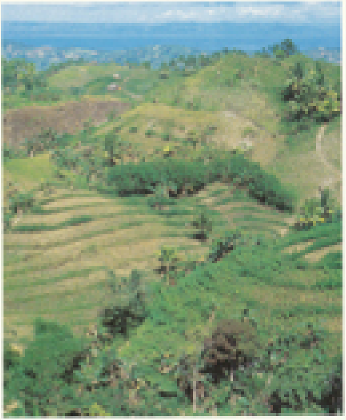
SOIL EROSION MANAGEMENT



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Soil Erosion Management

Proceedings of a Workshop
held at
PCARRD, Los Baños, Philippines
3-5 December 1984

Editors: E.T. Craswell, J.V. Remenyi, and L.G. Nallana

Co-sponsors:
Australian Centre for International Agricultural Research
Bureau of Soils
Philippine Council for Agriculture and Resources Research and Development

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Foreword

THE loss of soil through erosion reduces the productivity of land not only to present-day farmers but to the generations of farmers to come. The problem is widespread in the world and is being exacerbated by population pressure and extremes of climate such as intense rainfall and drought.

These factors operate to varying degrees in both the Philippines and Australia, but research administrators in both countries have recognised the need for work to define the scope of the problem of soil erosion, and to develop and evaluate technologies to reduce soil loss.

This workshop on soil erosion management was designed to review the state of the art of research in this field, and to define specific areas in which Filipino and Australian scientists could collaborate to help solve the problems of soil erosion in the Philippines.

ACIAR was pleased to join with the Bureau of Soils and PCARRD in cosponsoring the workshop which brought together physical, biological and social scientists to consider the problem using a truly multidisciplinary, interactive approach. This publication includes the papers presented and provides a record of the discussions and conclusions. We expect that the meeting will lead to collaborative projects suitable for support by ACIAR.

The success of the field tour and workshop is due to the excellent arrangements made by PCARRD, for which ACIAR extends its thanks to Dr Ramon V. Valmayor, PCARRD Executive Director, and his staff. We also thank the authors of the papers, the session chairpersons, and rapporteurs, and the technical editors — Thelma S. Cruz and Beatriz P. del Rosario of PCARRD and Reg MacIntyre of ACIAR.

J.R. McWilliam
Director, Australian Centre for International Agricultural Research

March 1985

Exploring New Areas of Technical Cooperation

Ramon V. Valmayor*

IT IS a sour fact but we have to admit it. In many instances, developed countries granting assistance to struggling economies apply a set of policies that reflect their own ideological or other biases. At times, although the recipient country has a fairly good idea of what should be under its own setting, the views of its technical people are conveniently ignored as the lending country insists on experimenting with its own concept.

Fortunately for the Philippines, our efforts to tap foreign sources of funds and harness technologies from international and regional research systems for national development have been met with genuine appreciation from collaborating nations.

Among these, of course, is Australia.

The history of this collaboration is quite recent. In August 1983 the Philippine government, represented by Science Minister and PCARRD Governing Council Chairman Emil Q. Javier, signed a memorandum of understanding for scientific and technical cooperation with Ambassador Roy Fernandez for the Australian Centre for International Agricultural Research (ACIAR). This agreement covers specific areas on grain handling and storage, and the performance and transfer of new technologies on rice-based farming systems.

In just over a year, eight research projects have been finalised to be undertaken by implementing research institutions in the Philippines elected by PCARRD, and their counterpart agencies in Australia.

Among the new areas under investigation are the post-harvest physiology of banana; the physiological, chemical and storage characteristics of mangoes and other tropical fruits in Southeast Asia, as well as the environmental constraints to increased productivity of rainfed rice-based farming systems in the Philippines. During the 139th Governing Council meeting on 28 November 1984, another proposal entitled "Pest Resistance and Post Harvest Technology for Sweet Potato and Cassava" was submitted by ViSCA for ACIAR consideration. Another proposed PCARRD-ACIAR project on integrated goat research for milk and meat production will be discussed by the Governing Council.

Undoubtedly, these inspiring developments have given impetus to our efforts to seek ways of raising research and development investments, particularly in agriculture and natural resources research, that will give more benefits to the small farmers. With ACIAR, we find meaning to the often-repeated tenet that any authentic research program made possible through external assistance must start with the real causes of the problems to be solved. Our projects must promote actions, perhaps less spectacular, but more efficient because they are based on a thorough situational analysis, the right perceptions, and the real need of our intended beneficiaries.

But perhaps even more than this, our partnership with ACIAR has proven without exaggeration and without undue vanity that PCARRD has set the pace in demonstrating the viability of applying a new strategy of generating financial

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support for Philippine agriculture and resources research and development.

Aware of the hard facts in the present economic situation, we are no longer pinning our hopes on foreign borrowings. From loans, we have graduated to quite a competent level, so that we are now being entrusted with grants.

It is even more gratifying to note that ACIAR genuinely recognises the fact that the projects which usually fail are those that lack the essential direct relation with the base groups, and so it has avoided the temptation of conceiving with us projects that depend on a mere transfer of resources to the intended target group. It is demanding from us an equal share of commitment, hard work, and most importantly, the same perspectives.

For three days, we are about to engage in an exercise of mutual sharing, consolidating, and dissecting of benchmark information in order to come up with a realistic analysis of another potential area of scientific cooperation — how to check the menace of soil erosion.

This workshop alone is clear proof of our Australian counterpart's intent to interact closely with us on projects based on an assessment of existing necessities at the local level, with their solutions, and definitions in operational terms of how the processes are to be fitted into a social reality that is in constant flux.

As we sit down together to develop strategies for collaboration on soil erosion research, the least we can do to show our appreciation is to give our best.

I wish you success in your deliberations.

Philippine-Australian Research and Development Programs

Roy Fernandez*

I WOULD like to present a brief outline of collaborative research activities taking place through projects being supported by the Australian Centre for International Agricultural Research (ACIAR), under the Australia-ASEAN Economic Cooperation Program (AAECP), in the international and regional programs supported by Australia, and in the integrated rural development projects in which we are participating in Zamboanga del Sur and Northern Samar.

One of the major cooperative programs in which ACIAR is engaged is in the grain storage program. This program draws together a number of research agencies as follows:

- The National Post Harvest Institute for Research and Extension (NAPHIRE) of the Philippine National Food Authority is collaborating with the Division of Entomology of the Commonwealth Scientific and Industrial Research Organization (CSIRO) in research aimed at applying CSIRO-developed techniques for storing grains in sealed plastic enclosures to bagged rice and other grains in the Philippines.
- The University of New South Wales and the Rice Growers Cooperative Mills Ltd., Leeton are collaborating with NAPHIRE on the application in the Philippines of techniques which they have developed for the drying of rice in bulk stores.
- The Queensland Department of Primary Industry is working with NAPHIRE on the development and implementation of pest control programs which will substantially reduce losses due to pests in bulk-stored cereals.
- The CSIRO Division of Entomology is collaborating with NAPHIRE on the analysis of pesticide residues, and modelling their decay in the laboratory and field for the purpose of applying the results to the use of pesticides in grain storage in the Philippines. Both agencies also study the effects of controlled atmosphere on the quality of grain in storage.

Some ACIAR projects include collaborative research on other areas, such as on the analysis of the transfer and performance of new technologies in rice-based farming systems involving the Australian National University and the Agricultural Research Organization of the Philippine Ministry of Agriculture and Food.

Two collaborative projects between the CSIRO Division of Food Research and the ASEAN Post Harvest Horticulture Training and Research Centre (PHTRC) work on postharvest handling of common Philippine varieties of bananas and of mangoes in Southeast Asia.

CSIRO (Division of Land and Water Resources) and the Agricultural Research Organization of the Philippine Ministry of Agriculture and Food are also engaged in a research project on environmental constraints to increased productivity of rainfed rice-based farming systems in the Philippines.

There are also a number of agricultural and natural resources research and development projects in the Philippines under the AAECP.

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*Australian Ambassador to the Philippines, Manila.

Australia is also supporting a number of regional and international programs in the Philippines and is making an annual contribution to the Southeast Asian Regional Centre for Graduate Study and Research in Agriculture (SEARCA) to support training and research scholarships and staff development in Australia.

As well, Australia makes a sizeable contribution to the annual budget of the International Rice Research Institute (IRRI) and other Consultative Group for International Agricultural Research (CGIAR) centres, and also provides substantial support to the Regional Network for Agricultural Machinery (RNAM) and the International Centre for Living Aquatic Resources Management (ICLARM).

There are, of course, many other areas where Australia is involved in Philippine research in agriculture and natural resources, and I believe that we are only at the beginning of what will be an expanding agenda of collaborative research.

Workshop Rationale and Guidelines

Amado R. Maglinao*

THE PRINCIPAL assets of agriculture in a country are the soil and land resources that are farmed and the farmers who till the soil. On these depend the production of food, fiber, and shelter not only for our growing population but also for export.

The pressure to produce more from this finite resource, however, is growing proportionally with the rapid increase in population. The choice left is between opening up new lands or intensifying utilisation of lands already under cultivation. The first alternative requires the extension of agriculture to marginal hilly areas where crop production is usually costly and uneconomical. Unless proper conservation measures are considered, the problem of erosion and declining productivity will become serious.

On the other hand, intensifying land use and cropping continuously without considering the amount of nutrients removed from the soil by the crops will result in the depletion of its natural fertility and capacity to produce. Thus, for both alternatives, effective technologies in crop production and in soil management and conservation are undoubtedly necessary.

All of us here have some ideas on the problem of soil erosion and what to do about it, particularly in terms of research and development. I am sure both PCARRD and ACIAR will consider these ideas most useful.

Through this workshop, we hope to consolidate specific benchmark information on the problems of soil erosion and possible strategies and approaches to counteract the problem. Ultimately, we expect to develop collaborative efforts on soil erosion research which are of mutual interest to Australia and the Philippines.

How do we plan to achieve those objectives and come up with the expected output? As a first step in developing a collaborative research program, some Australian and Filipino participants made a pre-workshop observation of areas with a conspicuous erosion problem and of activities being carried out to combat it. We hope this actual feel of the situation will be most useful in our discussion later.

