonable to assume that the selected reference area could have undergone some accelerated erosional processes since the fallout deposition in the 60’s. The study area is within Malaybalay City, an agricultural study site of the Bureau of Soils and Water Management. The original cover of the land may have been removed because of inland migration.

These results illustrate the difficulty of getting suitable undisturbed reference sites in the country discussed above.

Sampling for soil redistribution study:

Depth increment samples were obtained by the pit method in the study site from the top of a slope down to the foot (hill slope model) (Figure 3)
C) Sample measurement using gamma spectrometry, measurement of $^{137}$Cs by HPGe, Detector calibration, Use of Reference materials AQCS and presentation of analytical data)

C.1) Gamma metric analysis of $^{137}$Cs

Measurement of low-level gamma activity of $^{137}$Cs is now commonly done by instrumental gamma spectrometry using high purity germanium detector (HPGe). Our laboratory is equipped with liquid nitrogen-cooled co-axial HPGe, ORTEC GEM30, in low background streamline cryostat in vertical configuration. A lead cave surrounds the detector system. This unit is being used for $^{137}$Cs radiometric dating of marine sediment cores, as a complementary technique to $^{210}$Pb dating of the cores and now also used for $^{137}$Cs measurements in soil samples.

The associated NIM electronics for the detector are Ortec 659 5kV bias supply, Ortec 671 amplifier. Multichannel pulse height analysis is made using a Maestro 32 MCA and software.

The measured relative efficiency for the detector is 30%. Using a one-liter Marinelli reference standard (Isotope Products EG-ML) the efficiency factor at the 661.7 gamma energy of $^{137}$Cs is 0.01148.

Background measurement is done on a monthly basis. Energy calibration is done everyday prior to soil sample counting.
Prior to counting, samples are air-dried and disaggregated by hand and sieved through 2 mm sieve. Fractions are packed into either a 500 ml or 1000 ml Marinelli beaker (depending on available amount of sample).

An excel worksheet was prepared for the raw data entry and calculation of $^{137}$Cs activity and inventory. The worksheet contains the following information:

- Study site and sample description (sheet 1)
- Soil physico-chemical properties (sheet 2)
- Detector calibration (sheet 3)
- Radioactivity data calculations (sheet 4)
- Summary sheet (sheet 5)
- Charts (sheet 6)

C.2) $^{137}$Cs activity as a function of depth

Nine sampling points were established at the cultivated slope in a single transect design. The slope transect is use in areas with simple topography as in cases of most terraces and contour strips, as in this study site. Also, This was the initial attempt to collect samples for this study and the number of samples that can be counted at the time, were limited by the available resources, thus a single transect sampling was used. It was hoped that the variability in $^{137}$Cs inventories may be captured with a single transect.

Samples were collected to a depth of about 50 cm, at 5 cm increment (Figure 4). The $^{137}$Cs activity profile at different depths of each of the nine samples is shown in Figure 5.

![Figure 4. Total $^{137}$Cs inventory of the nine sampled prints](image-url)
Figure 5. Horizontal bar chart of $^{137}$Cs inventory as a function of depth in the nine samples collected across a transect in the sloping study area.

D) Calculation of soil loss/gain rates using conversion model. Selection of models and independent validation

To provide quantitative estimates of erosion or sedimentation rate, the $^{137}$Cs inventories in a landscape must be converted to soil loss or soil gain. A quantitative relationship must be derived to relate the measured $^{137}$Cs inventory to the desired erosion/sedimentation rate values. The conversion can be done using appropriate calibration or conversion models.

Empirical models making use of measured long term erosion rate data in a cultivated field of similar soil properties and which has undergone similar method of cultivation, and planted with similar crops and similar topography may be difficult to develop in the Philippine setting. Erosion plots have been used for estimating soil erosion only in the recent past, and the irregular terrain of the country may produce significant difference in soil movement.
In this study a simple proportional model was used for converting $^{137}$Cs data to soil loss/gain. This assumes that the proportion of the plough layer removed by erosion is directly proportional to the reduction in $^{137}$Cs inventory relative to the reference inventory. It is assumed here that the $^{137}$Cs is uniformly mixed in the plough layer, which may not be the case.

The proportional method uses the equation:

$$Y = \frac{10Bdx}{100T}$$

Where

- $B$ = bulk density of soil (kg/m$^3$)
- $d$ = depth of the plough or cultivation layer (m)
- $x$ = percentage reduction in total Cs-$137$ inventory defined as $(A_{ref} - A_{ref} / A_{ref} \times 100)$
- $T$ = time elapsed since the initiation of $^{137}$Cs accumulation (yr)
- $Y$ = erosion rate in tha$^{-1}$yr$^{-1}$

**Table 1.** $^{137}$Cs inventory in Dalawangan study site. DAC1 is at the foot of the hill, DAC9 is at the summit.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Total Inventory Bq/m$^2$</th>
<th>Counting Error Bq/m$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAC1</td>
<td>300</td>
<td>70</td>
</tr>
<tr>
<td>DAC2</td>
<td>420</td>
<td>60</td>
</tr>
<tr>
<td>DAC3</td>
<td>320</td>
<td>50</td>
</tr>
<tr>
<td>DAC4</td>
<td>250</td>
<td>50</td>
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<tr>
<td>DAC5</td>
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<td>60</td>
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<tr>
<td>DAC6</td>
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<td>40</td>
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<tr>
<td>DAC7</td>
<td>320</td>
<td>70</td>
</tr>
<tr>
<td>DAC8</td>
<td>240</td>
<td>20</td>
</tr>
<tr>
<td>DAC9</td>
<td>110</td>
<td>20</td>
</tr>
</tbody>
</table>

A qualitative comparison between the average $^{137}$Cs inventory from the reference site ($220 \pm 20$ Bq/m$^2$) shows that DAC1 to DAC3 are depositional sites while only the summit point exhibited erosion (Table 1). Using the proportional model, the deposition rate in locations DAC1 to DAC3 is about 18 t ha$^{-1}$yr$^{-1}$, while the erosion rate at the summit is of similar magnitude. Qualitatively, the net soil movement is from the summit to the bottom of the slope, with the slope suffering no net soil loss.

There are corrections that have to be done in this work. A single transect may not be a good representation of the $^{137}$Cs inventory in the study site, thus more samples have to be collected to reflect natural variations in inventory in the area and to reflect areal distributions. A suitable reference site must be identified and sampled systematically in order to get a reliable reference inventory value.
E) Spatial representation of data and interpretation of results: main factors/relationships

E.1) Reference inventory

In the first phase of the study, considerable effort was focused on selecting a suitable reference site in a particular study area. This is because the selection of reference sites is central for successful execution of a $^{137}$Cs-based erosion study.

The ideal reference site is one which has experienced no erosion or deposition since the time of fall-out, and thus level sites are ideal. These level sites should have continuous vegetation cover for the period since deposition of $^{137}$Cs began and grass or low herb cover is best.

We have explored so far three areas. The reference values obtained from the three sites are as follows:

a. Study Site 1 Southern Philippines
   $220 \pm 20 \text{ Bq/m}^2$, 6 samples

b. Study Site 2 Central Luzon
   $170 \pm 60 \text{ Bq/m}^2$, 8 samples
   $200 \pm 30 \text{ Bq/m}^2$, 6 samples

c. Study Site 3 (northern Luzon)
   $450 \pm 280 \text{ Bq/m}^2$, 16 samples

These reference values are lower than the Malaysian value of 550 Bq/m$^2$ and Vietnam Value of 808 Bq/m$^2$.

These areas are presumed to be forested areas during the time of maximum $^{137}$Cs fall-out, prior to cultivation. However, there has been considerable deforestation during the last three decades contributing to accelerated erosion even without cultivation.

Samples collected from the present study area (Bohol in Central Philippines), gave reference values of around 700 Bq/m$^2$, a more likely value for the Philippines. This area is a level area at high elevation, with no leafy cover.

E.2) Soil erosion studies in Bohol

After gaining some experience and preliminary data during the first year of the project implementation, the RCA project implemented by the Philippines is merging with a bigger project currently on-going in Inabanga watershed in Bohol.

According to the Bureau of Soil and Water Management (BSWM), 40 percent of the land in the Bohol is considered to be non-susceptible or moderately susceptible to erosion, while 60 percent is very susceptible to erosion. The estimated rate of land erosion is 10 m$^3$/ha annually (PPDO 1997). This is attributed to the lack of sufficient vegetative cover in the upland areas. Improper upland farming practices and deforestation are identified as the major causes of this problem.
Relative to the suitability of the profile area’s climate to agricultural production, the BSWM identified 2 agro-climatic zones within the profile area. Calape and Tubigon are under the moist zone, in which annual rainfall ranges from 1,500 to 2,500 mm and occurs mostly on upland areas. The moisture deficit during the dry season is moderate. The municipalities of Clarin, Inabanga (current study site), Buenavista and Getafe fall within the dry zone, where annual rainfall is less than 1,500 mm and occurs mainly on the lowlands. These areas experience significant moisture deficit during the dry season.

A national project is currently being implemented in Inabanga watershed in Bohol. The collaborating agencies are the Bureau of Soil and Water Management and the Department of Environment and Natural Resources, funded by Australian Centre for International Agricultural Research (ACIAR)- Project ID: LWR/2001/003: Integrated watershed management for sustainable soil and water resources management of the Inabanga watershed, Bohol Island, Philippines.

On Bohol Island, a province that is a priority focus for the Australian aid program in the Philippines, there is a move to protect water resources affected by soil erosion and runoff from agricultural lands. In this project scientists will evaluate the extent of soil erosion from agricultural croplands, and measure the sedimentation and water quality of surface waters in the Inabanga River watershed. Researchers will also examine socio-economic and policy issues, and identify constraints that impact on the agricultural sustainability and surface water quality of the Inabanga watershed. The project will evaluate different options and impacts for water resource uses in this watershed, using research methodologies that involve farmers, community groups, local and national government and non-government organisations to assist adoption of research outcomes (http://www.aciar.gov.au/web.nsf/doc/ACIA-5WELWT).

