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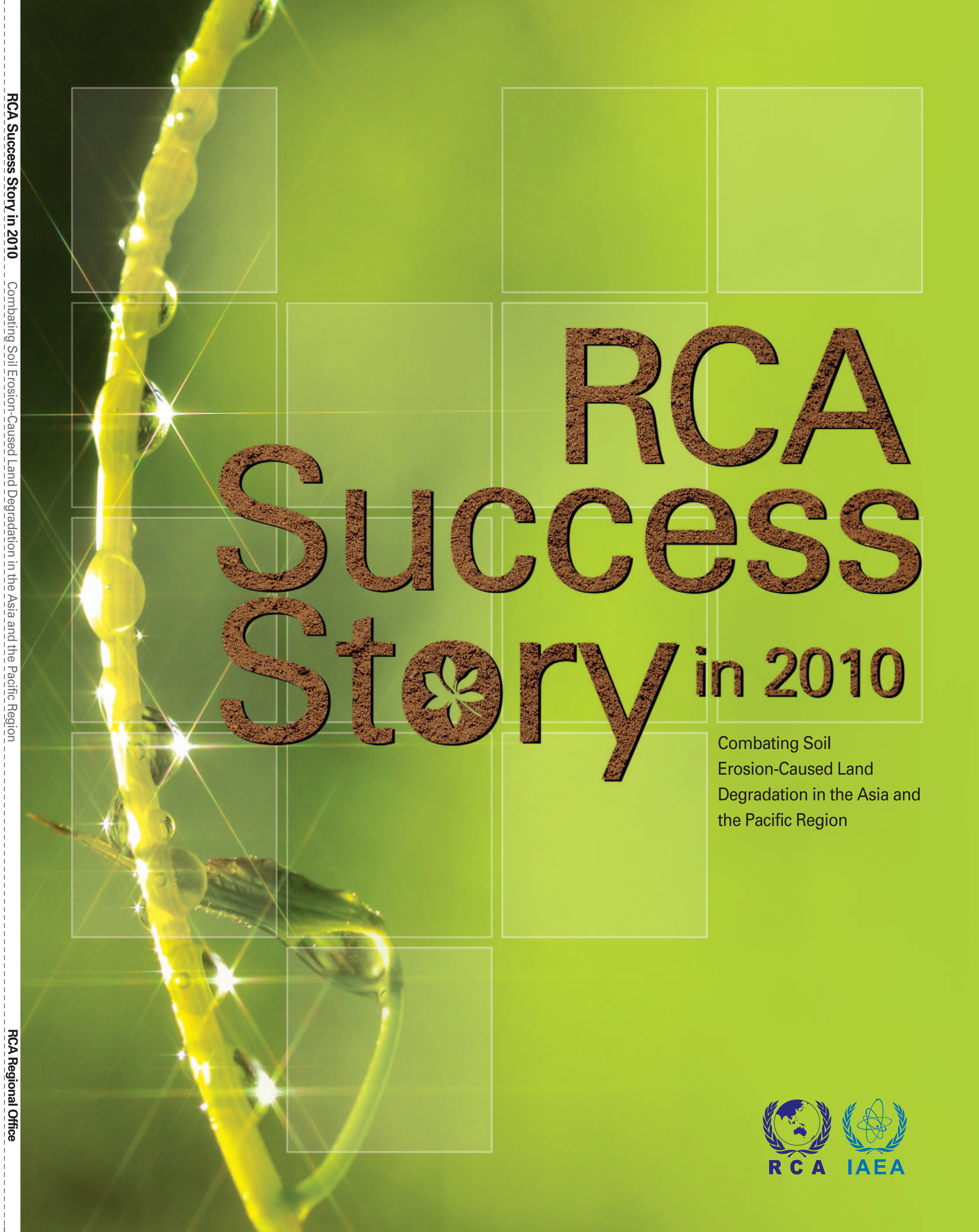
RCA Success Story in 2010 Combating Soil Erosion-Caused Land Degradation in the Asia and the Pacific Region

RCA Regional Office



RCA Success Story in 2010

Combating Soil Erosion-Caused Land Degradation in the Asia and the Pacific Region

RCA IAEA

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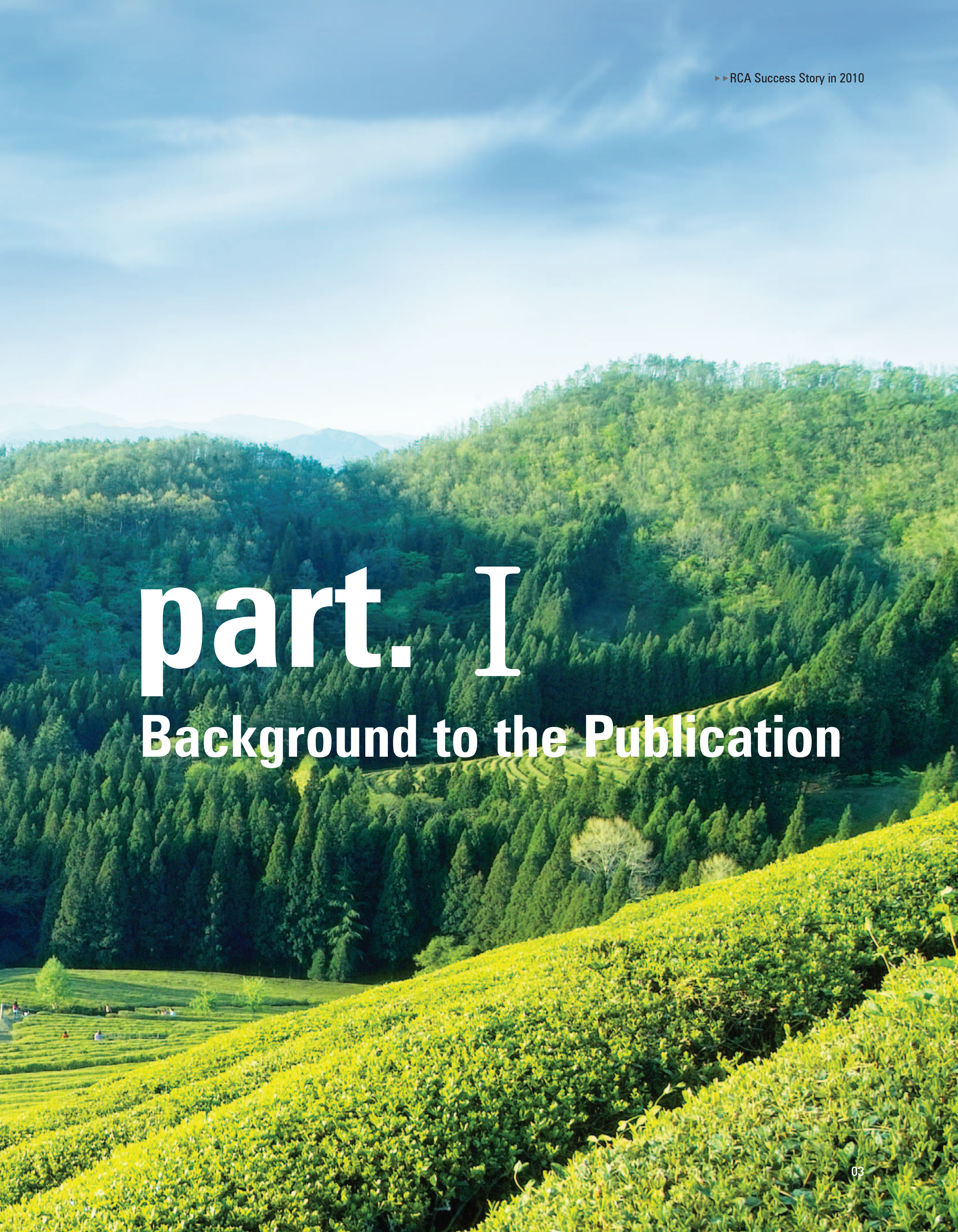

part. Ⅰ
Background to the Publication

I Background to the Publication

I. 1. Objectives of Publication of RCA Success Stories

One of the major roles of the RCA Regional Office (RCARO) is to promote and publicise the achievements of the RCA programme. A key element in this task is the preparation and maintenance of a portfolio of achievements set out in the form of success stories. These success stories also contribute to the achievement of the RCA Vision of earning recognition in the region as a resource capable of contributing to the provision of high impact solutions to significant technological problems in the region using nuclear science and technology.