We have divided the program into three main sessions, namely:

a) *Soil erosion management* in the Philippines which will examine the existing soil-erosion management programs and related policies, as well as the traditional practices of the farmers in relation to soil conservation;

b) *Advances in knowledge* on soil erosion management which will deal mainly with research findings and progress on the more technical aspects of soil erosion management; and

c) *The social and economic dimension* which seem to be the most problematic in soil-erosion management.

Summaries of each session appear elsewhere in these proceedings.

The research planning session will identify areas for research for possible collaboration between the Philippines and Australia. Also, we expect to identify

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people or agencies to work on these problems both in the Philippines and in Australia. This session will lead to the activities on the third day wherein Philippine and Australian researchers concerned will jointly develop research proposals, directions, and responsibilities of parties involved. I hope that we will be able to integrate all proposals and come up with a single program on soil erosion management.

I expect this will be a very fruitful and lively workshop. At its conclusion, I hope we will have agreement on how best we can tackle the serious problems of soil erosion.

An Assessment of National Soil Erosion Control Management Programs in the Philippines

Candido A. Cabrido, Jr.*

SOIL EROSION control management deals with the administration or management of soil erosion control/soil conservation programs, projects and activities. Administration, in this regard, covers organisation, policymaking, planning, coordination, resource mobilisation/allocation, program/project implementation, monitoring, and evaluation. It involves prevention, conservation, and rehabilitation/regeneration measures, or what is known as the PCR method.

Soil erosion control management is based on the following tenets: (a) highly erodible or susceptible soils must be protected to prevent accelerated erosion; (b) potentially productive soils must be conserved properly to sustain their fertility; and (c) eroded soils must be rehabilitated while averting their further degradation.

This paper discusses the nature and extent of the soil erosion problem in the Philippines, and presents an assessment of soil erosion control policies and programs. Major issues regarding soil erosion control management will be discussed and a policy research agenda suggested.

A macro assessment of the government's policies and programs on soil erosion control will be helpful in research planning and technology generation and transfer. An analysis of the problem of soil erosion, its causes and effects can help provide a better grasp of the problem from the systems perspective.

I formulated an assessment methodology, using the graphic model presented in Fig. 1. However, this graphic model will not be discussed in its entirety. The discussion will centre on government policies and programs, with emphasis on administration and technology. The last three submodules in the framework (Appraisal, Decision, and Implementation) are merely presented to provide a total view of the model.

Soil Erosion Problem

Soil erosion is a chronic intricate problem. While its rate of acceleration can be reduced, it can not be totally halted. The degree of effectiveness of soil erosion control is a function of several interrelated variables. Understanding these biophysical and socioeconomic variables and their interrelation is a major key in unlocking the complexity of the soil erosion problem.

NATURE AND CAUSES

The soil erosion problem is basically socioeconomic and ecological in nature. The socioeconomic factors that greatly influence human activities detrimental to soil resources are poverty, ignorance and profit. On the other hand, the ecological factors that affect soil erosion are physical and biological in nature. The interaction of these physical and biological factors determines the state of soil erosion in a given area.

The combined effects of these causative factors, socioeconomic/human and ecological dictate the degree and extent of soil erosion (Fig. 1).

Socioeconomic factors Soil erosion cannot be effectively abated without seriously considering the social and economic dimensions that confront poverty groups. Soil erosion is predominantly the result of human activities which are triggered by poverty and ignorance, and motivated by the need to survive. These factors lead the poor segment of the population to cultivate hilly land, adopt intensive cropping even in unsuitable lands, and employ destructive farming practices. Some human activities which cause erosion of topsoil are: improper land use and cultivation practices, (e.g., ploughing, harrowing and furrowing along the slope), slash-and-burn agriculture, and indiscriminate cutting of trees for firewood.

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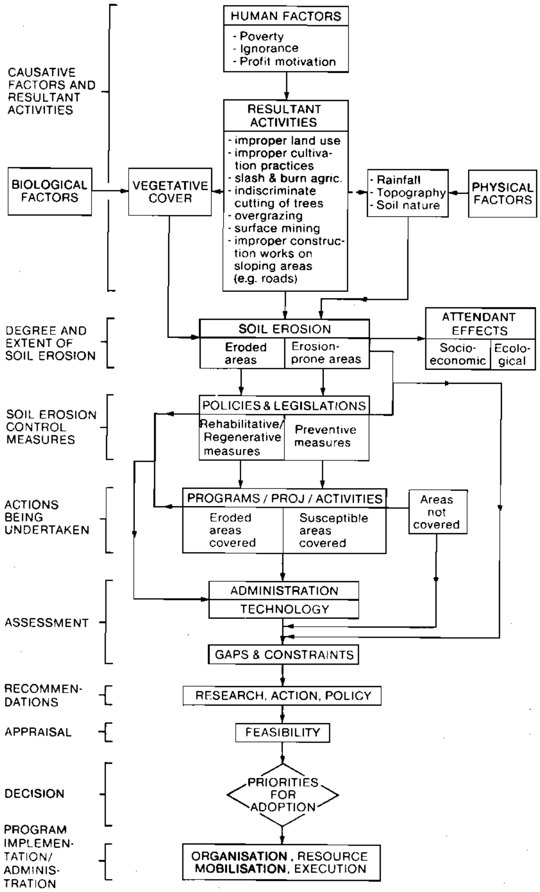

Fig. 1. Assessment framework for soil erosion control management.

In the long run, soil erosion is not only caused by poverty, it also breeds poverty.

Profit-motivated activities among big landholders and forest concessionaires are another major cause of soil erosion. Some of these activities are overgrazing, intensive logging, and expansive monocropping even in submarginal and sloping lands. In this case, soil resources (i.e., fertility and vegetative cover) are exhausted to maximise profit.

Another cause of soil erosion is hasty or ill-planned development activities such as improper surface mining, poor road alignment and construction, ill-planned subdivision development, land levelling in land consolidation projects, and other related activities.

Illegal logging also leads to wanton destruction of forest vegetation, thus accelerating, soil erosion.

Ecological Factors Prevailing heavy rainfall intensities, steep slopes and erodible soils coupled with the degraded vegetative cover have aggravated the soil erosion problem in the Philippines. Soil erosion significantly alters material cycle and energy flows in various ecosystems, thereby creating ecological problems. Soil erosion invariably results in the loss of top soil, sedimentation of water courses and water bodies, alteration of land forms or terrain, and changes in microclimate. Consequently, agricultural productivity is reduced. Floods and landslides occur, wildlife habitats are destroyed, reservoirs are silted, river systems are sedimented, and irrigation canals are clogged. Water for industrial and domestic use is polluted with surface runoff carrying eroded particles with nutrients.

A deeper understanding of the ecology of soil erosion is crucial in the formulation of strategic solutions and implementation of effective soil erosion control management measures.

EXTENT OF EROSION

The Philippines has a total land area of approximately 30 million ha. Nine million out of the 13 million ha of alienable and disposable land are eroded (Cabrido 1981). Thirteen provinces with more than half of their total areas eroded have been identified: Batangas (83%), Cebu (76%), Ilocos Sur (73%), La Union (70%), Batanes (68%), Bohol (66%), Masbate (66%), Abra (65%), Iloilo (63%), Cavite (60%), Rizal (56%), Capiz (55%) and Marinduque (51%).

Based on a slope of more than 11%, an estimated 58% of the country's total land area is susceptible to erosion (NEDA 1983). About 22% of existing and potential farmlands are susceptible to erosion, while about 30% of the estimated 17 million ha of forest land suffers from various types of soil erosion.

Control Measures

Various soil erosion control measures are reflected in the policies, programs and projects of concerned government agencies. Three government agencies, the Bureau of Soils (BS), National Environmental Protection Council (NEPC), and Bureau of Forest Development (BFD) are mandated to undertake soil conservation/erosion control programs/projects and related activities. Other agencies such as the Human Settlements Regulatory Commission (HSRC), National Irrigation Administration (NIA), Bureau of Lands

(BL), Bureau of Agricultural Extension (BAEX), Ministry of Agrarian Reform (MAR), Ministry of Education, Culture and Sports (MECS), Philippine Council for Agriculture and Resources Research and Development (PCARRD), and the National Council on Integrated Area Development (NACIAD) play supportive roles in soil erosion control.

National policies/legislation pertinent to soil erosion control are described briefly.

Land Use Policy Executive Order No. 648 empowers the Human Settlements Regulatory Commission (NSRC) to promulgate zoning and other land use control standards and guidelines which shall govern land use plans and zoning ordinances of local governments. Lately, Letter of Instructions No. 1350 created the National Land Use Committee to prepare the national and regional land use plans.

Environmental Policy Presidential Decree No. 1152 known as the *Philippine Environmental Code* embodies a provision on soil conservation. Chapter III, section 32, entitled 'Management Policy on Soil Conservation' decrees that 'the national government, through the Department of Agriculture and the Department of Natural Resources (now Ministries), shall undertake a soil conservation program including therein the identification and protection of critical watershed areas, encouragement of scientific farming techniques, physical and biological means of soil conservation, and short-term and long-term researches and technology for effective soil conservation.'

Letter of Instructions No. 549 directs the National Environmental Protection Council (NEPC) to 'organise and coordinate inter-agency task forces to study the major environmental threats in the Philippines, such as soil erosion . . .'

Presidential Decree No. 1586, entitled 'Establishing an Environmental Impact Statement System,' requires all entities undertaking environmentally critical projects to conduct an environmental impact assessment (EIA) of such projects, and submit an Environmental Impact Statement (EIS) to NEPC. No person, partnership or corporation shall undertake or operate any such declared environmentally critical project or operate within proclaimed environmentally critical areas without first securing an Environmental Compliance Certificate issued by the President of the Philippines or his duly appointed representative.

Soil Conservation Policy Presidential Decree No. 461 gives the Bureau of Soils the responsibility to assess, develop and conserve soil resources in the country, and conduct research on soil utilisation, management and conservation.

Forest Ecosystem Management Policy Letter of Instructions No. 1260 instituted the Integrated Social Forestry Program (ISF), also known as PROFEM II (Program for Forest Ecosystem Management), in line with the government's policy to democratise the disposition of suitable public forest lands and to promote a more equitable distribution of forest benefits.