In its first year of implementation, Current land use and water systems have been delineated using a range of resources, including, existing data held by BSWM, DENR and regional agencies. Landsat 7 imagery, ground truthing and existing maps in both hard copy and digitised formats. Experimental plots have been established within the watershed and sampling of water and sediments has commenced. The sites have been selected to allow evaluation of intensively cultivated crops (both irrigated and rainfed), agro-forestry, forestry, grassland and oil palm land usage. Considerable stakeholder input was incorporated into the selection of experimental sites and types of agricultural activity to be evaluated. Evaluation of sedimentation processes and water quality have commenced at a series of water quality monitoring sites transecting the watershed and the major storage dam, the Malinao Dam. To understand the socio-economic and policy issues, and constraints that impact on the agricultural sustainability and surface water quality of the Inabanga watershed, the research team has collected existing socio-economic information and is commencing integration of the data for incorporation as a GIS information layer.

The inclusion of $^{137}$Cs-based erosion study in the project will enriched the evaluation of erosion and sedimentation processes occurring in the watershed of Inabanga. One of the objectives of this national project is the same as the developmental objective of the RCA project: to transfer research outputs to stakeholders of soil and water management. This national project is then a good medium for realizing this objective.
F) Progress Report on “Soil redistribution and associated soil/water quality studies in an agricultural area: Inabanga Watershed” (TC IAEA-RAS-5-039)

Personnel:
- Elvira Z. Sombrito – Project leader (25%)
- Adelina DM. Bulos-Researcher (50%)
- Efren Sta. Maria –Researcher (20%)
- Richard Balog –Researcher (30%)
- Angelina Balagtas- Researcher (10%)

Collaborators:
- Bureau of Soils and Water Management, DA
- ACIAR (through BSWM)
- Bohol Agricultural Promotion Center (through BSWM)

Bohol, the 10th largest island in the country, is predominantly an agricultural province. Of the total labour force, 60% constitutes the agricultural sector. With most of its vast lands utilized for agriculture, the province is considered the leading food granary of the Central Visayas region. According to the Bureau of Soil and Water Management (BSWM), 40 percent of the land in the profile area is considered to be non-susceptible or moderately susceptible to erosion, while 60 percent is very susceptible to erosion. The estimated rate of land erosion is 10 m$^3$/ha annually (PPDO 1997). This is attributed to the lack of sufficient vegetative cover in the upland areas. Improper upland farming practices and deforestation are also identified as the major causes of this problem.

Temperate in climate and rainfall, Bohol has lush watersheds which affect the present and future conditions of the coastal zone. As mentioned earlier, there are 3 major watershed systems covering the profile area, including the Inabanga river system in the north (PPDO 1993a). Unfortunately, the watershed areas are currently experiencing 26–83 percent erosion due to uncontrolled human encroachment into protected upland forest areas (MTDP 1997).

On the average, soil depth is relatively shallow, ranging from a minimum depth of 24 cm to a maximum of 60 cm. Of the 4 major soil types in the area, the most prevalent is clay. The soils are divided among: Bolinao clay, clay loam, Bantug clay and hydrosol (regosols). Since clay soil has an extremely fine texture, it has the ability to retain large amounts of water and store plant nutrients at the surface. This makes clay, and especially organic clay loam, highly suited to agriculture. Due to the shallow soil depth, however, agricultural practices must be carefully managed to limit soil erosion and depletion.

The Bureau of Soils and Water Management (BSWM) and ACIAR are currently implementing a national project on “Integrated Watershed Management for Sustainable Soil and Water Resources Management of the Inabanga Watershed, Bohol Island, Philippines.” (BSWM) This watershed is the largest watershed in Bohol Island, with 50% of the land currently used for agriculture (Figure 6). The watershed contributes substantially to the agricultural output of Bohol. More than 60% of the agricultural land have a slope greater than 18%. Annual rainfall in the area is in excess of 2000 mm. High rainfall rate, sloping land and poor farming practices combine to cause major land degradation problems in the area.
The ACIAR project has the following objectives:

- To describe the current land and water resources of the Inabanga watershed using Geographic Information Systems (GIS) and ongoing natural resources management programs in the watershed.
- To evaluate the extent of soil erosion from agricultural crop lands, sedimentation and water quality of surface waters in the Inabanga watershed.
- To understand the socio-economic and policy issues, and constraints that impact on the agricultural sustainability and surface water quality of the Inabanga watershed.
- To evaluate different options and impacts for water resource uses in the Inabanga watershed. Options and impacts of water resource uses have been incorporated and reviewed in several workshops held with watershed stakeholders, November 2002 and May and July 2003, focusing on sustainable agricultural activity and water quality/quantity protection.
- To enhance/strengthen the research capacity/capability of staff in the Bureau of Soil and Water Management, Department of Environment and Natural Resources and local project collaborators.
- To transfer research outputs to stakeholders of soil and water management.

The PNRI has integrated its research under this program with funding from IAEA RAS/5/039 and PNRI. The PNRI project aims to provide long-term erosion rate and soil redistribution information using fall-out radionuclides (not included in the BSWM project). Through the use of $^{137}$Cs and $^{210}$Pb, the project aims to contribute to objective 2 of the ACIAR-BSWM project: to evaluate the extent of long-term erosion rate from agricultural croplands and assess sedimentation rate in a selected site in the watershed.

The data will be useful in the management of the watershed in terms of maintaining soil agricultural productivity and in limiting the sedimentation/siltation of Malinao Dam, located in the area.

The study site selected by the ACIAR-BSWM project has several land use practices:

Grain Crops (rice and corn) - 40%
Root crops - 9%
Coconut - 4%
Grassland - 31%
Forest - 14%
Wetland and special land use - 2%
Total area is 61600 hectares.

Experimental plots have been established within the watershed and sampling of water and sediments has commenced. The sites have been selected to allow evaluation of intensively cultivated crops (both irrigated and rainfed), agro-forestry, forestry, grassland and oil palm land usage. Considerable stakeholder input was incorporated into the selection of experimental sites and types of agricultural activity to be evaluated.
Highlights of Accomplishment:
A reconnaissance of the study area was made and an exploratory sampling was made during the first visit to the study site. To establish the reference inventory, scraper plate and core samples were taken from a possible reference site. Selected sites were also sampled during the reconnaissance survey.
The samples were processed and analyzed for $^{137}$Cs. The reference inventory in the site using the core sample values is $580 \pm 105$ Bq/m$^2$. Using the scraper method of sampling, a value of $440 \pm 105$ Bq/m$^2$. This inventory is in closer agreement with the expected inventory considering the latitude and rainfall in the area than the ones obtained earlier in Bukidnon, Neuva Ecija and Isabela. If values obtained can be validated with subsequent measurement, the $^{137}$Cs methodology could get reliable estimates of long-term erosion rate in the area.

A second trip was made to the site to collect samples from a cassava plantation. A 0.5 ha grid with cell size of 10 m x 10 m was chosen to represent the land-use type (cassava). Forty-nine cores were collected from the grid. And are now being processed in the laboratory.

3.5 Sri Lanka

*Soil Erosion and Sedimentation, and Agrochemical Movement Studies Using Radionuclides*

Tissa Senerath Bandara Weerasekara, Land Use Division, Irrigation Department.

A) Introduction

A.1) Background

With the recognition of the importance of soil conservation for achieving higher productivity in agriculture, the IAEA has been instrumental in organising research in the $^{137}$Cs technique for measuring soil erosion and redistribution in relation to the landscape. Since 1996 it has coordinated the research work on $^{137}$Cs technique conducted by a number of research groups throughout the world. This has helped the evolution of this technique as a standard method in assessing soil movement by erosion. Also, in the past few years the IAEA has taken steps to transfer the technology through a technical cooperation programme. The IAEA TC project RAS/5/039 part II on soil erosion is one project in this technical cooperation programme. In this project, Sri Lanka, China, Pakistan, Vietnam, Indonesia, Malaysia, and Philippines conduct erosion studies using $^{137}$Cs. The project started in 2002. After the project formulation meeting in Beijing, China in that year, the interim results were presented in the mid-term review meeting held in Jakarta, Indonesia in 2003.

A.2) Specific objective

The specific objective of the project is to measure soil erosion and redistribution in a selected watershed area. Associated with this objective is the determination of the movement of pesticides, although Sri Lanka currently concentrates only on soil movement.

A.3) Scale of work and available resources

A small watershed with an area of about 80 km$^2$ was selected for the study. This watershed has a variety of land uses and spreads across three agro-ecological regions. Because the erosion hazard is high in the watershed, some land use and land use management practices are not recommended. The study will evaluate the extent of erosion associated with inappropriate land use and land use
management in the area. The watershed has forest plantations that are more than 50 years old. These are used as reference sites for $^{137}$Cs measurements.

The study is conducted by the Land Use Division (LUD) which is the main counterpart, in collaboration with the Atomic Energy Authority (AEA) of Sri Lanka. The equipment and staff for field sampling are provided by the LUD. In addition LUD performs the physical and chemical analyses of the soil samples. The AEA has the facility for measuring $^{137}$Cs activity in the soil samples. Recently the IAEA upgraded the detection facility by providing an uninterrupted power supply system and a shield for the HPGe detector at AEA. The AEA has qualified and experienced scientific and technical staff for gamma detection. The LUD has land use scientists who will interpret the detection results in order to assess the erosion and redistribution of eroded material.

**B) Site selection and sampling**

**B.1) Field reconnaissance survey**

The watershed selected for the study is situated in the south-eastern region of the central hill country, about 215 km from the capital Colombo. After selecting the watershed, base material such as 1 inch to 1 mile topographic survey sheets, aerial photographs, agro-ecological maps, soil maps, hydrological maps, and current land use maps for the area was collected and the information was included in a geographic information system (GIS). Using the GIS, a large number of prospective sampling sites were marked on the map for inspection. Then, in several reconnaissance field surveys, forty sites that are most suitable as reference sites were selected for sampling.

While the reference sites were being sampled, field reconnaissance survey continued for the identification of the sites that are to be sampled for the assessment of erosion and redistribution of soil. These were selected in such a way that the sites represent different land use, different soils, and different agro-ecological regions.