Past success stories have been in a short one page leaflet format. The move in this publication to a booklet format is responding to requests to provide more detailed information that highlights the successful achievements together with the socio-economic impacts in the region as well as some basic information on the project.

What is RCA?

The RCA is an intergovernmental agreement among the International Atomic Energy Agency (IAEA) Member States of South Asia, South East Asia and the Pacific, and the Far East that entered into force in 1972 under the aegis of IAEA. It is an abbreviation for 'Regional Cooperative Agreement for Research, Development and Training related to Nuclear Science and Technology'.

The following 17 IAEA Member States in the Asia and the Pacific region are the current signatories of the RCA: Australia(AUL), Bangladesh(BGD), The Peoples' Republic of China(CPR), India(IND), Indonesia(INS), Japan(JPN), The Republic of Korea(ROK), Malaysia(MAL), Mongolia(MON), Myanmar(MYA), New Zealand(NZE), Pakistan(PAK), The Philippines(PHI), Singapore(SIN), Sri Lanka(SRL), Thailand(THA), and Vietnam(VIE).

I. 2. History of Publication of RCA Success Stories

The development of good RCA success stories was a regular discussion point at past RCA meetings and, following the establishment of the RCARO, this task was assigned to RCARO. A brief review of the milestones in chronological order is set out below.

■ Initial Formulation

Opening of the RCA Regional Office, March 2002, Daejeon, Republic of Korea

This was a landmark event in the history of the RCA. The publication task was assigned to the RCARO as a part of its mission. In 2002 the RCARO printed the 'RCA 2001 Annual Report' which included RCA success stories from the RCA Member States. The report was presented at the 31st National RCA Representatives General Conference Meeting (GCM) in September 2002 and the Meeting requested the RCARO to send it to all RCA Member States and also to international development organisations.

The Success Stories in the 'RCA 2001 Annual Report' gave summary on the Thematic Sectors at the time: Agriculture, Health, Environment, Industry, Radiation Protection and Energy / Research Reactor / Radioactive Waste Management.

The Meeting made recommendations concerning the highlighting those RCA projects that: contributed to the socio-economic development of the region; demonstrated the distinctive advantages of nuclear science and technology to solve or contribute to the solution of significant regional problems; showed potential sustainable benefits; and, displayed the potential for collaboration with others.

25th National RCA Representatives Regional Meeting (NRM), May 2003, Colombo, Sri Lanka

It was agreed that the RCARO should prepare the RCA Success Stories in the form of a brochure.

■ Development of Success Story Guidelines

5th RCARO Advisory Committee (AC) Meeting, April 2004, Islamabad, Pakistan

The Meeting recognised that there was a need to provide guidelines to help the Lead Country Coordinators to produce the Success Stories. Representatives from Australia (John Easey), the Philippines (Alumanda dela Rosa), Malaysia (Nahrul Alang Md Rashid) and Japan (Hideo Tatsuzaki) drafted guidelines and recommendations.

■ Publication of the 1st and 2nd Batch of Success Stories

The drafts for the first batch of five RCA Success Stories in leaflet form were submitted to the 2nd Standing Advisory Committee Meeting (SAC), which was held in conjunction with the 28th RCA NRM in March 2006. These drafts were further refined and edited by the stakeholders including the relevant Project Lead Country Coordinators, IAEA/RCA Focal Person, a professional editor and the RCARO.

The first batch of five RCA Success Stories in leaflet form was published in May 2007.

A similar process was used for the second batch of four Success Stories and these were published in 2008.

Each batch of leaflets was distributed to Member States and other target readers. The leaflets were also handed out at appropriate meetings and conferences held in the region.

■ Monitoring of Impact

30th NRM, April 2008, Hochiminh City, Vietnam

At this Meeting it was recommended that the RCARO conduct a survey on the impact of the two batches of the RCA Success Stories that had been published and distributed before continuing with publication of the 3rd batch. A survey questionnaire was designed by the RCARO and circulated to Member States for comment.

31st NRM, April 2009, Tokyo, Japan

The survey results were reviewed. Based on the positive survey results, the Meeting decided to proceed with the publication of the 3rd batch of Success Stories.

■ Test Publication in Booklet Form

38th RCA GCM, September 2009, Vienna, Austria

In addition to the four stories that made up the 3rd batch of the RCA Success Stories, the Meeting decided that there should be a trial publication of a Success Story in booklet form and the topic selected was, “Combating Soil Erosion-Caused Land Degradation in the Asia and the Pacific Region”.

I. 3. Summary of RCA Projects

The RCA projects have assisted Member States to gain knowledge and experience in the field of nuclear science and technology, which has enabled them to increase their contribution to national programmes with their enhanced technical capabilities and capacities. The Table 1 provides a detailed breakdown of the current and past projects with regards to the numbers in each of the nine thematic areas/sectors and 23 technical areas. The Member States have strongly responded that these projects have benefited them and have many examples of the strong outputs and outcomes that such projects have generated.

Since its establishment in 1972, the RCA Programme has delivered significant benefits to the participating Member States through 119 projects. At the start of 2010 the following inputs of training and assistance have been delivered to the Member States:

- 502 Regional Training Courses for 8,245 participants;
- 191 Regional Workshops or Regional Technical Meetings for 2,236 participants;
- 173 Project Management Meetings for 2,773 participants;
- 124 Fellowships;
- 64 Scientific Visits; and,
- 1,033 Expert missions.

The total expenditure on the programme up to the start of 2010 was US$59,259,923.

Table 1: Number of RCA Projects versus Areas

Sector	Technical Area		No. of Projects	
			Completed	Active in 2010
Agriculture	• Animal health and production		3	0
	• Food irradiation		4	2
	• Plant breeding		3	1
	• Soils and land use		2	0
	Sub-total		**12**	**3**
Human Health	• Cancer		8	1
	• Joint and bone disorders		3	0
	• Medical physics		0	1
	• Nuclear medicine imaging		5	1
	• Radioimmunoassay		4	0
	• Tissue grafts		2	0
	Sub-total		**22**	**3**
Industry	• Industrial applications *(sponsored by UNDP)*		13	0
	• Nuclear analytical systems (NAS) and nucleonic control system(NCS)		2	0
	• Non-destructive testing (NDT) and tomography		3	1
	• Radiation processing		5	1
	• Tracers and sealed sources		5	1
	Sub-total		**28**	**3**
Environment	• Air pollution		2	1
	• Fresh water resources		6	1
	• Marine and coastal environment		4	2
	Sub-total		**12**	**4**
Others	Energy	Sub-total	9	0
	Radioactive waste management	Sub-total	1	0
	Radiation Protection	Sub-total	7	1
	Research reactor utilization	Sub-total	8	0
	Technical Cooperation between Developing Countries	Sub-total	5	1
	TOTAL		**104**	**15**

I.4. Description of Criteria of Selection of the RCA Success Stories

A success story should be able to clearly describe how regional cooperation and the applications of nuclear technology have contributed to the solution of significant problems which would have then resulted in socio-economic benefits at the national level.

Examples could be:

- The introduction of new agronomic practices through RCA projects has resulted in an increase in agricultural productivity and this in turn has led to local farmers increasing their productivity and income;
- Improvements in the quality of health-care from the RCA projects are resulting in less lost time for workers, which is resulting in higher incomes and providing a boost to local economies;
- Improving productivity and safety of industrial processes through the RCA projects is boosting the output of local industries, increasing employment and benefiting the local economy; and,
- Monitoring environmental pollution using technologies transferred through the RCA projects has resulted in the local agencies introducing better control of plant emissions, which has lowered locally the incidence of health-related problems, decreased medical costs, and increased local school attendance and level of achievement at school.

Mere completion of activities of a project such as training of personnel should not be considered as a success story. A success story is not a progress report. However the establishment of a new capability and capacity that had the potential to benefit the local community might be something that should be publicized.