The ISF program aims to rehabilitate denuded forest lands, promote optimum land productivity, reduce the practice of kaingin-making and forest destruction, increase the income of program participants, especially the kaingineros, and to stabilise agricultural systems in the forest lands.

This policy provides 'security of tenure to kaingineros and other deserving forest occupants in identified kaingin settlements through the granting of a long term stewardship contract on economic-sized family land holdings, the effective duration of such contracts and specific size of farmholdings to be set as deemed appropriate by the Ministry of Natural Resources, provided that, areas which are too steep for ecological and economically sound development shall not be subject to this program . . .' Several agencies are mandated to implement the ISF Program, with the Bureau of Forest Development (BFD) taking the lead role.

Other related forest conservation policies include the following:

- Presidential Decree No. 705, better known as the Forestry Reform Code, provides measures for soil erosion control.
- Presidential Decree No. 1153 or Tree Planting Policy requires all able-bodied citizens of the Philippines at least 10 years of age and above to plant one tree every month for five consecutive years.
- Letter of Instructions No. 423 created the Presidential Council for Forest Ecosystem Management (PROFEM) which is directed to formulate programs, guidelines and policies that will maintain and enlarge the forest ecosystem.

NATIONAL PROGRAMS

A number of programs and projects are currently being undertaken by government agencies to implement major policies and legislation on soil erosion control. In many instances, soil erosion control/soil conservation projects are built-in components of larger programs like agriculture development, forest development, and environmental protection programs. They may also be incidental in development activities being undertaken by government entities.

Bureau of Soils The Bureau is engaged in four major programs/projects which are directly and indirectly related to soil erosion control. These are water impounding, soil and land resources survey, soil conservation guided farm, and soil erosion research.

The objective of the *water impounding project* is to reduce excess runoff using water impoundment structures such as check dams and farm ponds. The project, aside from mitigating soil erosion, provides irrigation water and ponds for growing fish. The Bureau of Soils has completed around 76 water impounding projects with a total pond area of 143 ha, a service area of 3297 ha, and a water-shed area of 17 236 ha.

In the *soil and land resources survey*, soil erosion is assessed in terms of actual state of degradation and susceptibility of the soil to various erosion processes (particularly when used for agriculture which requires clearing/cultivation). The project has completely covered Surigao City, Surigao del Norte, Cavite, Metro-Manila, Marinduque, Palawan, Bohol, and Panay.

Technicians of the Bureau extend assistance to farm owners in the preparation of *soil conservation-oriented farm* development plans. Soil demonstration stations were established in Regions II–XI to showcase various soil conservation methods such as water-impounding structures, terracing, contouring and agroforestry. The demonstration stations are meant to encourage farmers to adopt these methods.

Studies on *soil erosion* in relation to soil type, degree and length of slope and vegetative cover are being undertaken to provide empirical data for determining the degree and rate of soil erosion under certain conditions.

Bureau of Forest Development The BFD is currently undertaking the Integrated Social Forestry (PROFEM II), Watershed Development, Forest Protection and Land Classification programs:

Also known as PROFEM II, the *Integrated Social Forestry Program* integrates three people-oriented projects namely, Communal Tree Farming, Forest Occupancy, and Family Approach to Reforestation. The ISF has gained nationwide acceptance. It has been adopted by 82 862 kaingineros and marginal farmer families in 835 upland farming sites. The program covers 285 876 ha of denuded forest lands.

The main goal of the ISF program is to improve the living conditions of the kaingineros and other legitimate forest occupants, while undertaking renewal of forest resources through reforestation. The ISF program is supplemented by the Tree Planting Program as mandated by PD 1153.

The *watershed development* program involves the rehabilitation of eroded and denuded watershed areas through the construction of soil erosion control structures such as bench terraces, check dams, gabions, ripraps, diversion canals and ditches. Vegetative measures such as the planting of suitable and deep-rooted tree species and improving grass cover of denuded areas are also undertaken to minimise soil erosion.

Watershed rehabilitation and soil erosion control under the BFD's Small Water Impounding Project (SWIM) are being undertaken in the following areas: Benguet, Bataan, Nueva Vizcaya, Pampanga, and Davao del Norte. The BFD is also cooperating with the National Irrigation Administration (NIA) in the rehabilitation/establishment of soil erosion control in two of the largest watersheds in the country — the Magat and Pantabangan watersheds in Isabela and Nueva Ecija provinces, respectively.

The *forest protection* program aims to protect lands from illegal entry and unlawful occupation, and to reduce the risk of fire. Around 4000 forest guards, aided by about 2678 deputised barangay captains, 213 concession guards, and 355 public individuals maintain the task of forest protection.

Together with the Bureau of Lands, the BFD has entered into the final stage of the *land classification project*, pursuant to Presidential Decree No. 705 (Revised Forestry Code). Of the 30 million ha of the country's total land area, a total of 24 759 664 ha has been classified. Of these, 13 480 565 ha were classified as alienable or disposable and 11 279 099 ha as permanent forest land. About 5 240 336 ha of land have remained unclassified.

National Environmental Protection Council The NEPC created an interagency task force on National Soil Erosion Control Management by virtue of Letter of Instructions 549. The aim of this task force is to expedite the optimal use of soil resources through systematic management of various government programs on soil conservation. It puts into action the plans and programs of the National Soil Erosion Control Management Program (NASECOMP). The NASECOMP has four major sub-programs/projects:

Nationwide *soil erosion and susceptibility surveys* and soil mapping are currently being undertaken in critically eroded areas. Rapid survey methods and overlay techniques are being used for soil erosion and susceptibility assessment. Project activities include the validation and updating of soil erosion data and maps, and the formulation of soil erosion control guidelines. To date, fifteen provinces have been completely surveyed: Abra, Capiz, Davao, Masbate, Zambales, Zamboanga, Antique, Bohol, Cotabato, Ilocos Sur, Iloilo, Marinduque, Batangas, Cebu, and La Union.

The *manpower development for soil conservation* project has two major activities: training of field trainers from different government agencies on the technical and management aspects of soil erosion control, and the integration of soil conservation concepts in the school curriculum. The latter includes the preparation and publication of instructional materials on soil conservation/erosion control for elementary, high school, and college levels.

Pilot projects are established under the *rehabilitation and monitoring* sub-program to demonstrate various appropriate soil conservation technologies. The project also monitors erosion rates and evaluates the beneficial impact of soil erosion control measures. Small critical watersheds are selected as pilot sites for the implementation of this sub-program.

The objectives of the *information generation and dissemination* sub-program of the NASECOMP is to create awareness and generate public support for soil erosion control. Preparation and dissemination of primers in the local dialect and production of audiovisual materials on soil erosion control comprise the major activities of this sub-program.

Assessment of Programs

Despite government efforts to undertake massive soil erosion control projects, these efforts have remained inadequate because (a) the soil erosion control programs/projects of government agencies concentrate only on some provinces/sites and do not comprehensively cover all of the thirteen identified critically eroded provinces; and (b) the rate of reforestation, which is about 60 000 ha/yr, has not, until recently, kept pace with the rate of forest destruction which is around 170 000 ha/yr. More than 5 million ha of denuded lands still require rehabilitation (NEDA 1983).

Soil erosion control management is constrained by several interrelated factors. The most significant ones include: inadequate policy guidelines; poor or inadequate implementation of policies and legislation pertinent to soil erosion control/soil conservation; difficulty in the coordination of interagency programs/projects; lack of financial support; absence of systems for monitoring erosion and evaluation effectiveness of soil erosion control technologies; lack of appropriate technology for soil erosion control; and dearth of technical and managerial manpower.

Guidelines to implement policies relevant to soil erosion control are presently inadequate.

More specifically, there is a *lack of policy guidelines* for soil erosion control in urban land development. For instance, housing subdivision development in sloping areas and hillsides contributes to serious soil erosion and landslides during construction and post-construction, since water runoff during heavy rainfall erodes the unstabilised slopes. The eroded materials, in turn, clog drainage ditches and pollute natural streams.

Hilly land farming is likewise not regulated by guidelines to minimise soil erosion. Thus erosive farming practices prevail in hilly areas throughout the country.

In addition, policy guidelines for range/pasture lands and coastal lands are needed to minimise erosion due to improper use and management.

Existing policies and legislation adequately address the problems related to soil erosion. However, many of these *policies/legislations are not adequately implemented.* Examples of these are the tree planting decree, the environmental impact assessment decree, the Forest Protection policy, and the Land Use policy. Conspicuous gaps exist between these conservation laws and their enforcement.

Improper implementation of the policy guidelines on the Integrated Social Forestry program could exacerbate soil erosion and lead to adverse ecological effects. The implementors of this program should be cautioned on the possible risks and repercussions of upland farming if the necessary measures are not properly implemented. Apparently, the administration of the ISF program is a herculean task.

Soil erosion control management requires *co-*

ordination of the activities of concerned government agencies to minimise duplication of efforts. while optimising available resources through the complementarity of projects/activities. Thus, an interagency task force on National Soil Erosion Control Management was created in 1977 by the NEPC.

The essence of coordination was, however, not fully realised in this interagency organisational setup for the following reasons: lack of participation of some member agencies in the implementation of interagency projects; difficulty in mobilising resources due to differences in the priorities of member agencies; irregular attendance of meetings among official representatives which hindered decision-making and planning: and bureaucratic red tape that caused delays in the implementation of interagency projects and dampened the enthusiasm and interest of cooperating agencies.

The most common reason given by government agencies for their inability to fully implement plans and programs is *insufficient financial support*. In reality, it is not solely the lack of financial resources that hampers full-scale and effective implementation of programs and projects. Sometimes the problem lies in the lack of appropriate technology and a weak administrative system/capability.

The reforestation program, for instance, suffered setbacks due to insufficient funds, administrative constraints and technological problems. Weak administrative system/capability is manifested in the delay or untimely release of funds which affects project implementation, and the inefficiency of some reforestation personnel due to lack of supervision.

On the other hand, the technological problem lies mainly in the low survival rate of seedlings which is reported to be at 60–65%. This problem stems from improper choice of species, poor site preparation, poor seed quality, improper planting of seedlings, insufficient protection, care, and maintenance of seedlings, and low soil fertility.