**B.2) Field sampling design**

A probability-based grid sampling design was used. A grid of five parallel transects each having five sampling points were demarcated in each site. Transects were five meters apart, and the sampling points were also five meters apart. Geodetic information for each site was obtained before laying the design, and this information was used in adjusting the position of the whole grid so that the best topographic conditions were met. Adjusting the grid was particularly important in reference sampling because any sampling point where deposition has occurred had to be avoided.

**B.3) Reference sites**

Forty-reference sites were sampled. The sites were selected in such a way that they represent the three types of land form found in the area, namely, rolling, hilly, and mountainous (FAO). The sites were selected in the crest and upper slopes of the landscape so that reference $^{137}$Cs values are not contaminated with the effects of any deposition. All these sites were in forests that are more
than 50 years old and have not been disturbed by human activity. Because detailed geodetic survey information was not available for the area, each site was surveyed before sampling. This was necessary for the interpretation of the $^{137}\text{Cs}$ distribution in the profile. Such interpretations would reveal if the topography of the site has permitted any deposition of soil material due to natural erosion process. The coordinates of the sites were obtained using GPS technology.

**B.4) Sample collection and processing**

In order to obtain the $^{137}\text{Cs}$ levels of the soils and to observe the profile distribution of the radionuclide three reference sampling sites were selected at the beginning of the sampling phase. Sampling was done using a scraper plate. Samples from each site were collected at 2 cm intervals. Using the data from these three sites preliminary assessments of profile $^{137}\text{Cs}$ distribution and $^{137}\text{Cs}$ inventories were made. Based on this assessment the depth to which samples should be collected was determined. It was decided that at each reference sampling point sampling should be done at 10 cm intervals to a depth of 30 cm using core sampler.

The samples were air-dried, weighed, and were subjected to manual disintegration and grinding. Then they were sieved to obtain the fraction less than 2 mm.

The <2mm fractions of sub samples of each corresponding 10 cm segment from the 25 spatially independent points of a site were mixed. The composite sample was then sub-sampled by coning and quartering method. The sub-sample was oven-dried at 105°C and was sent for gamma detection at the Sri Lanka Atomic Energy Authority (AEA) where detection is performed using an HPGe detector.

**C) Measurement of $^{137}\text{Cs}$ activity in soil samples using gamma spectrometry**

**C.1) Detection methodology**

The soil samples collected from different sites were detected for $^{137}\text{Cs}$ radioactivity analysis. $^{137}\text{Cs}$ radioactivity was measured by counting the 661.5 keV gamma line (Gamma spectrometry) with a Hyperpure Germanium (HPGe) detector. The Gamma spectrometry system used consists of the following.

<table>
<thead>
<tr>
<th>Detector type</th>
<th>HPGe-Ortec Gem. 35 P- Coaxial Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Acquisition</td>
<td>Genie – 2000 Basic Spectroscopy software + Interactive peak fitting option.</td>
</tr>
<tr>
<td>Efficiency Calibration</td>
<td>LU466 mixed radionuclide standard was used and Gamatool computer software (ver. 2.1) was used for density correction for counting Geometry.</td>
</tr>
</tbody>
</table>
C.2) Uncertainty Budget

The following components were considered to calculate the uncertainty of the results given for $^{137}$Cs in soil samples.

Table. 3 - The Uncertainty Budget for determination of $^{137}$Cs in Soil Sample Ref 2

<table>
<thead>
<tr>
<th>Variable Names</th>
<th>Symbol of the variable</th>
<th>Value</th>
<th>Uncertainty Component Symbol</th>
<th>Uncertainty value</th>
<th>Relative standard uncertainty $(u)_c$</th>
<th>Percent contribution to combined uncertainty $(U)_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of the sample</td>
<td>M (g)</td>
<td>898.3</td>
<td>U (m)</td>
<td>0.898</td>
<td>0.10</td>
<td>0.04</td>
</tr>
<tr>
<td>Detector Efficiency</td>
<td>E</td>
<td>0.01286</td>
<td>U (E)</td>
<td>0.000195</td>
<td>1.52</td>
<td>9.56</td>
</tr>
<tr>
<td>Background corrected net area of the sample peak</td>
<td>N</td>
<td>656</td>
<td>U (N)</td>
<td>30.63</td>
<td>4.66</td>
<td>89.89</td>
</tr>
<tr>
<td>Emission probability</td>
<td>Y</td>
<td>0.85</td>
<td>U (Y)</td>
<td>0.003</td>
<td>0.35</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Value of the measure (activity concentration) $A = 6.343$ Bq/kg

Relative combined standard uncertainty $U_c (A) = 4.915$

Relative expanded uncertainty $U (A) = 9.83\%$ (coverage factor = 2)

Value of the measured ± expanded uncertainty $= 6.343 ± 0.6235$ Bq/kg

(Source: SOP for Uncertainty Budget for Gamma Spectrometry - AEA/NAT/Sop 08)

C.3) $^{214}$Bi correction

The main $^{137}$Cs peak is located at an energy of 661.5 keV, but there is some interference from an overlapping $^{214}$Bi peak on the high-energy side at 665.8 keV (Figure 1). Count rate of $^{137}$Cs peak was corrected for $^{214}$Bi interference using interactive peak fitting option in Genie 2000 computer software. Following is an example.

Figure 1. $^{214}$Bi Correction using interactive peak fitting
D) Calculation of soil loss/gain using conversion models

At present soil loss from four types of land use that occur in the same agro-ecological region are considered. The $^{137}$Cs levels of the soils were statistically analysed to obtain the mean activity and variability. The mean value was used in the proportional model to obtain the soil loss. Bulk density values of the soils measured at sites were used. Time elapsed since $^{137}$Cs accumulation was taken as 50 years.

(a) Tea lands with high management inputs

These are lands that occupy tea plantations that are agriculturally well managed. The tea stands are about 40 years old. The $^{137}$Cs levels of the soils are typically 212 Bq m$^{-2}$. The associated soil loss is 17 t ha$^{-1}$ yr$^{-1}$.

(b) Tea lands with low management inputs

These are old plantations that have been established about 100 years ago. The $^{137}$Cs level is typically 53 Bq m$^{-2}$. The soil loss has been 43 t ha$^{-1}$ yr$^{-1}$.

(c) Secondary forests

The primary forest in these lands has been removed 20 – 30 years ago. The secondary forest consists of forest plantations and shrub jungle. Observed $^{137}$Cs levels are typically 127 Bq m$^{-2}$. The soil loss has been 31 t ha$^{-1}$ yr$^{-1}$.

(d) Vegetable and home garden

This is a mixed land use. A high proportion of land however is occupied by vegetable plots. The top soil of the vegetable plots is constantly mixed with organic material and soil from outside. The lands are cultivated most part of the year. $^{137}$Cs levels are typically 87 Bq m$^{-2}$. The associated soil loss is 37 t ha$^{-1}$ yr$^{-1}$.

E) Interpretation of results

One of the early objectives of the sampling and detection process was to establish a reliable $^{137}$Cs measurement of the reference sites. It can be mentioned that this objective was achieved although the process was time-consuming. The variability of the $^{137}$Cs levels remains well within 10%.

The types of land use considered at present have been classified to the extent allowed by the scope of the study and the availability of base data. They could be further refined at a better scale of surveys and observations. The results obtained for each land use in the part of watershed considered are interpreted as follows.

The well-managed tea lands show least loss of soil per year. They are comparatively young plantations. It should be noted that in a well-established tea stand the erosion is minimum. When
replanting takes place the soil becomes exposed and erosion can occur. This can also happen after pruning. Because the economic returns from the plantation are high it is natural that more capital and recurrent inputs are associated with them. The agricultural management is adequate and the soil is conserved.

On the contrary, older plantations run the risk of being neglected once the economic returns become low. Slightly neglected management or a decrease in capital and recurrent inputs can cause the degradation of soils and the plantations have become unproductive. As a result, there is less and less capital and recurrent inputs allocated to them, and the soil continues to degrade.

The case of the secondary forest is unique in that most of the soil loss from this land may have occurred just after the removal of the primary forest. After the establishment of the natural vegetation and the forest plantations, the erosion could expect to have been minimal.

The mixed land use of vegetable and home garden present some complications in measuring the $^{137}$Cs levels associated with it. This is mainly because the lands have been terraced for both construction and cultivation at various points in time in the last 50 years. In addition, in cultivated areas the topsoil is regularly mixed with organic matter and in some cases soil from other areas. Therefore, the $^{137}$Cs values observed may not fully represent the erosion levels. Because strict conservation methods are applied in the cultivated area the soil loss from them is not high. The major contribution to the soil loss comes from construction. This needs to be further investigated.

### 3.6 Indonesia

*The use of the $^{137}$Cs technique for measuring soil erosion/sedimentation at a cultivated area, Bogor*


**A) Introduction**

**A.1) Background**

The global fallout of bomb-derived radiocaesium that occurred during a period extending from the mid 1950s to the late 1970s provides the basis for the $^{137}$Cs technique. The $^{137}$Cs reaching the land surface was rapidly and strongly fixed by the surface soil in most environment and redistributed by water within the landscape. Thus, the $^{137}$Cs technique can be used to identify the spatial pattern of erosion and deposition within the landscape, relative to the reference inventory.

Since the early 1980s $^{137}$Cs measurement have been used widely, mainly in the advanced countries to identify soil erosion and sediment redistribution from cultivated soils (Brown et al, 1981; Loughran et al, 1988). In recent past, $^{137}$Cs technique has now been successfully used to document soil erosion and sediment redistribution both qualitatively and quantitatively in a wide range of environments (Paolo P. et al, 2003; Walling and He, 1998).

In Indonesia, the use of $^{137}$Cs technique for measuring soil erosion-deposition rates has been started at the last 2 years through RAS/5/039. Due to a lack of experienced human resources in interpreting of data, during a period from 1993 to 2001, the $^{137}$Cs measurement was only
addressed to identify soil erosion and deposition qualitatively. However, the investigations of reference sites through $^{137}$Cs measurement at several locations in East Java were continuously conducted and aimed to seeing the potential of its use for erosion study (Ali A.L. et al, 2001).