A success story may either highlight the impact from “human interest” or “technical interest” point of view and preferably both aspects can be represented. “Human interest” stories would probably come most readily from projects covering Agriculture, Environment and Human Health Sectors, while “technical interest” stories would be mostly from Energy, Industry, Research Reactor and Radiation Protection Thematic Sectors.

Since most success stories would be the result of a combination of contributions from other inputs as well as those from the RCA projects, it would be necessary to highlight the contribution of the RCA Programme. For example, the reduction in cancer deaths in a country could be due to many other factors in addition to improvement of radiotherapy facilities. Claiming credit for the total reduction could affect credibility.

I.5. Published RCA Success Stories

The following 9 RCA Success Stories have been published in leaflet form and are available on the RCARO website at www.rcaro.org.

Table 2: List of 9 Published Success Stories

BATCH	AREA	TITLE
First Batch	Air Pollution	Nuclear analysis of airborne particles provides a key to alleviating air pollution
	Drinking Water	Isotope hydrology helps find water fit to drink
	Polymer Processing	New materials from natural polymers: using nuclear technology to improve Nature's gifts
	Tissue Grafting	Restoring health and saving lives: global benefits from RCA's trail blazing
	DAT on Nuclear Medicine	'Distance assisted training' strengthens regional skills in nuclear medicine
Second Batch	Plant Breeding	Cultivating better crops for sustainable agriculture
	Marine Environment	Turning the tide against marine pollution
	NDT Applications	Strengthening skills in NDT for regional industry
	Geothermal Investigation	Harnessing energy from the heart of the earth

Published Stories in Brief

■ Improving Air Quality

Through the application of the nuclear techniques transferred through the RCA projects, local agencies now are able to better monitor and understand air pollution. These new technologies provide them with the means of obtaining important information to assist in national efforts on the introduction of better control of emissions from industries and other sources. The projects have contributed to the development of a significant regional database to provide information about air pollution in the region, including source, distance, and trans-boundary aspects.

■ Contributing to the Search for Fresh Water

Applications of isotope hydrology techniques in RCA Member States have resulted in more accurate assessment of groundwater behaviour, providing better information on the search and management of clean drinking water resources. Use of these techniques has also contributed to informed decision-making on water policy and control in the region.

■ Enhancing Materials Properties

The transfer of radiation processing technology to the RCA Member States has helped them develop the capabilities to produce new and innovative products and deliver them to markets. An example is radiation processed polymer (Chitin), which is being developed for medical uses.

■ Enhancing the Use of Tissue Graft Materials

This project has greatly assisted national agencies build up their capabilities as well as their training and physical infrastructure in the production, use and promotion of tissue graft materials prepared using radiation sterilisation. This has resulted in tissue grafts become much more affordable, widely available and widely used in RCA Member States. This success has served as a role model for other regions.

■ Assisting Nuclear Medicine with Training at a Distance

The demand for qualified nuclear medical technologists is high in the region as the number of nuclear medicine departments grows at a rapid rate. There are competing demands for technologists to be trained while at the same time these technologists are urgently required to be working in the departments. The RCA projects have established a distance assisted training programme which has been able to address both demands. Hundreds of students from many Member States have taken part in the programme and other regions are now taking up the use of these training materials.

■ Improving Crops

The RCA Member States are acquiring nuclear technology to assist them to breed new varieties of crops which will have higher yield rates, greater resistance to drought, salinity, disease and pests, and improved quality for consumers. Several high performance varieties of soybean, groundnut, mungbean, wheat, and sesame have already been released into the market, and a number of other new crop varieties are being field-tested prior to commercial release.

■ Tackling Marine Pollution

RCA Member States have improved their regional capacity to deal with aquatic pollution in coastal areas. Hydrologists have been trained in the use of nuclear and conventional techniques and tools to sample and analyse the composition water-borne pollutants and then use this information together with relevant hydrodynamic models to carry out risk assessments using advanced computer simulation tools.

■ Strengthening Skills in Non-Destructive Testing

The NDT techniques use penetrating radiation (i.e., gamma- or x-rays) to examine the internal state of materials (such as identification of defects) that are widely applied in industry. A total of 300 personnel from 14 RCA Member States were trained initially through the RCA projects. In turn, these individuals have then provided training, disseminating the NDT knowledge and technology at the national level. The current aim is the harmonisation of the region's NDT qualification and certification process by 2012.

■ Helping the Search for Geothermal Power

In the search for sustainable energy sources, some RCA Member States have been developing geothermal power, which has now reached a collective capacity of about 3,500MWe. RCA has been providing assistance in the search for suitable new geothermal sources through the provision of regional training in the utilisation of isotopic techniques, including natural isotopes and artificial radiotracers. These techniques have provided valuable information on reservoir characteristics especially when the reservoirs are subject to changes in pressure, temperature, and fluid flow. Member States have carried out investigations on 33 new geothermal prospects (about 130 geothermal springs) and have contributed to the development of several geothermal power plants in Member States such as the India, Indonesia, and the Philippines.

part. Ⅱ

RCA Success Story: Combating Soil Erosion-Caused Land Degradation in the Asia and the Pacific Region

II RCA Success Story: Combating Soil Erosion-Caused Land Degradation in the Asia and the Pacific Region

II.1. Background to the Project

II.1.1. Introduction

At the end of the 20th century, the rapidly growing populations of most countries in the Asia-Pacific region coupled with the need for greater food production placed increased pressure on the region's land and water resources. Cropland resources were expanded largely at expense of forest cover and bringing marginal land (steep upland slopes) into production. Also, intensification of agricultural production due to changing market conditions led to increased commercial logging, overgrazing and the introduction of plantation crops. All these changes combined with the burgeoning urban and industrial growth and related increases in transport infrastructure have resulted in widespread degradation of natural resources through accelerated soil erosion and increased sedimentation, flooding and pollution of water bodies downstream.

The Treaty-level Intergovernmental Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology for Asia and the Pacific (RCA) brings together 17 countries in the Asia and the Pacific region[1] in a programme of cooperation in the peaceful application of nuclear science and technology that is carried out under the aegis of the International Atomic Energy Agency (IAEA). RCA Member States have responded to the deteriorating situation with soils by making it one of the priorities in their programme and directly addressing it through the formulation of the project "Sustainable Land Use and Management Strategies for Controlling Soil Erosion and Improving Soil and Water Quality", which was implemented through the IAEA Technical Cooperation programme as project RAS/5/043.

Figure 1: Uncultivated grassland in Sandamar catchment, Pakistan

Over the last 4 years, with the help of the inputs provided through this project, the national teams from the participating Member

1 Australia, Bangladesh, China, India, Indonesia, Japan, Republic of Korea, Malaysia, Mongolia, Myanmar, New Zealand, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Vietnam.

States have obtained a wealth of valuable information on soil erosion rates in agricultural landscapes and assessed the effectiveness of soil conservation measures through the use of nuclear and related techniques in a wide range of environments of the region. The project participants have recognised that information on the success of the project and the power of the nuclear techniques needs to be disseminated to a broad spectrum of end-users. They recommended that the project should be written up as a success story and that the public should be made aware of these achievements and the outcomes of the project as well as the end users.

This document presents the main activities and results achieved in this RCA project. The ultimate technological goal is to maximise transfer of technology in a targeted way, particularly for end-users such as land use managers and decision- and policy-makers at all levels, who may require information on appropriate technologies to formulate sustainable land use and management strategies for achieving food security with minimum environmental risk in countries in the Asia and the Pacific region.

II.1.2. Problem of land degradation by soil erosion in the Asia and the Pacific region

Currently unsustainable land and water use, changing food consumption patterns related to higher incomes in emerging economies, and the impacts of climate change are the major drivers of land degradation and environmental damage in the region. The cumulative impacts of these changes are a serious threat to water and biogeochemical cycles, biodiversity and agricultural production. Land degradation has also great social and economic impacts on the developing countries in the region. These are directly related to food insecurity and increased malnutrition. Such conditions are often cited as leading to higher levels of poverty, rural migration, social unrest and overall, resulting in poor economic development. Controlling land degradation has featured highly at international fora such as the Millennium Development Summit held in Johannesburg in 2000. As a result, several global, regional and national programmes have been formulated and implemented by a number of organisations.