At present, there is *no nationwide system for monitoring* the extent and rates of soil erosion for management purposes. No agency has been identified to undertake this task. Moreover, coordination of the efforts of various government agencies in soil erosion control requires the monitoring of their project activities, area coverage, and accomplishments. These two monitoring schemes can be very useful for soil erosion control management. Reports generated under these schemes will serve as vital inputs in the decision-making, planning and resource allocation for national soil erosion control programs and projects.

There is a dearth of local empirical findings needed to establish the effectiveness of currently adopted soil erosion control technologies and administrative systems. An evaluation method is required to document and determine the effectiveness of soil erosion control technologies and the system of administration under local conditions.

The term 'appropriate' refers to *technology* which is low-cost, easy to construct and maintain, uses indigenous materials, and is highly effective in reducing erosion rates. These features broadly describe a practical and replicable technology which is highly accessible and participative in nature (i.e. users can install/construct the technology themselves, with minimal instructions).

Most of the soil erosion control technologies adopted in the Philippines originated in the United States, Taiwan, West Germany, Japan, and other countries. These ready-made, packaged technologies have been of limited use to small farmers despite government efforts to make them readily available. This is attributed to the following reasons: small farmers do not have the money to invest in soil erosion control, especially if this entails purchase of materials and hiring of additional labor; small farmers are usually not aware of or place little value on the long-term ecological impact and economic benefits of soil erosion control; small farmers are skeptical about the effectiveness of soil erosion control technologies and still prefer their indigenous ways and means of soil conservation; tenants and kaingineros do not take responsibility in conserving the soil they till because of insecurity of tenure and the nature of their farming practice (i.e., shifting cultivation); and most users find the technology too complicated to adopt/establish and difficult to maintain. The primary constraints, therefore, in the adoption of soil erosion control technologies by small farmers are cost considerations and a lack of awareness and comprehension.

A nationwide *technical manpower survey* conducted by the NEPC among 19 government agencies and 8 agricultural schools in 1979 revealed that technical personnel knowledgeable and skilled in soil conservation/erosion control management numbered only 364. This means that personnel with technical capability to plan, implement, and manage soil erosion control programs are lacking, considering the magnitude of the problem. Out of the total 364 people, 53 were categorised as technical experts, based on their level of education and years of experience in soil conservation/soil erosion control.

The Manpower Development sub-program of the NEPC has so far conducted only two training courses (in Baguio City and Batangas) for extension workers and field technicians within a period of 7 years. The irregular implementation of this sub-program is traced to insufficient funds and difficulty in organising and arranging such types of regional field training courses. Around 100 trainers representing various government agencies from the different regions of the country have been trained in these two training courses. The courses were successful in imparting to the participants the necessary knowledge and skills in soil erosion control, but failed in their objective of integrating the knowledge and skills into the respective training programs of participating agencies. Thus, the sub-program did not achieve a multiplier effect.

Summary and Recommendations

Soil erosion remains the leading environmental problem gripping the country today. Efforts to contain the problem started in the 1930s with the reforestation program of the Bureau of Forest Development. These efforts were intensified in the 1950s with the creation of the Bureau of Soil Conservation. Since then, these two agencies have undertaken soil conservation programs and projects within their areas of jurisdiction.

As environmental consciousness grew in the 1970s, the government became more vigilant in conserving its environmental resources and maintaining the ecological integrity of its ecosystems. The National Environmental Protection Council was created in 1977 and an Environmental Policy was promulgated with soil erosion control as one of its major concerns. The NEPC initiated the coordination of various activities of government agencies in soil erosion control for purposes of mutual reinforcement. Thus, integrated soil erosion control management (SECM) was introduced.

The 1970s and the early 1980s witnessed the widespread emergence of the 'integration' and 'coordination' approaches in the bureaucracy. Programs of government agencies adopted the total development strategy involving the provision of the basic needs to target clientele. In addition, more government programs were designed along the objectives of organisational and sectoral integration. Developments along this line include the creation of the Ministry of Human Settlements and the National Council on Integrated Area Development, and integration at the regional level of the different bureaus of the Ministry of Agriculture (now Ministry of Agriculture and Food).

Soil erosion control management likewise adopted the same integration strategy: the BFD has instituted and made operational the Integrated Social Forestry Program; the BS has launched the integrated land evaluation and development program and has supported the implementation of the Integrated Area Management System for Agricultural Services, as mandated by Executive Order 803; and the NEPC continues to undertake the integrated soil erosion control management program.

In all aspects of integration, multi-sectoral and interagency cooperation is required. Integration is usually achieved through coordination of the different programs of concerned agencies. Activities are directed toward a common objective. However, integration and coordination are not easy tasks. The government machinery was established along sectoral lines. Thus, the introduction of such an innovation in development administration faces difficulty and poses a great challenge.

The major challenge in soil erosion control management lies in the development of operational mechanisms to achieve an efficient coordinating system. Many interagency programs fall short of their objectives due to constraints and impediments in coordination.

Other matters which need to be considered in the establishment of an efficient soil erosion control management system include the following:

- establishment of a nationwide monitoring system for soil erosion control management and designation of centres of responsibility;
- research on appropriate technology for soil erosion control with alternative designs for technology transfer;
- integration of soil conservation/erosion control measures in all land development activities and the promulgation of pertinent policy guidelines;
- greater support to the manpower development program for soil erosion control;

- reexamination of SECM policies and formulation of relevant programs or actions.

At this stage of development, soil erosion tends to focus on the technical aspects while overlooking the management or administrative dimensions. Unless the latter is strengthened, the former becomes ineffective. It is therefore imperative to simultaneously develop the technical and management aspects of any soil conservation program or project.

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Traditional Farmer Practices Affecting Soil Erosion and Constraints to the Adoption of Soil Conservation Technology

Abraham B. Velasco*

A group of Filipino and German soil-erosion experts has concluded that 'human interference (is) the main cause of erosion.' They devoted a whole chapter of their report to justifying their conclusion (Agpaoa et al. 1975), with the following examples:

(1) *Logging and fuelwood cutting* (e.g. excessive logging for mine timber in Binga-Ambuklao Watershed, excessive cutting of fuelwood in the Ilocos region for tobacco flue-curing);

(2) *'Kaingin' making* (especially in densely populated areas, very steep lands and strips adjacent to rivers);

(3) *Forest fires and grassland burning* (especially in forests with a ground cover of dry grasses and pasturelands);

(4) *Improper range management* such as, (a) 'premature grazing,' where cattle are allowed to graze when grasses and palatable herbs are just sprouting; (b) 'overgrazing,' where soil is compacted by trampling of livestock and browsing paths become the beginning of rill and gully erosion or even of landslides on the steep slopes; and (c) 'continuous grazing', where animals graze a pasture more than once a month;

(5) *Road costs* on steep slopes and dumps of excavated soil materials;

(6) *Improper disposal of mining wastes*, that is dumping them to form steep slopes; and

(7) *Improper drainage* and careless discharge of accumulated rainwater from roads or buildings with a large roof surface.

Of these seven items, the traditional farmer is blamed for 'excessive cutting of fuelwood,' kaingin making, forest fires, and grassland burning but not the others.

Watershed researchers of the Forest Research Institute have also pinpointed potential soil-eroding farming practices (FORI, 1975–83). Perino et al. (1981) list monoculture of sugarcane and corn in rolling areas, continuous ploughing activities of rolling areas, and planting during the period of heavy and long-duration rainfall. Makaset et al. (1979) identified two farming practices: burning of forests and indiscriminate cutting of trees.

Codamon and Atienza (1979) reported the practice of building forest fires which is culturally rooted among the Ifugao tribes in Northern Philippines. Codamon (1980) also reports that forest fires are caused by four groups: kaingineros, cogon cutters, charcoal makers, and passersby.

Calanog (1983) describes the practice of 'Inum-an' agriculture (among the Kalanguya) which follows five general phases—site selection, cutting, burning, planting and fallowing. Reyes and Maceda (1976) attribute soil erosion to human acitivities such as logging, shifting cultivation, grazing, seasonal planting of crops, and establishment of settlements.

Soil experts, watershed management specialists, soil engineers, and soil managers (not soil erosion managers) can contribute more to the list of potential soil-eroding practices of the traditional farmer.

Soil Conservation Technology

A number of soil conservation technologies are recommended for adoption by the traditional farmers (Agpaoa et al. 1975) including:

(1) *Fencing* of pasture to prevent grazing and browsing animals from destroying the ground vegetation;

(2) *Proper land use* which is determined by whether the land is below or over 18% in slope;

(3) *Proper range management* which includes prescribed burning, pasture rotation, and pasture improvement;

(4) *Restrictions on kaingin making* such as strips of natural vegetation being maintained between kaingins and terracing sloping land, use of irrigation, application of fertiliser and manure;

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(5) *Restrictions on logging in critical areas:* skidding of logs is to be avoided, cableways should be kept narrow, and logging debris must be prevented from clogging drainage canals;

(6) *Proper road construction and maintenance* which means the road has to have a camber or gradient against the hillside, water collected in ditches and conducted safely through culverts into stable waterways, and the road surface is kept graded and sloped against the hillside to get the rainwater quickly off the road;

(7) *Use of masonry, concrete, and gabions;*

(8) *Use of plants and other materials* such as trees, shrubs, vines, bamboos, grasses, bitumen emulsion, anchoring pegs, etc.

(9) *Slope stabilisation methods and techniques*—(a) Vegetative methods: planting and sowing; brush cover of 'matting'; bench brush layers; wattling; fascines; sodding; mulching and bitumen emulsion; hydro-seeding. (b) Solid retaining walls and combined methods—riprap or dry stone walls; retaining walls of concrete and masonry; gabions; riprap interplanted with cuttings; pole structure with worn-out tires.

(10) *Gully stabilisation;*

(11) *Control of riverbank erosion;*

(12) *Use of shelterbelts.*

Bostanoglu (1976) has added the following to the above practices:

(1) encouragement of natural vegetation;

(2) branch layering;

(3) grass-sodding where grass tufts and root cutting are planted;

(4) reforestation of rocky slopes;

(5) consolidation of unstable slopes such as crumbling slopes, subsiding slopes, sliding ground;

(6) wattling and fascining;

(7) low drystone walls;

(8) brush mulching;

(9) contour ploughing;

(10) terracing (e.g. level terrace, graded channel terraces, banquettes and gradings, and steppe-method terraces.)