Beside continuing the investigation of erosion/sedimentation rate in the same site as reported in Jakarta meeting, the other site in desa Tugu (Tugu village) was also chosen to be studied. The last site was selected to apply its technique to the end user, BATAN in collaborating with Bureau of Catchment Management (BCM) has been trying to conduct the study for measuring the distribution of erosion/sedimentation at a small catchment by using the $^{137}$Cs technique. Batan provides the human resources in related to collecting the soil samples and $^{137}$Cs inventory counting, BCM provides the supporting data such as type of soil, topography of the area, rainfall gauge, land use etc. Meanwhile, the chosen of the study site is based on the availability of supporting data that can be used to assess in interpreting of data from $^{137}$Cs measurements.

A.2) **Objectives:**

- To find $^{137}$Cs loss and gain rate relative to the reference inventory with different management practices.
- To measure soil redistribution using $^{137}$Cs at a cultivated area within the small catchment of upper part of Ciliwung catchment.

B) **Site Characteristics**

B.1) **Sites**

B1.1) **Site 1**

Two sites were selected to conducting erosion-sedimentation study at a cultivated land. The first site consists of 2 landscapes, namely communal and commercial land uses. These two landscapes are located in the same place as previous reported, that are in Bojong. These landscape were given name as land use III and land use IV, for communal and commercial, respectively. Land use III is about 1500 m from the top of slope, and slope gradient approximate of $2^\circ$. Land use III is planted with corn, cassava and bananas rotationally. The half of upslope and down slope area is planted in different kind of one season crop, which usually planted by corn and cassava rotationally. Land use IV is about 700 m from the top of slope, it has slope gradient of $14^\circ$ and it is planted with sweet potato, chilly and tomato rotationally. The last land use is cultivated by plow machine and the plough depth is about 30 cm. It is the only one land used that has highest slope. Here, the ridge and furrow cultivation system is also applied in cultivation practices. On ridges were covered by plastic bag at around the hole of crop.
B1.2) Site 2

The second site is a cultivated area within the small catchment, is situated in geographical coordinate from approximately 106°54'20" – 107°00'04" E and 6°39'12"-6°44'00" S with total area around 150 ha. The topography of study site can be seen in Figure 1. The elevation of the area is from 1460 m asl on the highest to 1080 m asl on the lowest. Its topography is characterized by hilly relief with average slopes ranging from 8 to more than 40 %.

The climate is tropical mountain with usually dry season from April to September and rainy season from October to March. In recent years, the rainy season was extended till the end of April. The average annual rainfall is about 2300 mm based on the last 8 years observed data. Most of the rainfall falls between January and March. Daily rainfall on the area is about 165 days each year. The highest suspended sediment yield observed at the outlet of the catchment usually occurred on February.

The type of soils of the area based on the USDA classification is associated of reddish brown inceptisol and brown inceptisol. It has granular structure and fine texture of silty loam to clay loam, with the depth of soil ranging from 90 to 120 cm.

Due to deforestation, about 22 ha of the original forest was bare land during a period from 1976 to 1990. Conservation practice was performed to rehabilitate the area through replanting made in middle of 1990 by BCM, Forestry Department. Since then, within the small catchment has been instrumented with automatic rainfall recorder (ARR) and automatic water level recorder (AWLR) at the outlet. The measurement of suspended sediment at the outlet has also been performed to assess and to monitor the impact of agricultural activity and land use practices with respect to erosion rate. Based on the annual report of Bureau of Catchment Management (2002), covering land consist of forest (approx. 25.9 ha), tea plantation (approx. 43.6 ha), un-irrigated land and garden (approx. 71.3 ha) and residential area (approx. 7.7 ha). In un-irrigated land, conventional cultivation practices used by farmers are being applied. Most of the farmers cultivate land by traditional method. Rejuvenation of tea plantation is done each 5 years rotationally.

Figure 1. Topography map of the study area
C) **Methods**

C.1) **Reference site sampling at Bojong**

In order to convert the inventory $^{137}\text{Cs}$ at the investigation area of landscape III and IV to soil loss or gain rate, the reference inventory of previous study was applied.

C.2) **Reference site at desa Tugu**

During visiting the investigation site of desa Tugu at end of March 2004, it was difficult to find the location that possible used as reference site. To overcome this temporary problem, the reference site was taken by simulation of estimate bomb $^{137}\text{Cs}$ inventory provided in Csmodel1-software.

C.3) **Soil sampling at Bojong site**

Soil samples were collected using corer tube of 7 cm diameter manually by hammer to push down the tube till 40 cm depth. The used sampling method was integration of grid sampling. From land use III (20 m x 45 m), 50 core samples were collected in 5 m spacing, both parallel and perpendicular to slope. From land used IV (40 m x 50 m) 30 core samples were collected in 10 m spacing both parallel and perpendicular to slope. 3 of 30 core samples in and used IV were taken on the ridges.

C.4) **Soil sampling at desa Tugu**

Soil sampling was performed at an area of cultivated, and located in middle slope. The sampling design was slope transect with irregular spacing along the slope from approximate 1180 to 1220 of height. The sampled area is about (30 m x 160 m). 3 samples with spacing 10 m perpendicular the slope were taken and measured individually. Mean of obtained three values of $^{137}\text{Cs}$ inventories were assumed as one value for representing of each section of the slope transect. Total number of samples to be measured was 21, while the single value represented for each section along transect to be 7.

D) **Results**

D.1) $^{137}\text{Cs reference inventory}$

Based on the data obtained in the previous study, the range of reference value (for N=17) with 95% confidence limit can be expressed as:

Reference mean ± 2 SEM = 286 ± 47 Bq/m$^2$, ranging from 239 to 333 Bq/m$^2$

2 SEM = 2 SD/$\sqrt{N}$ (95% confidence limit)

This above range value is needed to identify erosion /deposition points qualitatively. The inventory value within the range is considered as a transition points (no erosion and deposition). Values less than lower limit indicate erosion points, and values greater than upper limit indicate deposition point. The above value of reference was applied for calculating the erosion/deposition
rate on land use III and land use IV. Reference inventory that used for calculating erosion/deposition rate at desa Tugu is 305 Bq/m². This single value was obtained by simulation of estimated bomb $^{137}$Cs fallout.

D.2) Estimation of soil erosion/deposition rate

The result of estimated soil erosion/deposition rates can be seen in Table 1 to Table 3 and Figure 2 to Figure 4 for soil redistribution. The soil redistribution in land use III is characterized by both process of erosion and sedimentation in extreme value within the landscape, ranging from 0 to more than 60 t/ha/yr. However, the net soil export for land use III is 0.04 t/ha/yr only. This landscape can be considered to be one of the suitable area for all of agricultural activities without needed special soil management practices.

Land use IV is a commercial land for economic purpose. Intensive cultivation is done to produce more agriculture production. Land use IV is divided into ridges and furrows. The width of furrow is 40 cm with the depth of 30 cm, and the width of ridge is 100 cm. Based on the result of calculated erosion/deposition of each sampling point, 3 of 3 samples taken on the ridges showed positive value as an indication of accumulation point, and most of samples taken in furrows suffered from considerable erosion, ranging from 0 to 59 t/ha/yr. The net erosion of land use IV is 13.58 t/ha/yr.

Table 1. Erosion/deposition rate for land use III

<table>
<thead>
<tr>
<th>No</th>
<th>Cs-137 Inv. (Bq/m²)</th>
<th>MP (t/ha/yr)</th>
<th>No</th>
<th>Cs-137 Inv. (Bq/m²)</th>
<th>MP (t/ha/yr)</th>
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<tr>
<td>1</td>
<td>155.63</td>
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<td>243.76</td>
<td>0</td>
<td>49</td>
<td>204.21</td>
<td>-9</td>
</tr>
<tr>
<td>25</td>
<td>562</td>
<td>33.33</td>
<td>50</td>
<td>327.48</td>
<td>0</td>
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</table>
**Table 2.** Erosion/deposition rate for land use IV

<table>
<thead>
<tr>
<th>No</th>
<th>Cs-137 Inv. (Bq/m²)</th>
<th>MP (t/ha/yr)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>386.9 *</td>
<td>8.06</td>
</tr>
<tr>
<td>2</td>
<td>29.47</td>
<td>-47.98</td>
</tr>
<tr>
<td>3</td>
<td>59.57</td>
<td>-31.15</td>
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<tr>
<td>4</td>
<td>314.11</td>
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<tr>
<td>5</td>
<td>134.8</td>
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<td>6</td>
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<td>-2.41</td>
</tr>
<tr>
<td>7</td>
<td>270.66</td>
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</tr>
<tr>
<td>8</td>
<td>177.04</td>
<td>-12.7</td>
</tr>
<tr>
<td>9</td>
<td>130.51</td>
<td>-22.78</td>
</tr>
<tr>
<td>10</td>
<td>172.38</td>
<td>-16.6</td>
</tr>
<tr>
<td>11</td>
<td>155</td>
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<tr>
<td>12</td>
<td>295</td>
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<tr>
<td>13</td>
<td>61.72</td>
<td>-39.51</td>
</tr>
<tr>
<td>14</td>
<td>176</td>
<td>-14.64</td>
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<tr>
<td>15</td>
<td>333.27</td>
<td>0.04</td>
</tr>
<tr>
<td>16</td>
<td>196.48</td>
<td>-8.28</td>
</tr>
<tr>
<td>17</td>
<td>45.77</td>
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<td>18</td>
<td>23.83</td>
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<td>20</td>
<td>192.48</td>
<td>-12.43</td>
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<tr>
<td>21</td>
<td>68.95</td>
<td>-40.5</td>
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<tr>
<td>22</td>
<td>443.39*</td>
<td>19.65</td>
</tr>
<tr>
<td>23</td>
<td>276.83</td>
<td>0</td>
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<tr>
<td>24</td>
<td>196.52</td>
<td>-10.57</td>
</tr>
<tr>
<td>25</td>
<td>262.46</td>
<td>0</td>
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<td>26</td>
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<td>-36.48</td>
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<tr>
<td>27</td>
<td>216.79</td>
<td>-4.53</td>
</tr>
<tr>
<td>28</td>
<td>338.65</td>
<td>0.94</td>
</tr>
<tr>
<td>29</td>
<td>267.93</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>618.2*</td>
<td>51.78</td>
</tr>
</tbody>
</table>

* Samples from ridges.