Several reports highlight the seriousness of land degradation, in particular soil erosion at the regional and global level. Estimates of the extent of soil degradation by water and wind erosion show that more than three quarters of the surface land area affected by erosion is in the developing countries of Africa, Asia and Latin America, with about one-half of the total occurring in Asia. Across all regions soil losses by water are more serious than those by wind. Overall, there is less arable land per capita in the Asia-Pacific region today than other parts of the world and the population density is the highest in South Asia.

Many countries particularly in South and East Asia have well below the world's per capita land area average of 0.24 ha. With roughly 60 percent of the world's population depending upon only one third of the world's land area, the region is facing great challenges to optimise land use/management for competing needs, in particular to achieve food security with minimal environmental damage.

Recent estimates of global land degradation show that: a) Several areas of Asia such as Indo-China, Myanmar, Malaysia and Indonesia, South China and North-central Australia and western slopes of the Great Dividing Range are included into the most severely affected, and b) The estimated number of affected people is greatest in highly populated countries such as Bangladesh, China, India, Indonesia, Myanmar, Philippines, Thailand and Vietnam.

Figure 2: Deforestation and intensive cultivation on steep land led to severe soil erosion in the tropical uplands of Thailand

Figure 3: Eroded landscapes at the 4 study sites: Yan'an, Xichang, Baiquan, and Fengning in China

II.1.3. Technical solutions to the problem

1) Land care and watershed development programmes

It should be emphasised that most developing countries in Asia and the Pacific region do not have the resources to establish institutionalised land care and watershed development programmes for implementing long term soil conservation activities. Existing programmes focus on conducting inventories of land resources and monitoring land use/management changes. In many cases project activities in a given area are usually for a short term period and only concentrated on evaluation and monitoring of short term and direct benefits. It is reported that some countries like China have spent huge amounts of money in implementing soil conservation technologies to arrest soil erosion. However, the absence of adequate evaluation methodologies has hampered attempts to evaluate the effectiveness of such conservation projects.

2) Assessment of soil erosion losses: nuclear technology role/advantages

Current concerns about the adverse effects associated with accelerated soil loss, both on- and off-site, have generated an urgent need for reliable quantitative data on the extent and actual rates of soil erosion worldwide. Such data are required for a number of purposes such as: a more comprehensive assessment of the magnitude of the effects; a better understanding of the main factors involved; the validation of new soil erosion/sedimentation prediction models; and, the provision of a basis for developing scientifically-sound land use policies and selecting effective soil conservation measures and land management strategies, including assessment of their economic and environmental impacts.

Figure 4: Collection of samples for the assessment of reservoir sedimentation rates in an arid environment in South East Australia using fallout radionuclide techniques

Despite extensive literature on the soil erosion processes and problems, quantitative and reliable data on the extent and rates of soil erosion are scarce for many regions of the world. Soil erosion research is capital and labour intensive, as well as a time-consuming exercise. Well-designed experiments should be performed using standardised methodologies so that the data obtained are comparable and representative of the study areas.

The existing methods to assess soil erosion can be grouped into two main categories: a) erosion modelling and prediction methods and b) erosion measurement methods. In all cases, there is a need for direct measurement of soil erosion, which can be done using erosion plots, surveying methods and nuclear techniques. The selection of the particular method basically depends on the objectives of the study and the availability of resources. Existing classical techniques such as erosion plots and surveying methods for monitoring soil erosion are capable of meeting some requirements but they have a number of important limitations in terms of the representativeness of the data obtained, their spatial resolution, the potential to provide information on long-term rates of soil erosion and associated spatial patterns over extended areas and the costs involved. In addition, advances in the use of distributed numerical models and the application of the Geographical Information Systems (GIS) and geo-statistics to erosion modeling demand spatially distributed data that represents the spatial variability of soil erosion and deposition rates within the landscape, in response to the local topography and land use/management. The quest for alternative techniques of soil erosion assessment to complement existing methods and to meet new requirements has directed attention to the use of radionuclides, as tracers for documenting rates and spatial patterns of soil redistribution within a landscape. The use of the anthropogenic fallout isotope caesium-137 (^{137}Cs) has featured strongly in such studies.

3) Nuclear technology: Fallout Radionuclides (FRNs) as tracers in soil erosion studies

Environmental radionuclides is a term commonly used to refer to those radionuclides which are widely distributed in the environment or landscape. Whilst they occur at very low levels, they are generally readily measurable using modern techniques and instruments. For soil erosion and sedimentation investigations, work has focused on the use of a particular group on environmental radionuclides, namely fallout radionuclides, which include caesium-137 (^{137}Cs), excess lead-210 ($^{210}Pb_{ex}$), and beryllium-7 (^{7}Be). Table 3 summarises the main characteristics of these radionuclides for use in soil erosion/sedimentation studies.

The basic principles for the application of these FRNs in soil erosion and sedimentation studies are similar. These radionuclides have reached the land surface by fallout from the atmosphere. It is assumed that such fallout input is spatially uniform, at least over a relatively small area. Because these radionuclides are rapidly and strongly adsorbed by fine soil particles (clay and humus), they accumulate at or near the soil surface. Documenting the subsequent redistribution of the FRN tracers, which move across the landscape in association with soil or sediment particles, primarily through physical processes, affords a very effective tool for tracing erosion and deposition within agricultural landscapes. In essence, the fallout radionuclide provides the same function as a radioisotope tracer artificial labelling the surface of an area under study. Information about the subsequent redistribution of the radionuclide over an area provides a basis for establishing rates and patterns of soil and sediment redistribution within the landscape.

Table 3: Comparative advantages and limitations of fallout radionuclides ^{137}Cs, $^{210}Pb_{ex}$ and ^{7}Be for documenting soil redistribution by erosion and sedimentation

	^{137}Cs	$^{210}Pb_{ex}$	^{7}Be
Origin	Artificial, anthropogenic	Natural, geogenic	Natural, cosmogenic
Half life	30.2 years	22.3 years	53.3 days
Energy gamma emitted	662 keV	46.5 keV	477.6 keV
Erosion assessment	Medium term	Long term	Short term
Time span	50 years	100 years	$\leq$ 6 months
Area studied	Plot to large watershed	Plot to watershed	Local scale, plot to field
Sample collection	Simple	Simple	Requires fine depth incremental sampling
Equipment needs	Normal High Purity Germanium (HPGe) gamma detector	Broad energy HPGe gamma detector	Normal HPGe gamma detector
Laboratory measurement	Easy	More difficult	Easy
In situ measurement	Easy	Limited	Requires at least double counting time than that needed by ^{137}Cs
Sediment dating	Possible	Possible	Possible

4) The FRN ^{137}Cs technique

The application of the ^{137}Cs technique for determining rates and patterns of soil loss is based on several key assumptions and requirements, which have been fully described in many publications. The assessment of soil redistribution is commonly based on a comparison of the ^{137}Cs inventory (total radionuclide activity per unit area) measured at a given sampling site with the one of a reference site (inventory representing the cumulative atmospheric fallout input at the site). Because direct long-term measurements of atmospheric fallout are rarely available, the cumulative input or reference inventory is usually established by sampling adjacent stable and nearly undisturbed sites, where neither significant erosion nor additional deposition have occurred (Figure 5). The determination of ^{137}Cs inventories requires first sampling of soil cores following a field sampling design and then measuring the ^{137}Cs concentration as a function of its depth in the core. It is essential to determine the inventory (P) of the FRN ^{137}Cs at a reference site (position undisturbed by erosion or sedimentation) in the study area. Erosion and deposition sites can be distinguished by comparing the ^{137}Cs inventory of the given site with the one of the reference site. Inventories that are lower than the reference value represent soil losses by erosion while those in excess of the reference level indicate deposition (accumulation) of soil.