Constraints

There are two ways of looking at constraints from the farmer's point of view: (1) Why does the farmer not abandon traditional farming practices (TFP) in favour of the new soil-conservation technology (NSCT)? (2) What is it about the NSCT that makes him shy away from it, or even outrightly reject it?

Although the farmer would gain in economic terms by practicing the NSCT (and would be helping to promote ecological balance) he prefers to continue with his TFP. It is, therefore, not the promise of more economic gains that would make him abandon traditional farming practices. I believe it is beyond economic considerations.

The last thing a farmer will agree to, if ever, is the charge that he is destroying the land (forest land, for instance) with his 'destructive practices.' He knows very well that the land is a source of his livelihood so why would he destroy it?

Perhaps, to the soil manager, 'destruction' is defined *not* the way the farmer himself defines it. In the same way, erosion may not be defined by him the way we define it. (The word *erosion* may not even be found in his vocabulary, but he might have some equivalent term for it.)

Yet, we point an accusing finger and charge the farmer with something he cannot fully understand. Can we expect him to adopt practices that we designed and devised, and which will change considerably his customs, habits and lifestyles?

There has to be a common point of reference agreeable to both the farmer and the soil manager with regard to their 'perception' of soil erosion.

How can you then sell new soil conservation technology to people who do not share your perception of the eroded condition or the erodibility of their soil?

The farmer may be suspicious of the NSCT. If he adopts it, will it cost him anything? Will he sacrifice a part of his time? What about the reward or remuneration?

Perhaps, it is not so much the NSCT that the farmer is suspicious about, but more so about your (our) motivation in making him adopt it.

Our new soil conservation technologies may be quite appealing at first to the farmer but after some 'second thoughts' he may reject it because he finds out he is not prepared to adopt it. He may not have the necessary skills or adeptness to implement the practices, or he may not have the access to the material resources that such technologies demand.

Summary

What constrains the farmer from adopting the NSCT in favour of the TFP? The following factors seem to be the main determinants in adoption: (1) What the farmer *knows* about the NSCT and the people who want him to adopt it;

(2) What the farmer *feels* about the NSCT and the people who want him to adopt it; and (3) What the farmer *is willing* to do about the NSCT and for the people who want him to adopt it.

I have focused on the social and psychological constraints, particularly attitude. Whether we like it or not it is the individual person who makes the final decision in the adoption, or rejection, of a new soil conservation technology.

We should always review new soil conservation technologies, and evaluate them vis-a-vis the traditional farming practices, from the point of view of a farmer.

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Rainfall Intensity and Overland Flow in Relation to Soil Erosion Studies for Tropical Lands

A.K. Turner, T.A. McMahon and R. Srikanthan*

RAINFALL is the main cause of soil erosion. For land surfaces having slopes steeper than 3%, overland flow resulting from intense rainfall can become a dominant, if not the dominant, process in removing and transporting soil particles. For slopes that are less steep, removal and transport of particles is more likely to be caused by raindrop splash.

The measurement and definition of overland flow is basic to studies of erosion on steeper lands. Since overland flow, as well as the degree of raindrop splash, are partly the result of high intensity rainfall, the measurement and definition of rainfall intensity is also basic to all studies of sheet and gully erosion.

In addition to its dependence on rainfall intensity, overland flow depends on a number of soil and landscape features which are site-specific, namely:

(a) the physical, chemical and microbiological nature of the soil, particularly its properties of infiltration, slaking (shear strength), dispersion and organic matter (binder) content;
(b) antecedent soil water conditions;
(c) type and density of vegetative cover, mulch, and roughness (cloddines) of soil surface; and
(d) topographic features, including length of flow path, slope and uniformity of slope.

These factors all help to determine the hydraulic response of overland flow. Hydraulic response causes the formation of rills, which in turn modify overland flow.

Relatively little is known about the mechanism of erosion of agricultural soils by overland flow, mainly because of the complex interplay of forces of chemical and mechanical origin. The relatively simple movement of sands by flowing water has been extensively studied in fluid mechanics laboratories, but the erosion and transport of cohesive soils has not received nearly so much attention.

Studies of raindrop splash are easier to carry out than studies of overland flow because relatively small samples of either *in situ* or remoulded soils can be subjected to raindrops under some form of rainfall simulator.

Erosion 'models' such as the Universal Soil Loss Equation (USLE) of Wischmeier and Smith (1978) emphasise the importance of rainfall intensity (and, indirectly, raindrop splash), but largely infer the consequences of overland flow. In the practical use of this equation, overland flow is built into an L-S factor — erosion increases with steeper slopes (more splash, more runoff, and higher velocities) and with longer slopes (more runoff, deeper flows and faster velocities). In the development of this equation, the erosivity of the rainfall was taken to be the product EI_{30}, i.e. the total kinetic energy of a storm and its maximum 30-min intensity. This intensity value could be appropriate for many temperate regions (for which most worldwide data are available). However, it may not be so appropriate for tropical regions, which have a large number of thunderstorms and/or cyclones.

To focus attention on processes rather than broadly-based experimental trials, other workers, notably Rose et al. (1983a, b), have developed models for the erosion, transport and deposition of particles. These models are likely to be more rewarding in the future. Both the empirical and process types of models will depend on the measurement of soil loss from plots and small catchments, although varying emphases will be given to the extent and nature of the measurements taken. Process models will need a more detailed picture of overland and rill flows than the more empirical type of model.

Since the early 1930s, many plot studies for comparative erosion and land-use have been

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carried out in both temperate and tropical regions. One of the problems in these types of study arises from the ease with which plots can be established and measurements made of total rainfall and soil loss (and maybe rainfall intensity and overland flow — runoff). These data are then extrapolated for application to much larger areas of land, possibly in different contexts. Finally, political decisions are based on what were really empirical experiments.

At this stage in our knowledge, it is doubtful if the soil loss from a plot of length, say, 20 m can be predicted from an adjacent plot of length 10 m, all other factors being equal.

This paper highlights two topics that relate to overland flows and measurement of soil loss from plots, namely:

(1) the definition of rainfall events, need for short- and long-duration rainfall data, and ways of stochastically simulating rainfall data; and
(2) the definition of sheet flows and roles of surface roughness and raindrop impact on the hydraulics of overland flow, together with a discussion on the role of length of plot.

The work described in this paper has been carried out largely at the University of Melbourne. There is no good reason why the results so far obtained and the techniques developed and used in Australia should not be applicable to tropical regions.

Rainfall Data

Rainfall data are essential to any study of catchment or land behaviour. Long sequences of daily or weekly rainfall data are necessary for the study of landslides. A rainfall-runoff model with soil moisture built into it can be used to obtain soil moisture variation with time. For this type of study, daily or weekly rainfall data are sufficient. For sites where there are no long-term records, rainfall data can be synthesised using stochastic models.

For soil erosion studies, data on short-duration rainfall such as those that last for 1 h, 30 min or less, are necessary. Short-interval rainfall data can be used either in empirical equations like USLE or as an input to process models such as the full model of Rose et al. (1983a, b) to estimate soil erosion. The data necessary for this are rainfall intensity information in the form of depth-duration-frequency curves or sequential rainfall data (historical or synthetic).

In addition, one can obtain the extreme rainfall levels (high or low) from the rainfall data by fitting in an appropriate frequency distribution. Such values can be used to assess the changes in a catchment caused by extremes in rainfall levels. This procedure allows the effects of extreme events to be evaluated.

Stochastic Simulation of Rainfall Data Rainfall data synthesis can be performed for any time interval. Procedures developed at the University of Melbourne relate to annual, monthly, daily, hourly, and 6-min intervals (Srikanthan and McMahon, 1982, 1983a,b, 1984). These procedures have been successfully applied to 15 rainfall locations throughout Australia, including both dry and wet tropics. To illustrate the methodology, the generation of hourly rainfall data is briefly described below.

Hourly rainfall data are generated in two stages. In the first stage, a daily transition probability matrix (TPM) is used to determine the state of a day. The number of states will vary with station and month. Up to seven states have been used for Australian rainfalls and the state limits are given in Table 1. Table 2 shows the number of states for three stations used in the daily TPM. State 1 is dry and the other states are wet. Details of these three stations are given in Table 3.

If the day is wet, rainfall depths are generated at hourly intervals in the second stage. Wet days are divided into two types — those of low and of high rainfall — as follows:

type 1 — rainfall depth < RD
type 2 — rainfall depth ≧ RD
where RD is the dividing rainfall depth.

Using a two-state second-order Markov chain with an hourly TPM corresponding to each type of wet day, hourly data are generated.

To preserve the monthly variations, each month is considered separately. Because of this and the need to use two types of wet days, it is necessary to group the hours in a day into six

Table 1. State limits used in daily TPM.

State	Condition	Upper state limit (*mm*)
1	Dry	0
2		1
3		3
4	Wet	7
5		15
6		31
7		∞

Table 2. Mean monthly rainfall and number of states used in daily TPM.

	J	F	M	A	M	J	J	A	S	O	N	D
Mackay												
Mean monthly rainfall (*mm*)	324	314	298	151	94	68	41	26	40	46	72	164
States	6	6	6	6	6	6	6	6	6	6	6	6
Darwin												
Mean monthly rainfall (*mm*)	398	325	265	97	15	3	1	2	13	54	123	244
States	7	7	7	7	3	2	2	2	3	7	7	7
Broome												
Mean monthly rainfall (*mm*)	154	158	96	26	35	22	6	2	2	2	9	39
States	7	7	7	3	3	3	3	3	3	3	3	5

Table 3. Details of Australian rainfall stations used in this study

	Latitude	Longitude	Mean annual rainfall (*mm*)	Coeff. of variation	Topography
Mackay	21 06	149 06	1645	0.33	Hilly hinterland
Darwin	12 24	130 48	1540	0.17	Flat
Broome	17 57	122 17	549	0.43	Flat

units, each of a 4-h duration. Markov chain probabilities are assumed to vary from one unit to another, but to remain constant within a 4-h unit. The occurrence of rainfall in any hour is determined from this dependent second-order Markov chain and then the hourly TPM used to generate rainfall depths.