**Table 3.** Cs inventory and soil erosion deposition results for desa Tugu

<table>
<thead>
<tr>
<th>Sample Results</th>
<th>From top to down</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Cs-137 (Bq/m²)</td>
<td>176.5 463 546 479 365 443 394</td>
</tr>
<tr>
<td>Erosion deposition rate (t/ha/yr)</td>
<td>-20 24.3 37.6 27 9.4 21.4 13.8</td>
</tr>
</tbody>
</table>
From the desa Tugu site, only one section along transect indicated erosion and other sections indicated deposition. This may result from erosion from the top area of the slope or from a reference inventory value that is too low. To confirm this, more soil samples should be taken from the hilltop and a suitable reference site should be selected and sampled.

![Figure 2. Soil redistribution pattern as function of field topography for LU-III](image1)

![Figure 3. Soil redistribution pattern as function of field topography for LU-IV](image2)
E) Conclusion

Conversion model of proportional can be used to calculate soil erosion/sedimentation rate. Integration of grid point sampling is very useful to describe the pattern of soil redistribution in detail, as well as to simplify for calculating of the net erosion exported from an area to be investigated.  

\(^{137}\)Cs is an alternative method that can be used to study erosion-deposition process in an area effectively. The net erosion of land use at Bojong is supposed as contribution dominantly from commercial land use, comparable to other communal land. Erosion investigation at desa Tugu needs to be completed by more soil samples along the whole transect from the top to down of the hill, and by sampling a suitable reference site.

F) References


3.7 China

_Determination of soil redistribution-soil quality relationship and gully development using $^{137}$Cs- and $^{210}$Pb$_{ex}$ techniques in West China_

Yong Li, L. Bai, L. Li, Q. W. Zhang, X. C. Zhang, and F.H. He
Institute of Agricultural Environment and Sustainable Development, CAAS

A) Summary of work conducted from October 2003 to June 2004

Determining a cause-effect relationship between soil quality and soil erosion is the key issue for selecting effective soil conservation measures. Understanding of past gully development is difficult in the areas without historical records of soil erosion and land use. We assumed that fallout radionuclides might have potentials for solve these two issues. Accordingly, our research work since Jakarta Meeting in October 2003, mainly focuses on:

1) Determination of the reference inventories of fallout $^{137}$Cs and $^{210}$Pb$_{ex}$ in study watersheds.
2) Assessment of spatial variations in soil quality affected by soil erosion on steep hillslope catchment
3) Reconstruction of gully development using $^{137}$Cs and $^{210}$Pb$_{ex}$ dating and GPS survey

Our study areas are located Fangzhuang in Yanhe River Basin and Xichang in the Upper Yangtze River Basin (Figure 1). So far, we have completed the measurements of 400 soil samples collected, several papers were published in J. Soil & Water Conservation, and one paper was published in SSSAJ May 2004, and one book on gully erosion under global change was published in March 2004.

For the period from October 2003 – June 2004, we trained three senior scientists for use of fallout radionuclides in soil erosion assessment. Two of them are from Pakistan, and one from Sri Lanka.

B) Main results obtained from October 2003 to June 2004

B.1) Depth distributions and inventories of fallout $^{137}$Cs and $^{210}$Pb$_{ex}$ in reference sites

Reference sites for determining the $^{137}$Cs fallout in the study areas were established at undisturbed, uneroded, and level terraced fields constructed in 1954, and uncultivated grassland at hilltop within the study catchments (Figures. 2-3). Reference values of $^{137}$Cs and $^{210}$Pb$_{ex}$ inventories in the reference sites were calculated to $2390\pm360$ Bq/m$^2$ and $9600\pm1900$ Bq/m$^2$. 

81
respectively, for the Chinese Loess Plateau, and 845±53 Bq/ m² and 12571±2247 Bq/ m², respectively, for the Upper Yangtze River Basin. The coefficients of variation (CV, %) for 14 sampling sites were in range of 6-15% for 137Cs and 18-20 for 210Pbex. The depth-incremental profiles of both fallout 137Cs and 210Pbex in reference sites shows a typical exponential decrease with soil depth, and majority of the 137Cs and 210Pbex concentrated within the top layers of 0-10 cm.

B.2) Spatial variations in soil quality affected by soil erosion on steep hillslope catchment

In our previous studies, we indirectly estimated soil redistribution rates from tillage and water erosion using 137Cs measurements integrated with tillage erosion prediction model developed by Lindstrom, and then linked them to soil quality parameters. But our previous study only focused on several downslope transects. Here our objective is to assess the spatial variations in soil quality parameters as affected by soil redistribution at a hillslope catchment scale. Surface level surveyed using GPS and sampling points for measuring 137Cs and soil quality parameters are show in Figure 4a. Our results showed that there exists a clear increase in 137Cs inventory at each lower field boundary along down hillslope transects whereas a clear decreasing trend were found at upper portion of each field (Figures 4a and 4b). Tillage erosion should be the dominant soil redistribution process in the portion of the summit whereas water erosion should be dominant process at portions of the backslope of the hillslope. These spatial patterns in soil redistribution might have significant impacts on variations of soil quality within the study hillslope catchment. Measurements of related soil quality parameters and their relationship with soil redistribution are under process.

B.3) Reconstruction of gully development using 137Cs and 210Pbex dating and GPS survey

Gully erosion is the major contributor to the overall sediment delivered to both the Yellow and Yangtze Rivers in the west China. Few studies have been conducted on the long-term impacts of the land use change on gully initiation and gully development. The target areas of our research are the dry-valleys located in the upper Yangtze River Basin, SW-China. Our objectives are: a) to obtain the environmental information on gully patterns and their development at different spatial and temporal scale in the upper Yangtze River Basin, b) to reconstruct the historical record of gully development and land use change over the past 200 years, and c) to quantify the processes and the effectiveness of land use structures on spatial patterns of gullies. The first investigations were carried out in the Anning Warm-Dry Valley of southern Sichuan in the territory of Xichang. Three gully systems were investigated in details (Figure 5). The size (length, average depth and width) and the volume of the gully system were measured in the field with RTK-GPS. 137Cs and unsupported 210Pbex dating were used to distinguish the chronology of sediment profiles within the gully systems. Local culture and history records were analyzed, senior experts and farmers were interviewed for a detailed reconstruction of land use history. The temporal patterns of gully development processes at study gully catchments could be subdivided into five time periods. Gullies initiation occurred during 1920-1930, and maximum increase of gully development in the period from 1950 to 1970. Rapid decrease of gully development closely corresponded to increase in vegetation cover and reduction of intensive grazing intensity in the study area (Table 1). A detailed analysis of land use impacts on gully development is under process.
C) References:


Figure 2. Reference inventory of $^{137}$Cs in the Loess Plateau

Figure 3. Profile distribution of $^{210}$Pb$_{ex}$ in a reference site on the Loess Plateau

Figure 4a. Spatial distribution of $^{137}$Cs inventory in study hillslope catchment
Figure 4b. Percentage reduction in total $^{137}$Cs inventory (defined as $[(\text{Aref}-A)/\text{Aref}]\times100$) in study hillslope catchment

Figure 5. Gully system in Changshanling, Xichang

Table 1. Gully age and advance rate of the gully head determined by FRNs dating and GPS survey in Xichang system in Changshanling, Xichang

<table>
<thead>
<tr>
<th>Gully No.</th>
<th>Gully area (m$^2$)</th>
<th>Gully length (m)</th>
<th>Gully age (yr)</th>
<th>Gully advance (m/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gully 1</td>
<td>2944</td>
<td>206.53</td>
<td>70</td>
<td>2.95</td>
</tr>
<tr>
<td>Gully 2</td>
<td>447</td>
<td>34.04</td>
<td>70</td>
<td>0.49</td>
</tr>
<tr>
<td>Gully 3</td>
<td>2325</td>
<td>132.76</td>
<td>50</td>
<td>2.66</td>
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4. UPDATED WORK PROGRAM FOR THE REMAINING MONTHS OF THE PROJECT

4.1 Viet nam

<table>
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<th>2005</th>
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<tr>
<td></td>
<td>Q3</td>
<td>Q4</td>
</tr>
<tr>
<td>Soil sampling</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Measuring $^{137}$Cs, $^{210}$Pb and soil properties</td>
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<td>X</td>
</tr>
<tr>
<td>Data analysis</td>
<td>X</td>
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<tr>
<td>Specific sampling for soil deposition</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Data processing</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Assessing soil redistribution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final report</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Scientific visits*</td>
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* 3 people, 3 weeks

4.2 Malaysia

<table>
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</thead>
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<tr>
<td></td>
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<td>Q4</td>
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<tr>
<td>Sampling in a grid pattern</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>To continue soil sample collection from the study site for doubtful $^{137}$Cs results and refining the reference inventories.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Monitoring of insecticide from runoff*</td>
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<tr>
<td>Laboratory analysis of soil samples for $^{137}$Cs activity and insecticide contents in soil.</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Continuing data processing and analysis</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Assessing erosion/deposition rates and patterns</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Final report</td>
<td></td>
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</tbody>
</table>

4.3 Pakistan

<table>
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<tr>
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</thead>
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<tr>
<td></td>
<td>Q3</td>
<td>Q4</td>
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<tr>
<td>Field surveying (levelling and other physical measurements) in the catchment and preparation of site maps</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Collection and analysis of soil samples for $^{137}$Cs to refine reference inventories in the area</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Collection of soil samples from cultivated fields and non-cultivated slopes and analysis for $^{137}$Cs</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Testing/comparison of improved soil/crop management practices for erosion control</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Submission of Sub-contract to the Agency to organize a National</td>
<td>X</td>
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</table>
Executive Management Seminar/Workshop for dissemination of information and transfer of technologies related to application of nuclear (radionuclides) techniques in soil and agrochemical management.