The derivation of quantitative estimates of soil erosion and deposition rates from ^{137}Cs measurements, requires the use of conversion models which are developed on the basis of the physical processes linking

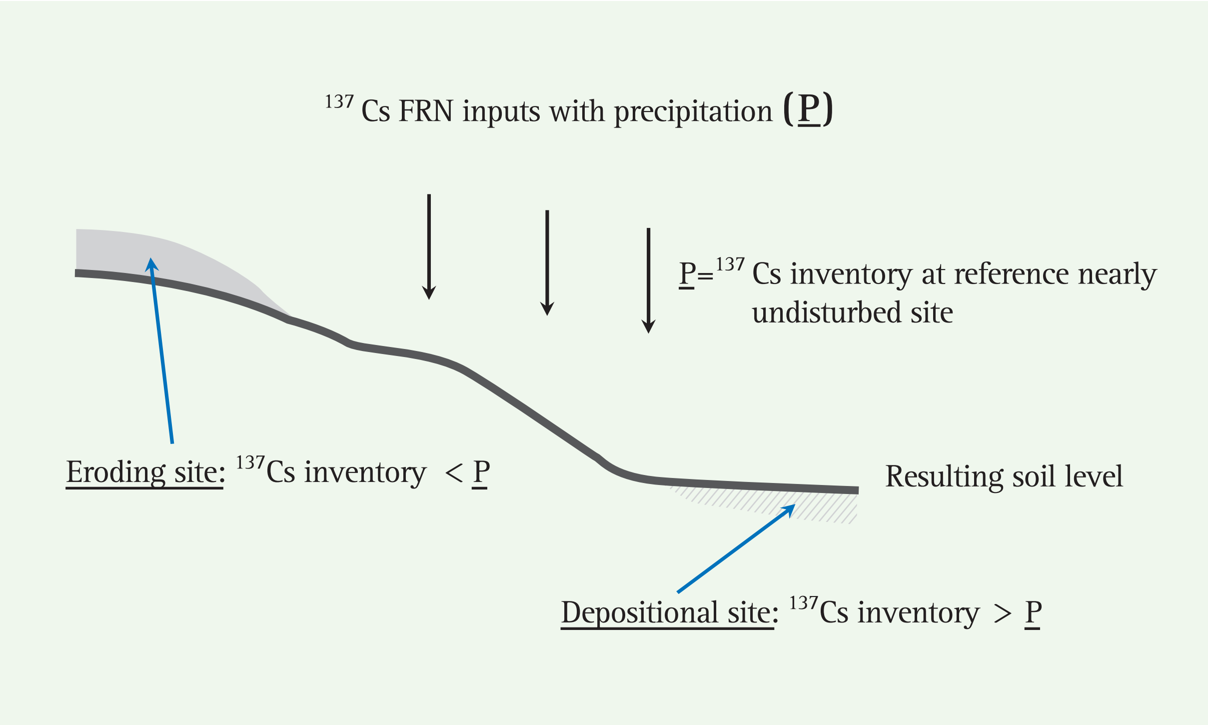

Figure 5: Diagram illustrating the application of the ^{137}Cs method to study soil erosion and deposition within a landscape

the magnitude of the reduction or increase in the ^{137}Cs inventory with the soil redistribution. The resultant soil redistribution data (soil and sedimentation rates and patterns) represent an integrated measurement of all effects leading to soil redistribution and occurring during the period extending from the main phase of atmospheric fallout input to the time of sampling.

When several radionuclides are used, soil redistribution data over different time scales can be obtained from a single sampling campaign, thereby avoiding or minimising the time-consuming and costly installations and procedures commonly required to monitor study sites over extended periods.

5) Challenges in the Project

A major challenge for each Member State participating in these regional projects was the need to form a multi-disciplinary and often inter-institutional team of researchers with complementary skills and expertise in soil erosion research (soil science, soil geography, hydrology, land care/husbandry, agronomy, ecology, soil conservation, etc.) and nuclear sciences. In addition basic infrastructure/equipment to perform the required field and laboratory work had to be available. The IAEA through this project assisted developing Member States, as required, in the establishment and strengthening of their human and institutional capacities as these were essential requirements for the successful and effective application of the FRN techniques in soil erosion studies. Laboratory quality control assurance and relevant expert services on the use of FRN techniques were provided for the participating Member States to improve their national capacities.

II.2. Objective of the Project

The overall objective of the regional project was: to develop sustainable land and water management strategies using FRNs for reducing soil erosion and improving soil and water quality in the Asia and the Pacific region.

The specific objectives were:

i) To measure soil erosion and deposition over several spatial and time scales by combined use of caesium-137, lead-210 and beryllium-7;

ii) To establish soil redistribution-soil quality relationship under different land management practices by using the results obtained;

iii) To develop guidelines to assess soil quality based on results obtained from i) and ii); and

iv) To apply management practices developed as a result of the soil redistribution-soil quality relationship for effectively improving soil and water quality as well as increasing soil organic carbon storage.

II.3. Participating Countries

Table 4: Counterpart/partner institutions, staff in the participating countries and IAEA staff

Country (Abbreviation)	Counterpart and partner institutions	Counterpart staff
Australia (AUL)	Commonwealth Scientific and Industrial Research Organization (CSIRO), Cotton Catchment Communities Cooperative Research Centre, Australian Cotton Research Institute, Narrabri, NSW 2390 University of Newcastle, Callaghan, NSW	Ms. Paula Jones (NPC*) Mr. Robert Loughran
Bangladesh (BGD)	Bangladesh Institute of Nuclear Agriculture (BINA), P.O Box 4, Mymesingh	Mr. M. A. Sattar (NPC) Mr. Md Ekram-ul Haque Mr. Md Mohsin Ali
China (CPR)	Institute of Environment and Sustainable Development in Agriculture (IEDA), Chinese Academy of Agricultural Sciences (CAAS), 12 Zhongguancun South Street, Beijing 100081 ALMERA (Analytical Laboratory For Measuring Environmental Radioactivity) Institute of Soil and Water Conservation, Chinese Academy of Sciences, Yanling Beijing Forestry University, Beijing China Agricultural University, Beijing	Mr. Yong Li (NPC) Mr. Junjie Li Mr. Hanqing Yu Ms. Xiaochen Geng Mr. Mingan Shao Mr. Xinxiao Yu Mr. Liming Liu
India (IND)	G.B. Pant University of Agriculture and Technology; College of Agriculture, Pantnagar National Institute of Hydrology, Inco Secretariat, Roorkee	Mr. P.C. Srivastava (NPC)
Indonesia (INS)	Centre for Application of Isotopes and Radiation Technology (PATIR), National Nuclear Energy Agency (BATAN), Jakarta, Selatan 12070 Directorate General of Land Rehabilitation and Social Forest, Forestry Department. Forestry Office, Local Government of Nganjuk	Mr. Barokah Aliyanta (NPC), Rahmadi S., Simon P., Nita. S, Tommy H.
Korea, Republic of (ROK)	National Agricultural Science and Technology Institute (NASTI), Agroecology Division, Suwon	Mr. Jung, Pil-Kyun
Malaysia (MAL)	Malaysian Nuclear Agency, Ministry of Science, Technology and Innovation, Bangi, 43000 Kajang, Selangor	Mr. Othman Zainudin (NPC) Mr. Faizal Azrin Abdul Rahman

Country (Abbreviation)	Counterpart and partner institutions	Counterpart staff
	Dept of Agriculture, Wisma Negeri, Seremban, Negeri Sembilan Sultan Idris Teaching University (UPSI)	Mr. Asmadi Ahmad Toyo Mr. Mokhtar Jaafar
Myanmar (MYA)	Department of Atomic Energy, Ministry of Science and Technology, Street No.21, NAY PYI TAW Mandalay Technological University, Dpt. Advanced Science and Technology, Mandalay	Ms. Theint Mr. Mon Khin Aye (NPC)
Mongolia (MON)	Ministry of Food and Agriculture, Mongolian Government Soil Laboratory of the Institute Geography, Mongolian Academy of Sciences (MAS) Nuclear Center of the National University of Mongolia Agriculture Institute Darhan Mongolian Agriculture University	Ms. Burmaa Badral (NPC)
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Philippines (PHI)	Chemistry Research Division, Philippine Nuclear Research Institute (PNRI), Commonwealth Avenue, Diliman, PO Box 213, Quezon City 1101 Bureau of Soils and Water Management (BSWM)	Ms. Adelina Bulos (NPC) Ms. Gina Nilo
Sri Lanka (SRL)	Land Use Division, Irrigation Department, Ministry of Lands and Minor Agricultural Exports, Baudhaloka Mawatha, Jawatte Road 26, Colombo 7 Atomic Energy Authority of Sri Lanka	Mr. Tissa Senerath Bandara Weerasekera (NPC)