The number of states used for the hourly TPM is given in Table 4. State 1 is dry and the other states are wet. The upper state limits (in mm) adopted are 0, 0.4, 1.0, 2.0, 4.0, 8.0, ∞. If the number of states is k, it should be noted that in Table 4 the upper state limit for the k^{th} state will be infinity. A linear distribution is used for intermediate states (Srikanthan and McMahon 1983b) and the Box-Cox transformation (Box and Cox 1964) for the largest state; thus

$$y = (x - \Delta)\,\lambda$$

in which Δ is the lower state limit of the largest state, λ is a parameter to be estimated, and y is the normalised variate corresponding to a value x in the largest state.

The major steps involved in the hourly generation process are given below:

Step 1: Generate a uniformly distributed random number $U_d(0, 1)$. Using the daily TPM corresponding to the month, determine whether the day is dry or wet. If it is dry, repeat this procedure; otherwise go on to Step 2.

Step 2: Based on U_d and using daily TPM, determine the type of wet day (1 or 2). Generate another uniformly distributed random number $U_m(0, 1)$. Using hourly Markov chain probabilities corresponding to the time unit of the day, type of wet day and month, determine whether the hour is dry or wet. If it is dry, repeat this procedure. If it is wet, generate the hourly rainfall depth using the corresponding hourly TPM. When 24 values of hourly rainfall are generated, go on to Step 1.

Steps 1 and 2 are repeated until the required length of data is generated.

To illustrate the ability of this model to generate rainfall data, results of its application to Darwin's rainfall data are presented in Tables 5–7 and Fig. 1 and 2.

Eight replicates of hourly rainfall data, each of

Table 4. Number of states in hourly TPM.

Station	RD mm	Type	J	F	M	A	M	J	J	A	S	O	N	D
Mackay	15	1	5	5	5	5	5	4	4	4	3	4	5	5
		2	7	7	7	7	6	6	3	3	2	3	3	7
Darwin	31	1	7	7	7	6	6	2	2	2	3	6	6	6
		2	7	7	7	6	—*	—	—	—	—	3	5	7
Broome	15	1	5	5	5	5	5	4	3	2	2	2	3	4
		2	7	7	6	-	-	-	-	-	-	-	-	4

* Because of the small number of wet days, months marked by a dash are not subdivided into two types.

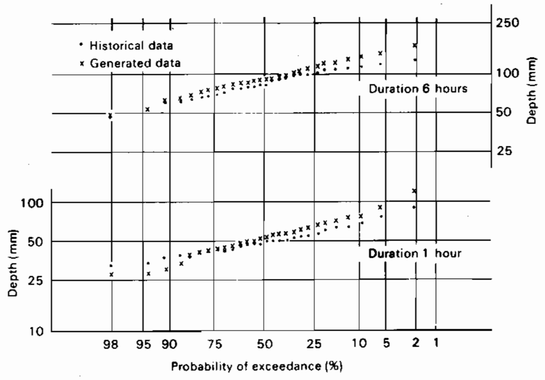

Fig. 1. Comparison of 1 and 6 hour depth probability of exceedance curves based on historical and generated data for Darwin.

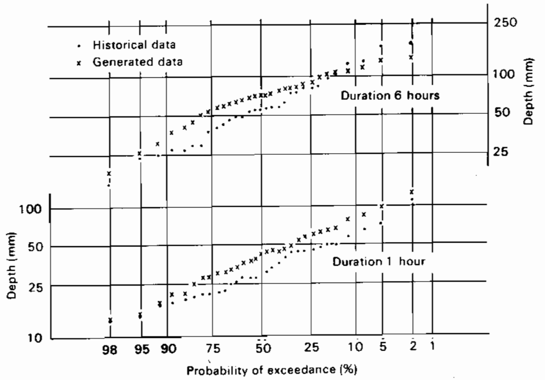

Fig. 2. Comparison of 1 and 6 hour depth probability of exceedance curves based on historical and generated data for Broome.

a length equal to the historical record (28 years), were generated. For a given parameter, the historical value was compared with the average of the values obtained from the replicates. Many parameters were compared. Some of these are presented in the tables and figures.

Rainfall data corresponding to other intervals can be generated by similar procedures, the details of which can be found elsewhere.

Usually some data are required at the location in question so that model parameters can be determined. Our studies indicate that a minimum of about 10 years of data is necessary to model rainfall lasting up to 1 day, but this will depend on the relevant coefficient of variation. For locations where no data are available, analysis can be carried out at similar locations which have rainfall data. The results can be transposed to the location in question. Transposition can be carried out with the aid of isohyetal maps.

Table 5. Comparison of hourly historical and generated parameters for Darwin.

Parameter		Jan	Apr	July	Oct
Maximum hourly rainfall (*mm*)	H[a]	67	47	8	88
	G	72[b]	66	11	71
Longest wet spell (*hours*)	H	26	30	3	9
	G	25	17	3	8
Correlation between rainfall depth and duration	H	0.68	0.73	-	0.55
	G	0.59	0.71	-	0.55
Correlation between hourly rainfall depths	H	0.33	0.30	-	0.09
	G	0.26	0.27	-	0.04
Mean hourly rainfall (*tenths of mm*)	H	36	32	20	51
	G	33	33	18	44
Standard deviation hourly rainfall (*tenths of mm*)	H	65	54	24	96
	G	61	59	28	82

[a] H = historical; G = generated.
[b] Generated results are based on eight replicates.

Table 6. Comparison of daily historical and generated parameters for Darwin based on hourly data.

Parameter		Jan	Apr	July	Oct
Mean daily rainfall (*mm*)	H[a]	21	12	1.5	11
	G	19[b]	16	4.2	13
Standard deviation daily rainfall (*mm*)	H	27	19	1.7	16
	G	27	24	5.3	21
Number of wet days	H	19	6.1	0.3	5.2
	G	19	7.4	0.3	5.5
Maximum daily rainfall (*mm*)	H	174	168	5	91
	G	202	184	17	163

[a] H = historical; G = generated.
[b] Generated results are based on eight replicates.

Table 7. Comparison of monthly and annual historical and generated parameters for Darwin based on hourly data.

Parameter		Jan	Apr	July	Oct	Annual
Monthly and annual mean rainfall (*mm*)	H[a]	406	74	0.4	57	1455
	G	348[b]	99	1.4	70	1537
Standard deviation of monthly and annual rainfall (*mm*)	H	152	70	1	48	242
	G	154	85	4	58	313
Maximum as ratio of mean	H	5.7	2.2	0.05	1.8	1.3
	G	5.3	2.6	0.15	2.1	1.6
Minimum as ratio of mean	H	0.57	0.00	0.00	0.00	0.72
	G	0.85	0.05	0.00	0.02	0.64

[a] H = historical; G = generated.
[b] Generated results are based on eight replicates.

Overland Flow

If water flowing over a surface is slow and shallow, the layers of water tend to glide over each other and little or no mixing occurs, and the flow is laminar. When water flows faster and deeper, the laminar motion becomes unstable and intermixing of layers occurs, resulting in turbulent flow. With this type of flow, shear stress is proportionately higher near the surface or bed than in the case of laminar flow.

The velocity profile also becomes relatively uniform with depth. For most surfaces, there is a wide band of velocities where the flow properties are either "transitional," between laminar and fully turbulent, or "mixed" where the flow is unstable and changes from one form to the other. This nature of the flow sheet is usually determined by referring to the empirical Reynolds Number, defined as:

$$R_e = \frac{vh}{\upsilon} \text{ or } q/\upsilon$$

where

v = the mean velocity in a profile
h = the mean depth of a profile
q = the discharge per unit width of the flow sheet
υ = kinematic viscosity

For example, Emmett (1970) quoted limits for turbulent flow as > 6000 and laminar flow as < 1500, with the transitional and mixed phases in between. The above limits are not universally accepted. D'Souza and Morgan (1976) in their work emphasised the role of raindrop impact in creating turbulence in the flow sheet. Savat (1980) suggested that there could be a laminar superlayer gliding over a turbulent sub-layer in the vicinity of bottom grains. These issues were reviewed by Wrigley and Turner (1984).

At the University of Melbourne, studies of overland flow have been carried out in relation to uniform discharge (i.e. no contribution throughout the length of a plot, as from rainfall), simulated rainfalls, bare surfaces, bare soils and vegetative covers. The results have been mainly discussed in Langford and Turner (1972, 1973), Turner et al. (1978) and Turner and Chanmeesri (1984).

For earlier studies in this series, a plot 23 m long and 4.6 m wide was prepared on ground having a slope of about 1.5%. The plot was exposed to both natural rainfall and simulated rainfall supplied by a machine built according to the general design of Meyer and McCune (1958). Unfortunately, with such a simulation system, the supply of rain is intermittent in order to provide droplets of the desired intensity, size, and energy. For a good size of nozzles, rainfall intensity is varied by changing the application/dwell periods.

Since overland flow over an uneven, fallow-type surface was the objective of the study, a typical fallow condition for wheatlands was prepared and then "fixed" with a thin coating of bitumen. A layer of coarse-fine sand was then dusted into the bitumen.

The Darcy-Weisbach f to define surface roughness is given. For example, in Chow (1959):

$$f = 8g\, S_0\, h^3/q^2 \qquad \text{... (2)}$$

where

g = acceleration due to gravity
S_0 = the energy slope (approximately the same as the soil surface),

Combining equations (1) and (2) with the discharge-depth equation,

$$q = \alpha\, h^m \qquad \text{... (3)}$$

gives

$$f = \frac{8g\, S_0}{\alpha\ 3/m}\ \vartheta\,(3/m\text{-}2)\ R_e\,(3/m\text{-}2) \qquad \text{... (4)}$$

and

$$K = \frac{8g\, S_0}{\alpha\, \vartheta} \text{ for laminar flow} \qquad \text{... (5)}$$

since $f\, R_e = K$ defines laminar flow and $m = 3$.

In order to apply these equations to such a surface, the depth term h should include a value for the average depression storage. From ponding and also photogrammetric tests, this value was about 1.1 mm for this plot.

Tests were carried out for both uniform flow (inflow supplied only across the top end of the plot) and under various rainfall intensities, the measured runoff values being about the same for comparative tests. Results for the uniform flow are given in Fig. 3, which shows a marked transition between laminar and turbulent behaviour as the flow increased, at about $200 < R_e < 300$. These values are much lower than those reviewed earlier and reflect the uneven nature of this "fixed," but real, surface.