Compilation of results of pesticide (herbicide) contamination of runoff sediment and residue in plants and field.  X

Fellowship training of two months to get practical knowledge in application of $^{137}$Cs conversion models and application of $^{210}$Pb and $^{7}$Be techniques (sampling, analysis and data interpretation) for soil redistribution. A request has already been submitted to the Agency.  X

Data processing/interpretation and preparation of the final report  X  X

National Executive Management Seminar/Workshop for dissemination of information on integration of nuclear and conventional techniques in soil erosion and sedimentation, and agrochemical management.  X

Expert services for one week to give lectures in the National executive management seminar/workshop mentioned below and discuss the interpretation/results of the field studies. (Request will be submitted)  X

### 4.4 Philippines

<table>
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<tr>
<td>Collection of additional soil samples</td>
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<tr>
<td>Analysis for $^{137}$Cs and soil quality parameters</td>
<td>X</td>
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<tr>
<td>Data analysis for soil redistribution and erosion rate quantification</td>
<td>X</td>
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<td>Report preparation</td>
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<tr>
<td>TSC Grant</td>
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<tr>
<td>Implementation of expert mission</td>
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<td></td>
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<tr>
<td>Implementation of scientific visit (researcher)</td>
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<tr>
<td>Submission of Scientific Visit request</td>
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<td>X</td>
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<tr>
<td>(end-user, study site visit)</td>
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<tr>
<td>Implementation of Scientific visit (end-user, study site visit)</td>
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<tr>
<td>Meeting with soil conservationists and other relevant government agencies and farmers</td>
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<td>Information drive activities</td>
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<td>Final Meeting, March 2005</td>
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### 4.5 Indonesia

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<td>Model design</td>
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<td>Sampling (continue)</td>
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<td>Treatment and sample analysis</td>
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<td>Dissemination of the results of the project</td>
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<tr>
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### 4.6 Sri Lanka

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</tr>
</thead>
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<tr>
<td></td>
<td>Q3</td>
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<tr>
<td>Selection of sampling sites</td>
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<tr>
<td>Detailed field surveys</td>
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<tr>
<td>Collection of soil physical and chemical characteristics by field and laboratory analyses of samples obtained from the sites.</td>
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<tr>
<td>Analysis of soil for $^{137}$Cs activity.</td>
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<tr>
<td>Data processing and data analysis.</td>
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<td>Pesticide analysis</td>
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<tr>
<td>Interpretation of $^{137}$Cs activity in terms of site characteristics and the landscape.</td>
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<tr>
<td>Local workshop for dissemination of information generated in this project and for the comments of personnel from other institutes.</td>
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<td></td>
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<tr>
<td>Preparation of publications</td>
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<tr>
<td>Draft reports and maps</td>
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### 4.7 China

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<tr>
<td>Intensive collection of soil samples from different cultivated and non-cultivated hill-slopes for $^{137}$Cs, $^{210}$Pb, and $^{7}$Be activities and soil quality parameters, and agrochemical levels</td>
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<td>X</td>
</tr>
<tr>
<td>Collection of sediment samples from the reservoir for analysing $^{137}$Cs, $^{210}$Pb, and $^{7}$Be and agrochemical</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Monitoring of sedimentation rates of the reservoir</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Lab analysis of soil and sediment samples for $^{137}$Cs activity and</td>
<td>X</td>
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</table>
soil quality parameters

<table>
<thead>
<tr>
<th>Data processing and analysis</th>
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<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil erosion and soil quality modeling</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Three scientific visits (2 for national coordinator/leading scientist, 1 for researcher)</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>One fellowship of three months to learn measurement and interpretation of 210Pb using gamma spectrometry</td>
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<td>Final report</td>
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5. PROGRESS IN NATIONAL PROJECTS IMPLEMENTATION

Following the presentations done by counterparts at the meeting and from the reports they submitted, the main achievements of the participating countries, since the Jakarta meeting, may be summarized as follows:

5.1 Viet nam

- A collaboration was established with the National Institute for Soils and Fertilizers (NISF).
- At Doan Hung, soil losses obtained by direct measurement were compared with estimates from $^{137}$Cs and $^{210}$Pb techniques. The resulting three Figures agreed well.
- A new project was initiated at Dong Quyt, on erosion-runoff plots of NISF. Erosion measurements are done under varied land uses, by direct measurements and indirectly, by $^{137}$Cs. Soil quality indicators and $^{210}$Pb will also be measured. The first results indicate soil redistribution along slopes and important deposition above hedgerows.
- An expert mission was done by R. J. Loughran (one week).

5.2 Malaysia

- A collaboration was already established with the University of Science of Malaysia and the Department of Irrigation and Drainage.
- A study was initiated at the Perlis, where a 4300 ha sugar cane plantation was established in the early 1970s.
- Reference sites were sampled and $^{137}$Cs levels determined.
- Soil sampling was done in plantation. Low $^{137}$Cs inventories translate into high erosion rates. Their relative uniformity suggests topsoil removal at plantation time.
- Soil quality parameters will be measured at sampling points. Suspended sediments and pesticide (malathion) losses by runoff will be collected at the outlet of the experimental area.
5.3 Pakistan

- A cooperation was already established with the Water Resources Research Institute, the National Agricultural Research Center, the Pakistan Agricultural Research Council and the Nuclear Institute for Agriculture and Biology. $^{137}$Cs measurements were used to study soil redistribution along a hill-slope-streambed landscape. The results show $^{137}$Cs spatial redistribution on slopes, gully head and floor in accordance to the hypothetical model.

- From the Fateh Jang site, two fields were sampled for $^{137}$Cs. The analyses were completed and soil losses calculated, using several models. Re-sampling will be done because $^{137}$Cs inventories may have been underestimated due to a sampling depth too shallow. Runoff samples are also collected for sediment and pesticide measurements.

- In the Satrameel: Catchment No. 2 of Rawal Watershed, transects in and off animal tracks were sampled for $^{137}$Cs. The soil loss estimates can be compared to sediment discharge measurements.

- At the Sandaymar Catchment, a new project was initiated after Dr Loughran’s Expert Mission. Reference sites and several slope transects were sampled and analyzed for $^{137}$Cs.

- A Scientific Visit was done by Jamal Tariq Ahmed (PINSTECH) to CAAS, Beijing, China, and to Newcastle, Australia (one week each). Another scientist in this project made a Scientific Visit to CAAS, Beijing, China.

- Dr R J Loughran made an Expert Mission to PINSTECH (one week).

5.4 Philippines

- The projects are executed in cooperation with the Bureau of Soils and Water Management (BSWM), ACIAR (through BSWM) and the Bohol Agricultural Promotion Center (through BSWM).

- A new project was initiated on Bohol, in the Ingabanga watershed. The project aims to provide long-term erosion rate and soil Redistribution information using fall-out radionuclides, using $^{137}$Cs and $^{210}$Pb.

- After his training at the University of Newcastle (February – April), Richard Balog (PNRI) has taken 49 soil samples from a cassava field for $^{137}$Cs analysis. Determinations are underway.

5.5 Sri Lanka

- The study is conducted jointly by the Land Use Division (LUD) and the Atomic Energy Agency of Sri Lanka.

- In the study area, the Uma Oya catchment, reliable reference values have been established.

- Four land-uses (tea under high or low management, secondary forest and vegetable and homestead gardens) have been sampled for $^{137}$Cs. Data were obtained and soil losses have been estimated. Noticeable differences in $^{137}$Cs inventories and derived soil loss rates between land uses were reported.
• The detection equipment was upgraded by the addition of a lead shield.
• Scientific Visit by Dr Tissa Weerasekara to CAAS, Beijing, China, and to CSIRO, Canberra, Australia (one week at each).

5.6 Indonesia

• A co-operation was already established with the local Government of Bogor and the Agricultural Division of CRDIRT-BATAN and the Bureau of Catchment Management of the Forestry Department.
• Two new land uses (LU-III and IV) have been sampled on slope where LU-I and II had been previously done.
• The samples were counted for $^{137}$Cs and the data were converted to soil losses. The results indicate contrasted soil losses according to the land use.
• Some pesticide (Fenitrotion) measurements were also done on soil samples.
• A catchment (167 ha) study was initiated. The major land uses in the catchment are: forest ($\pm 21.7$ ha), tea plantation ($\pm 56$ ha), un-irrigated land and garden ($\pm 58.7$ ha) and residential area ($\pm 8.6$ ha). Some 8 years of direct measurement of suspended sediment yields are available, against which soil losses assessed from $^{137}$Cs measurements will be compared. Soils were sampled in reference sites and in tea plantations and cultivated areas. $^{137}$Cs counting are going on.

5.7 China

• The work is being done as a collaboration between the Institute of Agricultural Environment and Sustainable Development and the Institute of Soils and Fertilizers (CAAS), the University of Hangzhou and the Institute of Soil and Water Conservation (CAS)
• Spatial relationships between soil quality and redistribution on hillslopes were established.
• The reconstruction of gully development has been done using radionuclide and GPS data.
• The variation in time of erosion and deposition rates could be established from radionuclide data collected in two downslope depositional areas.
• A new project on the effectiveness of soil conservation measures or soil covers was initiated. Soils along transects were sampled and spatial variations in $^{137}$Cs and $^{210}$Pb$_{ex}$ were reported.
• On a slope catchment, the relative contribution of tillage and water erosion could be assessed from $^{137}$Cs and $^{210}$Pb$_{ex}$ measurements.
• A Scientific Visit was done by Prof. Yong Li (CAAS) to the University of Newcastle and CSIRO, Canberra (one week each).
• An Expert Mission to CAAS was done by R J Loughran (one week).
6. ACHIEVEMENTS IN THE IMPLEMENTATION OF THE PROJECT

After reviewing the reports from the participating countries, it can be stated that the following progresses have been achieved so far and that all the participants now:

- have collaborative partners interested and involved in the $^{137}\text{Cs}$ technique for soil erosion/sedimentation studies
- have a good understanding of the principles underlying the $^{137}\text{Cs}$ technique for assessing soil erosion/deposition.
- have adequate soil sampling equipment
- have a good understanding of the characteristics required by a good reference site and have a good understanding of the different procedures for sampling soil or sediments for $^{137}\text{Cs}$ measurements
- have an effective system for $^{137}\text{Cs}$ analysis
- have correctly selected reference sites meeting the requirements, have sampled these sites and have produced valuable data on the magnitude of $^{137}\text{Cs}$ fallout in their study area
- have completed or are in the process of completing study site selection
- have completed or are in the process of completing the sampling of the study sites and have produced reliable and valuable data on spatial redistribution of $^{137}\text{Cs}$
- know how to convert $^{137}\text{Cs}$ data to soil loss or deposition using some models
- are aware of the requirements of different models and of the impacts of these requirements on the produced estimates of soil erosion/sedimentation rates.
- Are aware of the complementarities of soil erosion/sedimentation data derived from $^{137}\text{Cs}$ data and estimates obtained from erosion models
- know the potential of the technique and have the capacity to use it independently
- have received support from IAEA: e.g. expert service, training on $^{137}\text{Cs}$ technique and data acquisition, etc.