Country (Abbreviation)	Counterpart and partner institutions	Counterpart staff
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Vietnam (VIE)	Center for Environment Research and Monitoring, Nuclear Research Institute, Vietnam Atomic Energy Commission (VAEC), 01 Nguyen Tu Luc Street, PO Box 61100, Dalat	Mr. Son Hai Phan
	National Institute for Soils and Fertilizers, Tu Liem	Mr. Tran Duc Toan (NPC)
IAEA	RCA Focal Person, Asia and the Pacific Section 1, Division Asia and the Pacific, Dept Technical Cooperation	Mr. Mahendra Prinath Dias
	Technical Officer, Soil and Water Management and Crop Nutrition Section, FAO/IAEA Division	Mr. Gerd Dercon

※ NPC - National Project Coordinator

Figure 6: Participants to the Final Progress Review Meeting

II.4. Contents of the Project

II.4.1. Main issues for developing land use and management strategies to control soil erosion and improve soil and water quality in the region

The project involved a wide array of studies/activities related to the following main issues:

a) *Establishment of national (human and institutional) capacities to conduct soil erosion studies using FRNs to measure soil redistribution (soil erosion/deposition) on an area-wide scale.*

Figure 7: Multi-disciplinary team

This issue needed to be addressed through the establishment of a multi-disciplinary and in many cases inter-institutional (2 up to 5 institutes) team working in soil erosion research in the participating Member States. Moreover the skills and expertise of these teams should be developed and/or strengthened through appropriate training and expert missions. Adequate field and laboratory infrastructure was also an essential requirement.

b) *Application of the FRN techniques to measure soil redistribution (soil erosion/deposition) rates over different spatial and temporal scales.*

This aspect included field studies on an area-wide scale (reconnaissance survey, study site selection, and field sampling design for sample collection); laboratory work (analysis of FRNs by gamma spectrometry, quality control/proficiency testing exercise to ensure the production of reliable radionuclide data) and desk work for reporting (use of conversion models, compilation of erosion/deposition datasets, graphical representation and data validation). During the period 2007-2008 ALMERA (Analytical Laboratory for Measuring Environmental Radioactivity) from CAAS, CPR provided external quality assurance (EQA) services to monitor the regional laboratory performance for analysis of FRNs in soils/sediments.

Figure 8: Collection of bulk soil samples for assessing soil erosion and sedimentation rates under different land uses in the Philippines using Fallout Radionuclide (FRN) analysis

Figure 9: Use of scraper plates in Chinese Loess Plateau for detailed soil sampling before FRN analysis

c) *Assessment of the impact of selected soil conservation technologies (SCT) to control/mitigate soil erosion.*

This aspect involved the comparison of erosion data obtained with SCT against a baseline (reference of comparison). Where no such relative comparison was made, the erosion data was related to the particular land use/management in the studied agro-ecosystem.

Figure 10: Learning together the principles of the FRN analysis held at workshop in China

d) *Assessment of the relationship between soil redistribution and selected soil quality parameters as influenced by land use/management strategies.*

This required the provision of guidelines to assess soil quality using FRN data on a country basis.

Figure 11: Analysis of samples for FRN analysis by using high purity germanium detectors with a 30% relative efficiency in Vietnam

II.4.2. Project implementation details

The project concept was developed by China (CPR), the Project Lead-country in the RCA Agriculture Thematic Sector and circulated for consultation among RCA Member States. Thereafter, a project proposal was prepared and submitted by China for approval by the RCA National Representatives. The project was incorporated into the IAEA TC Programme and was approved in 2004 for implementation over the 4 year period 2005 to 2008. Over these four years the total project expenditure was US$213,274.42, with US$198,025.88 (93%) spent on the human resources and the remaining US$15,248.54 (7%) on minor items of procurement. While the IAEA provided expertise and financial resources for human capacity building, the national teams were supported by their own governments to carry out field and laboratory activities of the project.

At the start of the project (Project Planning Meeting, Manila, PHI, 2005), regional and national work plans were outlined and the following expected outputs were identified:

1. Project implementation and monitoring structure in each country.
2. Personnel trained on the standardized methodologies and guidelines for the use of FRNs for the assessment of the soil erosion.
3. New soil and water resource management practices to control/minimize soil erosion.
4. National Programmes for dissemination of knowledge on soil and water resource management practices to farmers.

This project has been implemented through two consecutive phases as follows:

a) Phase I (2005-2006) was devoted to the formation of working teams, building of national human capacities through training of staff on the use of nuclear and related techniques in soil erosion/sedimentation studies, regional networking, expert missions for selection of study site(s) and initial field sampling for the application of the FRN techniques in soil erosion studies;

b) Phase II (2007-2008) : further field application, laboratory measurements and soil erosion/deposition estimates using FRNs methodologies; implementation of EQA (External Quality Assurance) exercise for the measurement of FRNs in soil/sediment samples; soil redistribution and soil quality studies; formulation of management (interventions) practices for controlling soil erosion and improving soil and water quality; start pilot testing and dissemination of technologies to the end-users. This final activity is still underway in several of the participating countries.

During project implementation three co-ordination meetings were held as follows: the Project Planning Meeting in March 2005 (Manila, PHI); the Mid-Term Progress Review Meeting in January 2007 (Beijing, CPR) and the Final Progress Review Meeting in January 2009 (Beijing, CPR).

II.5. Results and Impacts

II.5.1. Regional project networking achievements

The project assisted participating Member States in combating land degradation by soil erosion through the building/strengthening their human and institutional capacities for the successful application of FRN techniques in soil erosion/sedimentation studies as well as the selection of effective soil conservation measures to improve soil and water quality. In addition this project has made an important technical contribution to the enhancement of food security, conservation of natural resources and environmental sustainability in the Asia and the Pacific region. The project provided scientific, technical and administrative support, which has contributed to achieve the following outputs:

- Networking/partnerships of institutions at national, sub-regional and regional levels were established to implement project activities. The networking of project activities, through the coordination meetings, promoted national, regional and international co-operation, enabled and facilitated the sharing of knowledge and experiences among the participating Member States, and very importantly produced standardised protocols for the application of the FRNs techniques under various land use and environmental conditions in the region.

- The regional project was implemented in close co-ordination with other IAEA projects. These included: a) TC national projects related to soil erosion/sediment delivery using FRNs such as (CPR5015 "Assessment of soil erosion and effectiveness of soil conservation"; MON5015 "Implementation of the fallout radionuclide technique for erosion measurement"; PHI5031 "Assessment of erosion and sedimentation for effective formulation of soil conservation and water quality protection measures"; and SRL5038 "Application of isotopes for soil erosion studies"), and b) IAEA CRP on "Assessing soil conservation measures using fallout radionuclides for sustainable watershed management" (D15008): the national teams of China, Pakistan and Vietnam participated as research contractors. This co-ordination enhanced synergies between the regional and the national IAEA TC and/or CRP projects and contributed to achieve greater effectiveness and impact of IAEA's TC Program with regards to natural resource management and environmental sustainability in the region.

- This project has enabled participating Member States to build/strengthen their human capacity to conduct soil erosion studies using FRN and related techniques. A total of 31 technicians/scientists were trained and the majority continue to be active in their institutes. Also, countries like CPR and VIE have included lectures on the use of FRN for soil erosion assessment in courses at the undergraduate and graduate levels.

- Twelve expert missions were carried out to backstop specific expertise needs of the national teams. The experts' recommendations helped the project teams with the proper implementation of the FRN technology in soil erosion. Further training was also provided during these missions.

- Selected data utilised for the assessment of the effectiveness of soil conservation technologies in the participating Member States are shown in Table 5. In general it demonstrates that the provision of guidelines for soil conservation is dependent on the studied sites, specific agro-ecosystems/management, and type of conservation measure, highlighting the importance of the use of FRN tracers in targeting the appropriate soil conservation measures to sites with different levels and types of erosion.