Kinematic wave theory was used to describe the flow when it was generated by rainfall. The rising limb of the hydrograph of runoff can be described by:

$$q = \alpha\, (p.t)^m \qquad \text{... (6)}$$

where

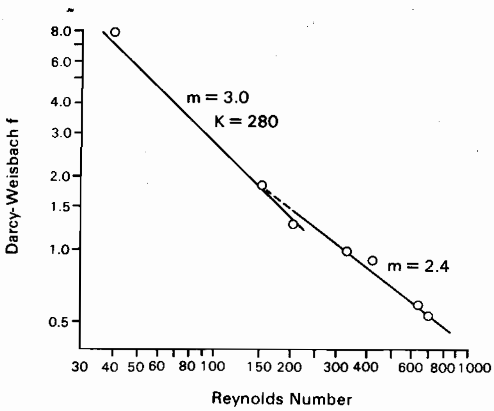

Fig. 3. Reynolds Number versus Darcy-Weisbach f — uniform flow tests.

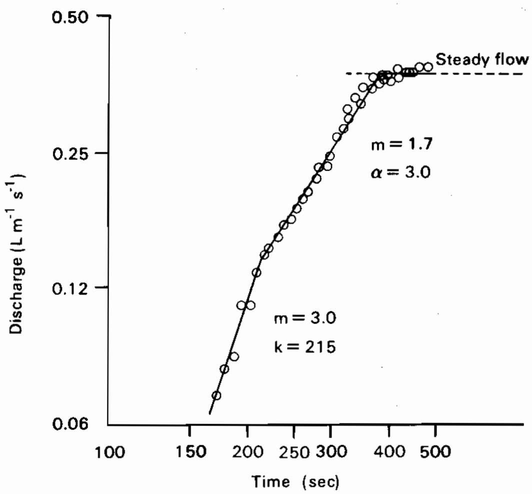

Fig. 4. Rising stage of hydrograph of plot runoff from simulated rainfall of 63 mm hr^{-1}.

p = excess rainfall intensity
t = time after depression storage is satisfied

In effect, $p.t. = h$, as before, and the constant α and exponent m are as given in equation (3).

Figure 4 shows a hydrograph for a test with a rainfall rate of 63 mm hr^{-1}. Values of m and α can be obtained from this graph, using the above equations and allowing for depression storage. For the two segments of the hydrograph, m values of 3.0 and 1.7 were obtained, indicating that the overland flow sheet was initially laminar at the measuring point and became turbulent after about 250 sec.

The relationship between f values and R_e for flows from three rainfall intensities and uniform flows were also obtained (Fig. 5).

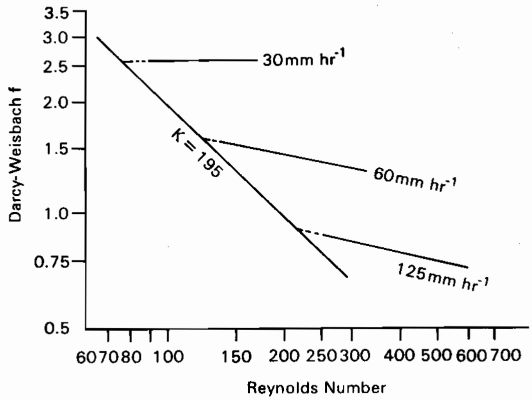

Fig. 5. Reynolds Number and Darcy-Weisbach f for three intensities of simulated rain.

Results indicate that: (a) the laminar flows, whether caused by rainfall or not, had similar slopes and hence similar behaviour — i.e. the raindrops did not affect the flow sheet under these laminar-type conditions; and (b) increasing the rainfall intensity reduced the f values and delayed the onset of turbulence.

These tests show that for the high values of relative roughness met in this study (flow depths less than 10 mm), with low values of R_e, increasing the rainfall intensity reduced the hydraulic roughness f. An explanation for this result, based on interference patterns of spherical bodies in moving fluids, is given in the papers referred to. There is little doubt that for higher values of R_e, turbulence patterns developed by rainfalls could change from those shown.

Another aspect of rainfall intensity and overland flow results from the change of momentum of the drops as they enter the flow sheet. In this study, as the drops entered the flowsheet the pressure within the sheet increased only about 4% and was regarded as negligible. A more serious test would be that posed in storms such as tropical cyclones, where high intensity rains occur along with high velocity winds. The effects for field plots would be difficult to determine in such cases.

Uniform Shallow Flows Over Soil and Through Vegetative Covers Some other work at the University of Melbourne has been in relation to the definition of hydraulic behaviour under conditions of high flow resistance. Most studies reported have used the well-known equation of Manning for determining flow in rivers and channels. Results of studies carried out indicate

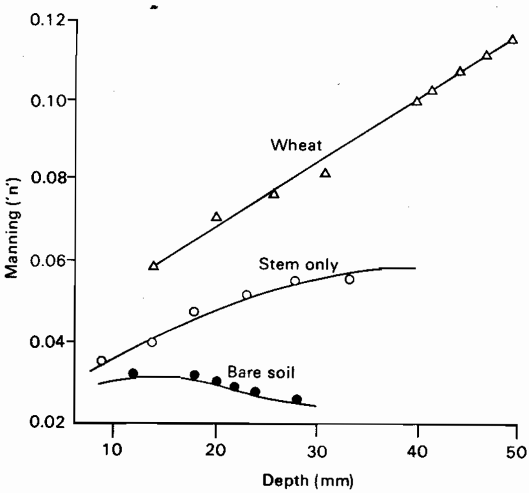

Fig. 6. Manning's n versus depth in shallow flow through vegetation.

that the sheet is not fully turbulent, as implied by Manning, and that mixed flow dominates under these conditions. A practical solution is to use equation (3). Some appropriate values of the constant and exponent are given in the relevant papers for a range of crop, pasture and bare soils. The problems associated with the use of Manning's equation are shown in Fig. 6 and the usefulness of the discharge-depth equation shown in Fig. 7.

A typical result for shallow flow through a grass cover is:

$$q = 1.0 \times 10^{-3} h^{1.9} S^{0.4}$$

where

q = discharge in L $m^{-1}\,s^{-1}$
h = depth in mm
S = longitudinal slope in meter per meter

Implications for the Design of Runoff Plots

It is likely that little erosion occurs under conditions of purely laminar flow. In general, water moving near the top edge of a runoff plot will be in a laminar-transition phase and at some stage in its progress downslope it will become fully turbulent, with much greater scope for erosion. This transition could be associated with the process of entrainment, as referred to by Rose (1985), i.e. entrainment is initiated by turbulent flow.

The problem is posed qualitatively in Fig. 8 for two plots that each have different land use but otherwise similar conditions. Plot (a) has a bare, smooth soil and the change from laminar to turbulent flow takes place near the top end. Plot (b) has ploughed-in stubble and the change to

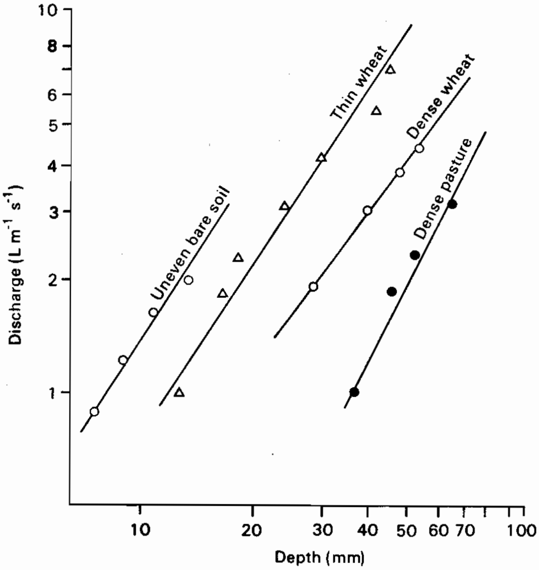

Fig. 7. Discharge versus depth for shallow flow through various vegetative covers.

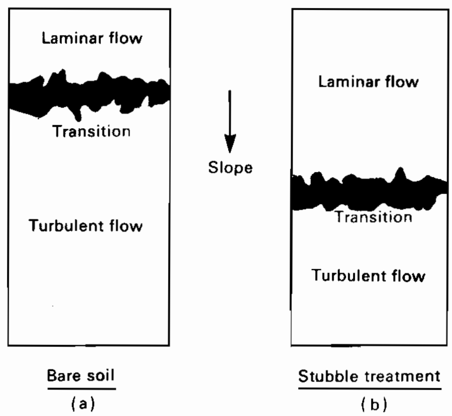

Fig. 8. Possible flow regimes for sheet runoff from erosion plots.

turbulent flow takes place near the lower end of the plot. In comparing the overall test results for erosion, it should be borne in mind that the generating areas are different and that this difference is difficult to define.

In the absence of better knowledge about overland flow in runoff plots, it is advisable to use as long a length as possible. By this means, error will be minimised. However, the problem posed highlights the need for more studies of overland flow under natural surfaces.

Conclusion

The importance of rainfall data and the proper understanding of overland flow in soil erosion studies has been illustrated. Recommendations for future research are listed below:

- Intensity-duration-frequency curves are necessary to define erosivity and estimate soil erosion;
- The use of process models to estimate soil erosion requires sequential rainfall data. Stochastic simulation enables one to obtain long sequences of rainfall data from short records. These sequences are also useful in studies relating to landslides;
- Procedures should be developed and validated to obtain rainfall data at locations with no records;
- A set of discharge-depth relationships should be derived for a range of slopes and soil surfaces. When available, these should be used instead of Manning's equation; and
- Experiments should be carried out to examine the effect of plot length on soil erosion. Recent developments in process models should be invaluable for such studies.

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Progress in Research on Soil Erosion Processes and a Basis for Soil Conservation Practices

C.W. Rose*

THE OBJECTIVES of research in all areas of enquiry appear to develop with time. Early objectives are commonly concerned with mapping how the variable of interest (here, the rate or amount of soil erosion per unit area) depends on the range of factors involved. The methodology developed in the USA which led to the Universal Soil Loss Equation has been very successful in meeting this objective (at least for the mid-west of the USA). It appears that this very success may have delayed development of the incentive to move on to further objectives in the way that is common in most areas of research.