A web site has also been established for the project RAS/5/039 part II. It presents the general objectives of the project, the country projects and their specific objectives and some of the main achievements obtained so far. This web site can be accessed at the following address: http://www.rca.org.cn/whats.asp

6.1 PROJECT CONTINUATION

All the participants prepared an updated workplan for the remaining months of the project (section 4 of Report). Two main types of activities will be carried during this period:

- continuation of soil sampling and analysis for $^{137}\text{Cs}$ inventories
- activities for the dissemination of the results of the project to interested groups such as farmers, policy-makers, etc.

Although it had been identified as an objective of the project, relating soil erosion, as revealed by $^{137}\text{Cs}$ inventories, to soil quality indicators and environmental issues (pesticide losses for example)
could not be implemented so far, except partially for a few countries. From the counterparts’ reports, it appears that before considering such objectives, it was necessary for the participants to fully understand all the requirements of the $^{137}$Cs technique and to develop the skills to apply the technique correctly. This was achieved in the present project. All the participants agree that, as a second step, soil erosion must be addressed in a wider context of natural resource conservation and of development of sustainable agricultural system.

Since soil erosion results partly from prevailing agri-environmental conditions, but also from upstream soil degradation processes induced by inadequate cropping systems (Figure 1), it is essential to investigate and understand the relationship between soil erosion and soil quality indicators. Eroding soils experience a reduced productivity, following export of carbon, nutrients and other agri-chemicals. In addition, eroded soils become a source of agricultural pollution of receiving water bodies (Figure 1).

**Figure 1. Interrelationship between soil degradation, soil erosion and agri-environmental impacts**

The soil quality and environmental pollution issues will then be addressed in a future project dealing with the assessment conservation practices using radioisotope techniques (see Annex D of report).

The participants agreed to publish the most significant results obtained in this project in a peer-reviewed scientific journal. All participants will provide a paper that will be appraised according to the usual procedure of the journal. As a first step, contacts will be made with the editors of Catena.
7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

1. The objectives of the Meeting were successfully achieved.

2. The overall progress made in implementation of the part II of TCP is satisfactory, though there are differences in targets, amount of work to be realized between the participating countries.

3. Individual work plans of the participating countries were updated and issues for completion of the TCP were defined.

4. The final report will include the revised version of the national work plans and project framework matrices as well of the regional project.

5. The following regional activity was also proposed:

6. Final Evaluation Meeting, 14-18 March 2005 in Manila, the Philippines (No. of participants: 8 maximum).

7.2 Recommendations

1. The meeting recommended the adoption of the Country Project Work Plans contained in this report.

2. It is recommended that appropriate linkages to beneficiaries (policy makers, land managers) be established to ensure the achievement of the potential impact of the project. Sustained support from local managers/officials of the national institutes is also required.

3. It is important to create public awareness on land degradation and environmental protection issues. Appropriate dissemination mechanisms of the results obtained should be defined and utilized to transfer the results to end-users.

4. To continue soil erosion/sedimentation studies using environmental radionuclides under the new regional TC project proposal “Development of Sustainable Land Use and Management Strategies for Controlling Soil Erosion and Improving Soil and Water Quality” to be implemented during the biennium 2005-2006.

5. To prepare a special issues of a peer-reviewed scientific journal to report the scientific achievements of this project. Each participant will prepare a manuscript.

6. Given the variability of $^{137}$Cs inventories at reference sites, a range should be used for reference inventory instead of a single value. From experimental points, inventories below the lower limit of the reference range would indicate a net loss of soil, values above the

95
upper limit of this range would indicate a net deposition, and no net soil movement would be considered for $^{137}$Cs inventories within the reference range.

7. It is recommended that Dr Robert Loughran keep contributing as expert, as required, for the continuation of the present project and for the new TC project.

7.3 Acknowledgement

The Malaysian Institute for Nuclear Technology Research (MINT) should be commended for their kind hospitality and the excellent organization of the meeting.
8. ANNEXES

Annex A - INFORMATION SHEET

Title: IAEA/RCA Meeting on Exchanging of Experiences using the Cs-137 technique

Place: Grand Maya Hotel  
138, Jalan Ampang  
50450 Kuala Lumpur, Malaysia

Date: 5-9 July 2004

Deadline for Nominations: 30 April 2004

Organizers: The International Atomic Energy Agency (IAEA) in co-operation with the Government of Malaysia through the Malaysian Institute for Nuclear Technology Research, Kuala Lumpur, Malaysia.  
Local organizer: Dr. Zainudin Othman  
Phone: +60 3 89282972  
Fax. + 60 3 89250907  
E-mail to: zainudin@mint.gov.my

Language: English

Participants: Representatives from the participating countries in IAEA/RCA TC project Restoration of Soil Fertility and Sustenance of Agricultural Productivity (RAS/5/039); part II. Measuring Soil Erosion/Sedimentation and Associated Pesticide Contamination (China, Indonesia, Malaysia, Pakistan, Philippines, Sri Lanka and Viet Nam), and a regional expert.

Background of the Meeting: In East Asia and the Pacific region the decline in arable land area is exacerbated by conversion of agricultural land into other uses (urbanization, infrastructure and industrial development) and a series of soil degradation processes. Accelerated soil erosion is the predominant type of soil degradation. This results in not only reduced capacities of the society to produce sufficient food for the ever increasing population due to arable soil losses and decline in crop productivity but also off-site pollution effects associated with erosion. The overall objective of this regional project is to develop improved soil, water, nutrient and crop management practices while counteracting predominant soil degradation processes in order to increase and sustain crop productivity in the East Asia and the Pacific region. Two complimentary approaches will be utilized to achieve this main objective. The specific objective of Part 2 of this project
will be to assess soil redistribution and associated agrochemical (pesticide) contamination at the landscape level.

Soil erosion and sedimentation cause not only on-site degradation of a natural resource but also off-site problems such as downstream sediment deposition in fields, leaching and washing off of pesticide residues and pesticide-contaminated soils/sediments to waterways, floodplains and water bodies, eutrophication and reservoir siltation. Pesticides are being extensively used in many countries of the region to maintain agricultural production over the long term. Excessive use of agrochemicals in hilly areas of the concerned countries affects both the water and soil quality. Eroded soil particles are the best carrier for pesticides and their metabolites that may be toxic to aquatic plants and animals. The core activities of part 2 of this regional project involve the use of the Cs-137 technique to determine soil redistribution rates and patterns in the landscape. The associated pesticide studies will focus on the effects of soil redistribution (and their spatial and temporal changes in soil quality properties) on the fate and distribution of pesticides in agricultural landscapes. The pesticide studies involve a thorough knowledge of the fate-determining processes, i.e. uptake, biodegradation, volatilization, leaching, sorption, and movement in the landscape. The implementation of the project activities require a multi-disciplinary and in many cases inter-institutional team of trained staff and functional laboratory facilities for measuring the fallout radionuclides (Cs-137 and Pb-210) and pesticide residues with nuclear and conventional techniques. Two training workshops on the Cs-137 technique and pesticide studies have been held in Beijing/Yan’an and Huangzhou respectively. IAEA inputs in terms of training, expert services and minor equipment have been provided. Results obtained so far in this project were evaluated at the Mid Term Project Review Meeting held in Jakarta, Indonesia, October 2003.

Purpose of the Meeting:

The main purpose of this meeting will be to strengthen the capacities of the staff actively involved in the implementation of these activities of the project by exchanging experiences in the application of the Cs-137 technique in the countries of the region, and thus, to better understand the several aspects/issues of the technique, correctly interpret the results and obtain reliable soil erosion/sedimentation data. The meeting will be based on:

- Country progress reports included in the report of the Mid-Term Project Review Meeting.
- Presentations by the participants. Each participant will prepare short working papers on the topics above for discussion as case studies. These working papers (5 in total) should be submitted together with the application form of the participant.

The meeting will be implemented covering the main aspects of the Cs-137 technique and will focus on the practical issues brought forward by the participants as follows:
• Introduction to the use of the Cs-137 technique in the soil erosion and sedimentation studies of the region. Background information. Framework of reference for the study. Objectives of the study. Scales of work. Evaluation of available resources.
• Field reconnaissance survey. Field sampling design. Reference sites. Sample collection and processing
• Sample measurement using gamma spectrometry. Measurement of Cs-137 by HPGe. Detector calibration. Use of reference materials for AQCS. Presentation of analytical data.
• Calculation of soil loss/gain rates using se of conversion models. Selection of models. Independent validation.
• Spatial representation of data (interpolation methods) and Interpretation of results: main factors/relationships.

Participants’ Qualifications: The candidates must have basic knowledge of the application of the Cs-137 technique and be actively involved in the implementation of the project. Main national counterpart of the project responsible in implementation of the project activities. Please note that submission of the working papers is a pre-requisite for participation at the meeting.

Nature of Workshop: The instructor will introduce the main topics and will guide the discussion of the case studies prepared and presented by each of the participants. The meeting will include consist of lectures, laboratory sessions, calculation exercises, discussions and a field visit related to the topics described above.

Expected Outputs: The outputs to be expected are as follows:
• Increased knowledge and skills to apply correctly the $^{137}$Cs technique for obtaining reliable quantitative erosion and sedimentation rates.
• Increased capacities of local staff to undertake soil erosion research and related studies
• Improved understanding of the relationships between the rates of soil loss and soil quality, soil carbon and nutrient redistribution, and the fate of agrochemicals at the landscape level.