- The combined support of the government of CPR and IAEA made it feasible to further strengthen the position of ALMERA Laboratory from CAAS, CPR, as IAEA collaborating center, to act as a focal point for technical and scientific development in the use of FRNs in soil erosion/sedimentation studies. This will ensure the sustainability of the activities started by the IAEA TC projects on these issues in the region.

- National teams gained knowledge and experience in all aspects (field, laboratory and desk analysis) of the application of the FRNs techniques in soil erosion studies. The project has contributed to the scientific advancement in the region. The results were published in scientific publications (scientific papers and postgraduate thesis), technical documents and other ways.

- Increased awareness of the project among scientists, policy/decision makers and public in general has been also achieved. As there is further potential for enhancing the socio-economic impacts, this success story intends to promote further dissemination of the results to end-users and beneficiaries of the project.

Overall, advancement in the technical and scientific development in the region through regional networking, international co-operation and enhanced human and institutional capacities to undertake soil erosion /sedimentation studies using FRN and related techniques is the major achievement of the project as evidenced by the results obtained in the project and documented by selected data, which are mainly based on published and unpublished material provided by the national teams.

Table 5: Summary Table Effectiveness of Soil Conservation Technologies

Country	Study area Location (longitude/latitude)	Land use/management	Net erosion rates
Australia	Broken Hill, New South Wales Australia (29° S, 141° E)	Grassland/ grazing land by sheep and goats	1 t $ha^{-1}yr^{-1}$
China	Baiquan county, Heilongjiang Province in NE-China (47° 30' N, 125° 51' E)	Crop land / One annual season's soybean	22.6 t $ha^{-1}yr^{-1}$
Indonesia	Nganjuk district, East Java Province (07° 40' 45" - 07° 45' 45" S and 111° 45' 45" -111° 53' 00" E)	- Production Forest - Mixed garden - Cleared forest	76 t $ha^{-1}yr^{-1}$ based on Cs-137 50 t $ha^{-1}yr^{-1}$ based on Pb-210
Malaysia	Sendayan/Seremban/Negeri Sembilan (101° 53' 18" N and 2° 38' 01" E)	Orchard fruits and vegetables	8.1 t $ha^{-1}yr^{-1}$
Pakistan	Sundaymar Catchment Area Rawalpindi (Punjab) Pothowar; (33° 39' 32" N, 72° 51' 47" E)	Barani agriculture mostly wheat and maize in terraces mixed with grassland and barren land	6.5 t $ha^{-1}yr^{-1}$
Philippines	Inabanga Watershed, Bohol Island (9° 50' N, 124° 10' E)	Agroforestry Woodlands Croplands: Rainfed rice Grasslands Cassava	3 t $ha^{-1}yr^{-1}$ 3.6 t $ha^{-1}yr^{-1}$ 2.8 t $ha^{-1}yr^{-1}$ 11.3 t $ha^{-1}yr^{-1}$ 22 t $ha^{-1}yr$
Thailand	High Land, Nong Hoi Royal Development Center, Nong Hoi Kao village, Tambon Mae Ram, Mae Rim District, Chiang Mai Province in Mae Sa Watershed, north of Thailand. (48° 05' 22-48° 09' 17 N and 20° 93302-20° 93760 E)	Reforest / no disturbance Vegetable land / cash crop, more than 1 cycle (start to settle, since 1969)	7.5-8.5 t $ha^{-1}yr^{-1}$ 54.8 - 89.8 t $ha^{-1}yr^{-1}$
	Upland, Nong Tun village, Tambon Phra Yean , Phra Yean District, Khon Kaen Province in Phra Yean Watershed, northeast of Thailand (25° 74' 31-25° 99' 72 N and 18° 05752-18° 07496 E)	Ruzi grass, cover surface land all time Para-rubber tree with tractor tillage (earlier it was cropland for more than 20 years.)	27 t $ha^{-1}yr^{-1}$ 5 t up to >100 t $ha^{-1}yr^{-1}$
Vietnam	Dongnai river-basin, Baoloc District, Lamdong Province; (11° 35' N; 108° 03' E)	Coffee plantation Contour-strips of *Vetiver* grass	33 t $ha^{-1}yr^{-1}$ 2.3 t $ha^{-1}yr^{-1}$
	Dongnai river-basin, Baoloc District, Lamdong Provice, (11° 35' N; 107° 48' E)	Mulberry plantation Contour-hedgerows of shrub	28 t $ha^{-1}yr^{-1}$ 1.2 t $ha^{-1}yr^{-1}$
	Daklak province, (12° 38.33' N; 108° 07.82' E)	Cropland: corn Contour hedge rows of *Tephrosia candida*	32.3 t $ha^{-1}yr^{-1}$ 6.98 t $ha^{-1}y^{-1}$
	Xuanhuong lake watershed, Dalat City (11° 57.34' N, 108° 26.93' E)	Cropland: Vegetables Contour strips of natural grass	28 t $ha^{-1}yr^{-1}$ 0.5 t $ha^{-1}yr^{-1}$

Soil Conservation technology	Comments
Grass cover/ controlled grazing	The estimated soil redistribution rates in these grasslands are consistent with the estimates using SOILOSS (an Australian modified version of the USLE) and the estimated reservoir sedimentation rates in the studied catchments.
Contour tillage, Terracing and hedgerows	Soil erosion can be significantly reduced through the studied soil conservation measures. As compared with downslope (gradients of 10-18%) farming, terraces and contour tillage have kept 20-60% of surface soil materials on site over the last 40 years, and crop yield has significantly increased.
Flat bench terraces	Bench terraces alone without ground cover in the study site were not effective due to the intensive field cultivation. Applying both mechanical and vegetative conservation practices was found the most effective way for controlling soil erosion as well as reducing soil fertility decline. Integrated bench terraces and land cover by grass since 1976 have shown to be very effective land management to reduce soil erosion, as evidenced by the sedimentation rates in the check dam.
Vegetation strips	Reasonable soil erosion losses in agreement with field observations. The soil erosion losses can be controlled by vegetation strips in gentle sloping land.
An original long steep slope was terraced to a series of narrow bench terraces with banks at the downslope side.	Severe erosion was completely controlled by the terraces and the net erosion rate was reduced. Terraces captured nearly all runoff and the crop yields increased.
Natural and cultivated vegetation strips	FRN-derived soil erosion estimates are comparable to those data obtained from soil erosion plots. Natural and cultivated vegetative strips are effective means to control erosion (by about 84-86% in relation to cassava). They are under study in large scale demonstration plots. Vegetative strips were planted (Pineapple, low grass, peanut) along contour at about 20 meters apart or according to the landform.
Land Reforested versus cropland under intensive cultivation	Very high erosion rates under intensive tillage/cultivation of vegetables as compared to the reforested area. Erosion under reforested land was reduced by 85-89% compared to cropland under vegetables.
Grassland versus Cropland/tropical tree plantation (tillage)	Land use history is essential to assess the impact of soil conservation measures. Tillage in upland high rainfall areas promotes strong water erosion. Erosion rates are very variable but they can be reduced by a grass cover.
Contour *Vetiver* strips	Seven 0.4 m wide Vetiver grass strips, equidistant from the hilltop to the base, were created along contour-lines in 2000. Soil erosion rate in coffee plantation with Contour *Vetiver* strips was reduced by 93%.
Contour-shrub hedge rows	Five 1.5 m wide green manure crop hedgerows were empirically planted along contour lines in 1982. Soil erosion rate in mulberry plantation with contour shrub rows was reduced by 95%.
Contour- *Tephrosia* hedge rows	Seven *Tephrosia* hedgerows were planted 7 metres apart along contour lines in 1995. Soil erosion rate was in cropland with contour *Tephrosia* hedge rows was reduced by 78%.
Contour strips natural grass	Three 1.2 m wide grass strips equidistant from the top to the bottom of the plot were established. Soil erosion rate in cropland with contour natural grass strips was reduced by 98%.

II.5.2. Potential socio-economic impact of the project

Preliminary impact assessment of the project in terms of policy development and farmers communities for the participating countries is shown in Table 6.

Table 6: Overview of impact of findings on policy development and farmers communities (Observer countries are not included in the table).

Country	Policy Development	Farmers Communities
China	Furthermore, expertise in FRN techniques achieved through this project has been used to provide technical support and recommendations to the Chinese central and local governments at Yan'an, Fengning, and Baiquan for 'soil erosion' prevention measures. Results obtained from this project and other related IAEA TC projects have been adopted by the Office of the World Bank Project in Baota district, Yan'an for selecting effective soil conservation measures to control soil erosion. Project data were used by the Ministry of Soil and Water Resources, Central government to establish water quality maps.	The project has contributed to a substantial reduction in soil erosion at Yan'an site (80000 ha) in the Loess Plateau (Yan'an site), and provided valuable guidance in selecting best soil conservation measures for controlling soil erosion at Fengning site in North China and Baiquan site in North East China. Soil erosion rates, as measured by the fallout radionuclide tracer method, declined by 16 to 80% depending on the type of conservation measures (terracing hillslopes, vegetated hillslopes, contour cultivation and no tillage) and the studied sites.
Indonesia	Through the project, soil management has been improved on the study site (11.000 ha). There is as well stronger collaboration between the stakeholders involved in the management of the natural resources.	In June 2008, farmers were actively involved in reforestation programmes with multi-purpose trees; the awareness about the importance of protecting the natural resources has increased.
Malaysia	Indirect impact through scientific outputs (papers, seminars, pamphlets and exhibitions)	In total, 3000 ha of plantations have been improved through the findings of the first phase (RAS/5/039), Farmers have been installing retention ponds to prevent sediment from flowing into the water stream network.
Pakistan	Several councils and departments involved in the management of soil and water resources in the study area are using the project data to improve their guidelines to enhance soil conservation.	As the work has been carried out on farmers' fields, farmers could observe the impact of the soil conservation practices, and started to adopt the techniques (without subsidizing these activities). Improvement of soil and water quality leading to better environmental conditions and increased crop yields could be observed.

Country	Policy Development	Farmers Communities
Philippines	Contacts with local governmental officers, involved in the dissemination of soil conservation measures. Results were shown in the national science and technology fair (2007)	Positive appreciation by farmers, high interest, participatory approach. This regional project focused on a Pilot Project covering an area of 6600 hectares within the Inabanga watershed. Initial estimates give an increase in crop production and income of roughly 10-15 percent.
Sri Lanka	Enhanced maps on land use and its impact on erosion will be available in 2011, and this will lead to improved land use policies.	Farmer communities might benefit from subsidies for soil conservation measures (after 2011).
Thailand	Through the Land Development Department the findings were given to the Ministry of Agriculture and Cooperation	Semi-participatory approach. No direct impact can be reported.
Vietnam	Based on the findings of this regional project new guidelines formulated by the government for improving the management of cultivated steeplands	Research is carried out in farmers' fields. Some adoption by the farmers in the remaining fields can be observed (visual observation).

Figure 12: Management strategies such as proper leveling the field, Pakistan

Figure 13: Vegetable cultivation with soil conservation measures in the highlands, Sri Lanka

Figure 14: Combination of soil conservation measures at Yan'an site in the Loess Plateau, China

II.6. Project Outcomes and Future Prospects

II.6.1 General outcomes of the project

The main project outcomes were related to the human capacity building and the regional co-operation.

- The participating Member States reported that this project has allowed them to successfully establish and/or further strengthen their capacity in the proper application of the FRNs technology in the assessment of soil erosion and evaluation of the efficiency of soil conservation measures for improving soil and water quality. In this process of capacity building of the project teams, important elements were: a) Organization of Regional Training Course on "Sustainable Land Use and Management Strategies for Controlling Soil Erosion and Improving Soil and Water Quality" at the start of the project (Beijing, China, 9-20 May 2005); b) Fellowship and the expert missions that have also contributed to the training in practical and site-specific aspects of the use of FRN technology; and, c) Relevant scientific information on the use of nuclear techniques in soil erosion and the reports of the co-ordination meetings, which were provided to the participants of the project. The enhanced skills and sound capacity of the project teams were evidenced by the quality of the final outcomes of the RAS/5/043 project, which showed the successful uptake and use of the FRN technology by the participating Member States.

- International cooperation through partnerships and spin-off projects linked with the RAS/5/043 project: the participants also reported that they established partnerships with related policy-making and development-oriented institutions for further land development projects aiming at promoting the adoption of effective soil conservation technologies and disseminating the FRN technology in soil erosion studies. National and international financial support (e.g. ACIAR-Australia, IRD-France) has been successfully obtained by the participants and/or their partners for such projects.

II.6.2. Specific outcomes on technical issues:

The participants of the regional project also shared their skills and experience on several technical and methodological issues.

- *Advantages and limitations on the use of FRNs for the measurement of soil erosion and deposition over several spatial and time scales*
  ^{137}Cs technique was the most widely used for medium term (~40 years) soil erosion assessment. Limitations due to low ^{137}Cs inventories (< 400 $Bq.m^{-2}$) in some study areas were reported by some participating Member States. The $^{210}Pb_{ex}$ technique has been used to provide long term (~100 years) soil and sediment redistribution rates, as a complement to the ^{137}Cs method. The use of ^{7}Be permitted a short term (<30 days) soil erosion assessment in connection with individual rainfall events and seasonal changes in land use/management practices.

- *Models to convert FRN data into soil erosion and redistribution rates*
  The selection of conversion model depended on the aim of the application of FRN technology. For land use/management purposes, the simpler proportional model was recommended, whereas more complex models can be used for achieving more accurate soil erosion estimates and better understanding of the processes influencing soil redistribution. The use of conversion models still poses challenges for assessing soil redistribution in complex landscapes.

- *Laboratory Proficiency Tests*
  The proficiency test report from ALMERA laboratory, CPR showed that the current analytical capacities of most participants were sufficient to further successfully implement the FRN technology, in particular for the radionuclide ^{137}Cs in Asia and the Pacific region. Therefore this FRN technology can be continued to be reliably used in a sustainable way in the region. Recommendations have been made to further improve the measurements of ^{210}Pb.

- *Soil redistribution - Soil quality relationship*
  The outcomes of the RAS/5/043 project also made clear that FRNs are useful and effective tools to establish the dynamic relationship between soil redistribution and soil quality at different spatial and temporal scales.

II.6.3. Concluding remarks and the way forward

1) Concluding remarks

- The FRN technology has been successfully used by the participating countries in the RCA project RAS/5/043 to assess soil erosion, to evaluate soil conservation measures, and to better understand the link between soil redistribution and soil quality. The inter-institutional and multi-disciplinary approach (collaboration between nuclear and land/soil science institutes) and international cooperation employed by most participating Member States were the key reasons of this success.

- The enhanced capacities and skills/expertise gained through this regional project RAS/5/043 can be used to further train scientists and technicians from the region.

- The proficiency test for fallout radionuclide analysis in soil samples showed that the current analytical resources in the Asia and the Pacific region are sufficient to further successfully implement the ^{137}Cs-based technology. Recommendations were given to further improve the quality of the analytical capability for measuring ^{210}Pb activities in the region.

- Partnerships have been established between participating institutions, relevant land use organizations and end-users/beneficiaries, which have led to the formulation and execution of national land development projects (Spin-off projects). National governments/regional offices should support the implementation of such projects to further promote the adoption of improved soil and water conservation practices and enhance the socio-economic impacts of the project.

- The participants agreed on the preparation (and structure) of a public information document (brochure) of the project to increase the awareness of the regional project RAS/5/043, to disseminate the project results and to enhance the impacts of the project.

2) The way forward

- Future studies involving integrated approaches for the application of FRN techniques allied with innovative sediment fingerprinting techniques will allow the identification of critical soil loss and sediment production areas and thus, target cost-effective soil conservation strategies within the watershed.
- There is a need for more comprehensive long term studies to establish improved baselines for better understanding the soil quality dynamics as influenced by soil redistribution in agro-ecosystems. Soil quality assessment and mapping are essential tools to support area-wide (watershed scale) sustainable land and water development and thus significantly contribute to achieving the UN Millennium Development Goals of extreme poverty and hunger eradication and environmental sustainability.

RCA Success Story in 2010

Combating Soil Erosion-Caused Land Degradation in the Asia and the Pacific Region