Application Procedures: Nomination may be submitted on the standard IAEA application form for meetings/workshops. Completed forms should be endorsed by and returned through the official channels established (the Ministry of Foreign Affairs, the National Atomic Agency or the Office of United Nations Development Programme). They must be received by the International Atomic Energy Agency, P. O. Box 100, A-1400 Vienna Austria, not later than 30 April 2004. Nominations received after this date or applications, which have not been routed through one of the aforementioned channels, cannot be considered.
Advanced nominations by facsimile (+00-43-1-2600-7), or e-mail (Official.Mail@IAEA.ORG) are welcomed. The facsimile/e-mail should contain the following basic information about the candidate: name, age, academic qualifications, present position including exact nature of duties carried out, proficiency in English and full working address including e-mail address and telephone/facsimile numbers.

Administrative and financial arrangements:

Nominating Governments will be informed in due course of the names of the candidates who have been selected and will at that time be given full details on the procedures to be followed with regard to administrative and financial matters.

During their attendance at the workshop, participants from countries, eligible to receive technical assistance, will be provided with a stipend sufficient to cover accommodation, food and minor incidental expenses. The IAEA will also provide the participants with a round-trip air ticket, economy class, excursion fare if applicable, from their home countries to Jakarta, Indonesia. Shipment of accumulated course materials to the participants' home countries is not the responsibility of the IAEA.

The organizers of the course do not accept liability for the payment of any cost or compensation that may arise from damage to or loss of personal property, or from illness, injury, disability or death of a participant while he/she is traveling to and from or attending the workshop, and it is clearly understood that each Government, in nominating participants, undertakes responsibility for such coverage. Governments would be well advised to take out insurance against these risks.
Annex B – AGENDA

INTERNATIONAL ATOMIC ENERGY AGENCY

REGIONAL CO-OPERATIVE AGREEMENT FOR ASIA AND THE PACIFIC REGION

IAEA/RCA Workshop Meeting on
“Exchanging of Experience using the Cs-137 Technique for Measuring Erosion/Sedimentation and Associated Pesticide Contamination”

Restoration of Soil Fertility and Sustenance of Agricultural Productivity (RCA) – Measuring Soil Erosion/Sedimentation and Associated Pesticide Contamination RAS/5/039 (Part II)

5-9 July 2004, Kuala Lumpur, Malaysia

AGENDA

Monday, 5 July

08:30 - 09:00  Registration

09:00 - 09:10  Welcome and Opening
  • Dr. Zainudin Othman, Chairperson of the Organizing Committee

09:10 - 09:25  Keynote Address by the IAEA Representative
  • Dr. Claude Bernard, IAEA Technical Officer, Vienna

09:25 - 09:45  Opening Remarks
  • Dr. Nahrul Khair Alang Rashid, Deputy Director General (RTD) of MINT /RCA National Representative

09:45 - 10:00  Group Photo Session

10:00 - 10:30  Coffee/Tea

Session I: Organization and overview
  • Chairperson: Robert Loughran

10:30 - 12:00  • Introduction of participants. Appointment of rapporteurs
  • Recall of revised national plans
  • Objectives of the meeting

12:00 - 14:00  Lunch
Session II: Presentations by countries: Review of progresses and achievements
  - Chairperson: Barokah Aliyanta

14:00 - 14:45 Dac Dung Bui - Viet Nam
14:45 - 15:30 Zainudin Othman - Malaysia
15:30 - 16:00 Coffee/Tea
16:00 - 16:45 Manzoor Ahmad Choudhry - Pakistan
16:45 - 17:30 Elvira Sombrero - Philippines
17:30 - 18:30 Discussion on presentations

Tuesday, 6 July

Session III: Presentations by countries: Review of progresses and achievements
  - Chairperson: Elvira Sombrero

08:30 - 09:15 Tissa Senerath Bandara Weerasekara - Sri Lanka
09:15 - 10:00 Barokah Aliyanta - Indonesia
10:00 - 10:30 Coffee/Tea
10:30 - 11:15 Yong Li – China
11:15 - 12:00 Discussion on presentations
12:00 - 14:00 Lunch

Session IV: Lecture
  - Chairperson: Yong Li

14:00 - 15:30 Lecture
  Dr. Robert. Loughran
  “Soils, Sediments and Caesium-137 in Maluna Creek Catchment”
15:30 - 15:45 Coffee/Tea
15:45 - 16:45 Open discussion about the lecture

Wednesday, 7 July

Session V: Review of progress and achievements
  - Chairperson: Robert Loughran

09:00 - 10:00 Assessment of progress and achievements by country
10:00 - 10:30     Coffee/Tea
10:30 - 12:00     Update of national plans, work plan for the remaining time to the project
12:00 - 14:00     Lunch

**Session VI:** Future technical cooperation project
  • Chairperson: Zainudin Othman
14:00 - 15:30     Discussion on a future regional project
15:30 - 15:45     Coffee/Tea
15:45 - 17:00     Discussion on a future regional project (continue)

**Thursday, 8 July**

7:30 - 18.00     Visit to Cameron Highlands and Discussions

**Friday, 9 July**

**Session VII:** Summary and wrap-up of the meeting
  • Chairperson: Robert Loughran
08:30 - 10:30     Finalization of meeting report
10:30 - 11:00     Coffee/Tea
11:00 - 11:30     Review of meeting report
11:30 - 12:00     Conclusions and recommendations
12:00 - 12:30     Closing remarks
12:30 - 14:00     Lunch
Afternoon        Closure of meeting and Individual consultations
Annex C - LIST OF PARTICIPANTS

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Annex D - NEW REGIONAL PROJECT PROPOSAL

A new regional project in continuation of RAS/5/039 part 2 has been presented and accepted.

This new project, entitled “Development of Sustainable Land Use and Management Strategies for Controlling Soil Erosion and Improving Soil and Water Quality”, was developed with the overall objective of developing sustainable land and water management strategies for reducing soil erosion and improving soil and water quality in the Asia-Pacific Region. The specific objectives of the project are:

- to measure soil erosion and soil re-deposition over several spatial and time scales by combined use of $^{137}$Cs, $^{210}$Pbex and $^{7}$Be.
- to establish soil redistribution-soil quality relationship under different land management practices by application of the above techniques.
- to enhance the capacities of the member states from Asian Pacific Region in improving soil and water quality, and increasing soil organic carbon storage.

In the RAS/5/039 part 2 project, the emphasis was on the $^{137}$Cs technique itself. Participants learned all the aspects of the technique (requirements for an adequate reference site, sampling strategy, counting procedures and quality insurance, data processing and interpretation, use of conversion models, etc.).

In the new project, the emphasis will be on the interactions between soil erosion and soil quality, and on the positive effects of soil conservation practices in terms of soil and water quality. Under this new project, $^{137}$Cs measurements will be a tool and no more the focal point of the project. Besides, in order to meet the specific objectives, $^{7}$Be measurements will have to be introduced.

The expected outputs of the new project may be summarized as:

- standardized methodologies and guidelines for the use of fallout radio-nuclides for the assessment of the soil quality-soil erosion relationship;
- reliable data on impact of different land use and management practices on changes in physical, chemical and/or biological properties of soils /water quality parameters and the main factors influencing soil erodibility;
- better understanding of the role of specific soil conservation measures in controlling soil erosion for sustainable crop production;
- dissemination and demonstration of results to end users through training, workshops and other activities;
- recommendations for effective land use and management measures to combat soil erosion and improve soil and water quality.

Australia, China, Indonesia, Korean Republic, Japan, Malaysia, Pakistan, Philippines, Sri Lanka and Vietnam will be the participating countries in this new regional project. The new project is expected to expand over two biennia since it is believed that two years are not long enough to implement all the work that has to be done in this project. It must be considered that in some cases, conservation practices will have to be introduced in the current cropping systems. In such cases, the first year of the project will be used for the implementation of these measures. Should the project last for only one biennium, this would leave only one year for comparative measurements, which is clearly insufficient to be able to draw conclusions. Even in
the case where conservation practices would already be in place, it is necessary to pursue measurements over 3 years to integrate the natural variability of climate and obtain reliable data that can be transferred to farmers.

$^7$Be measurements will be introduced in the new project. These are required to investigate the interrelationships between soil erosion, on one hand, and soil degradation and water pollution on the other hand. Under some circumstances, $^{137}$Cs may not be the most appropriate indicator of erosion for this purpose, since this isotope integrates some 40 years of soil movements, which may have occurred anytime during this period. Then, it may be much difficult, if not impossible, to relate spatial redistribution of $^{137}$Cs with soil nutrient depletion or accumulation, since these may have occurred on different time scales. The same holds for pesticide transportation. Since these products are generally short-lived in the environment, it may prove impossible to relate pesticide losses to soil erosion indicated by $^{137}$Cs. It would also be difficult to compare soil spatial redistribution under conventional and conservation tillage practices with $^{137}$Cs, on a short-term period. For such purposes, $^7$Be measurements offer an interesting alternative. Given the short half-life of this isotope, its use is done basically on a rainfall event basis. This way, it is possible to confidently relate soil movements to measured nutrient and/or pesticide movements. However, $^{137}$Cs measurements can still be used to assess the efficiency of conservation practices such as filter strips, terraces, sedimentation ponds, etc.

The following activities were proposed for the workplan of the new project:

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<tr>
<th>Activity</th>
<th>Date</th>
<th>Inputs</th>
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<tr>
<td>National workshops</td>
<td>2005/Q1</td>
<td>CP</td>
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<tr>
<td>Regional meeting: review national plans, finalize project program</td>
<td>2005/Q1</td>
<td>IAEA</td>
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<tr>
<td>Adoption of national programs</td>
<td>2005/Q2</td>
<td>CP</td>
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<tr>
<td>Subcontract submitted to IAEA</td>
<td>2005/Q2</td>
<td>IAEA</td>
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<tr>
<td>Regional training workshop on the use of radio-nuclides for erosion/conservation studies</td>
<td>2005/Q2</td>
<td>IAEA</td>
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<tr>
<td>Start field activities: site selection, sampling, soil analysis</td>
<td>2005/Q2-2006/Q4</td>
<td>CP</td>
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<tr>
<td>Subcontract submitted to IAEA</td>
<td>2006/Q2</td>
<td>IAEA</td>
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<tr>
<td>Initiate data interpretation</td>
<td>2006/Q4</td>
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