The time is right for a review of the objectives and methodology employed in soil conservation research. It is a purpose of this paper to contribute to that review, and to illustrate recent relevant developments in modelling soil erosion and deposition processes. Such a model is then applied to examine some of the major practical issues in conservation planning and management.

Soil Erosion Models

Scientific investigation of agriculturally related questions has often begun by a series of experiments in which each of the variables thought to be important is varied or allowed to vary over a significant range. Then statistical models can be used to investigate the body of results obtained, perhaps leading to a concise summary of the major apparent relationships. This sequence of experimental investigation followed by statistical analysis has occurred in the study of soil erosion carried out by the United States Soil Conservation Service. The statistical summary of data from field plot experiments in the mid-west of the USA is called the Universal Soil Loss Equation or USLE (Wischmeier and Smith, 1978).

In the USLE experiments the variables of land slope and plot length could be chosen (within limits), and a range of soil types in the geographic region investigated. The experimental program was quite massive since on each soil type the effect on soil loss of different degrees of cover was investigated, as was a suite of land management practices of interest at the time. The significance of environmental and hydrologic characteristics was recognised. It was hoped that rainfall characteristics would be adequate to cover both these aspects — a hope not fully fulfilled with the advantages of hindsight.

The USLE equation summarises this vast body of regionally derived data, thereby greatly increasing the usefulness of the data base from which it is derived. However, a summary of a data base, whether or not expressed as an equation as in this case, is just that. It is therefore increasingly recognised that the USLE is not universal in its application, partly because it reproduces correlations between rainfall and runoff specific to the data set, and because of limitations in the range of soil types. Any model (such as the USLE) which is based solely on collected data is a captive of the extent of that data set.

There are more important and general considerations, however. There is now widening recognition that the objective and role of the USLE is not to test a representation of the process involved in soil erosion. Processes are universal, even though the relative and absolute significance of different processes will vary, as will the par-

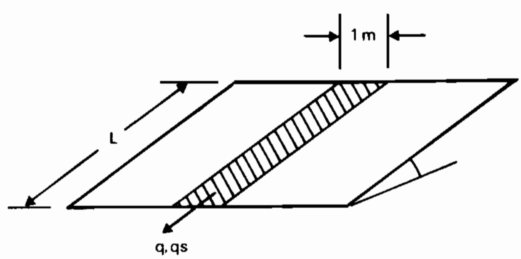

Fig. 1 Illustrating flow of water (q) and sediment (q_s) from unit strip width on a planar land element of length L.

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ticular outcome in any specific set of circumstances. Hence there is a desire to develop models to represent the processes at work in soil erosion and deposition. An attempt to meet such objectives is outlined in following sections.

There are quite practical reasons for moving from the purely experimental/statistical approach of the USLE to a process-type approach. First, the USLE deals with the "average annual soil loss," a useful concept in the climatic context in which it was developed. For much of the tropical, semi-tropical and semi-arid world, a far more satisfactory concept is that of a probability distribution of soil loss. The second reason favouring a move to a process-oriented type of objective is that, in many countries, limitations in research resources make it impractical to derive such a probability distribution by direct measurement in all contexts of relevance, despite the historic ability of the USA to do this for agriculturally important soils in its mid-western regions.

Basic Approach

Let us restrict consideration to sediment flow on a sloping planar land surface (Fig. 1). Rates of flow per unit strip width of plane are called fluxes (Fig. 1). Thus the sediment flux (q_S) is the mass of sediment flowing per unit time across unit width perpendicular to the direction of the flux. (This sediment mass is expressed on an oven-dry basis.) Likewise, the volumetric water flux (q) is the rate of volume flow of water per unit strip width (in $m^3\ m^{-1}\ s^{-1}$ or $m^2\ s^{-1}$).

The sediment concentration (c) is expressed as oven-dry mass of sediment per unit volume of suspension. (All symbols are listed in the Appendix.) By definition of these terms, it follows that:

$$q_s = q\,c \qquad (\text{kg m}^{-1}\ \text{s}^{-1}) \qquad (1)$$

Soil loss from the land area during an erosion event is given by summing the time-variable flux q_s at exit from that area (Fig. 1).

From Eqn (1) it follows that a description of soil erosion processes involves description of the hydrology of surface flow (because of term q), and a description of the various erosion processes which add to sediment concentration c, and deposition, the only process which tends to decrease c. The magnitude of c arises from the balance between these opposing processes. All these quantities can vary with time and distance down the plane. However, since average values per unit plane width are used (Fig. 1), there is no separate explicit representation of rill as distinct from inter-rill processes, even though rilling is a common though not universal feature of land surfaces losing soil.

An approximate analytic model relating runoff to rainfall will be outlined in this section, postponing consideration of sediment until the following section.

The Approximate Analytic Model for Overland Flow of Rose et al. (1983a)

The excess rainfall (R) for a land element is defined by:

$$R = P - I \qquad (\text{m s}^{-1}) \qquad (2)$$

where P is the rainfall rate and I the infiltration rate into the land surface (all being functions of time, t).

Let Q = runoff per unit area. Then from Fig. 1:

$$Q = q/L \qquad (\text{m s}^{-1}) \qquad (3)$$

where q is the water flux at x = L, where x is distance from the top of plane, where it is assumed that $q = 0$ (Fig. 1).

If the land element is small (say $1\,m^2$), then the excess rainfall is quickly shed by overland flow from the element, in which case:

$$Q = R \qquad (\text{m s}^{-1}) \qquad (4)$$

However, if plane length (L) is substantial, and R is time variant (as it normally is), then changes in Q will lag behind those in R, because of the time taken for water to gather on the soil surface and flow down the plane. Thus, in general, $R \leq Q$. Using the approximate analytic theory of Rose et al. (1983a), it may be shown that:

$$R \doteq Q + K_p\,(dQ/dt) \quad (\text{m s}^{-1}) \qquad (5)$$

where the term K_p depends analytically on the length, slope and roughness of the plane, on Q, and on how close to laminar or turbulent the overland flow may be. The roles of roughness and turbulence on such flow are discussed in Turner et al. (1985).

For an assumed simple time variation in P, the approximate form of the corresponding relationship between R and Q given by Eqn (5) is illustrated in Fig. 2. Note that it follows from Eqn (5) that R = Q when Q is a maximum (i.e. $dQ/dt = 0$). For a rougher surface the time at which Q is a maximum would be later, thus extending and flattening the Q(t) relation in Fig. 2.

In general, R cannot be measured. However, Q is readily measured, and Eqn (5) allows R to be calculated from Q. With R known, I can be calculated using Eqn (2) since P is also easily measured. Hence, infiltration characteristics can be derived allowing I to be estimated from measurements of P (Rose et al. 1984).

The flux $q(x)$ at any x is given from this theory by:

$$q(x) = Rx \qquad (m^3\ m^{-1}\ s^{-1}) \qquad (6)$$

Erosion Deposition Process Model

A full description of this model is given by Rose et al. (1983b, c, d). The model relates the sediment flux at any position on a plane, and at any time in a runoff event, to factors on which this sediment flux depends. The theory also has the capacity, suitably extended, to predict the rate and size-distribution characteristics of sediment accumulation elsewhere in the landscape, given information on relevant surface geometry.

EROSION AND DEPOSITION PROCESSES

When situations of landslides or gullies are excluded, the following three processes affect sediment concentration:

(1) *Rainfall detachment*, in which raindrops splash sediment from the soil surface into the water of overland flow;

(2) *Sediment deposition*, which is the result of sediment settling out under the action of gravity;

(3) *Entrainment of sediment*, the process whereby overland flow picks up sediment from the soil surface, whether in rills, between rills, or in sheet flow without rills. The onset of entrainment may correspond to the transition from dominantly laminar to turbulent flow as discussed by Turner et al. (1985).

Processes (1) and (3) increase sediment concentration; process (2) decreases it, as is illustrated in the Forrester-style flow-chart of erosion and deposition processes which occur simultaneously at different rates (Fig. 3). The resultant sediment concentration (c, Fig. 3) is determined by the relative magnitude of these different rates, denoted e, d and r respectively.

The rates of these three processes can be expressed quantitatively as follows:

1. *Rate of Rainfall Detachment*, t, is given by:

$$e = a\ C_e\ P^2 \qquad (kg\ m^{-2}\ s^{-1}) \qquad (7)$$

where 'a' is a measure of the detachability of soil by rainfall of rate P, and C_e is the fraction of the soil surface exposed to raindrops.

2. *Rate of Sediment Deposition, d.* This rate depends on sediment size distribution, being very rapid for sand and very slow for clay-sized aggregates or particles. Thus d must be calculated as the sum

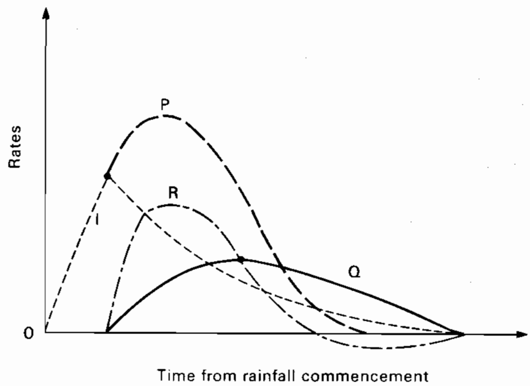

Fig. 2 Simplified time-variation in rainfall rate (P), infiltration rate (I), rate of runoff per unit area of plane (Q), and the approximate analytic solution for the excess rainfall rate (R).

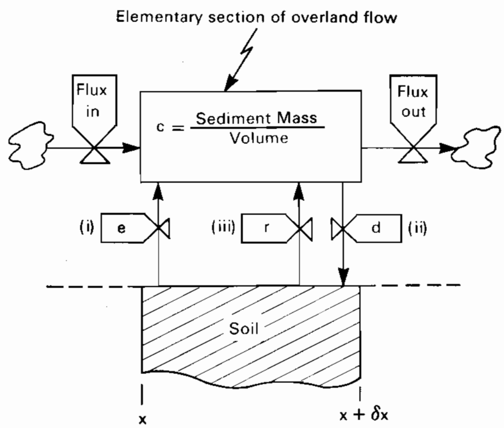

Fig. 3 Flow chart (after the style of Forrester) representing the three erosion/deposition processes explicitly represented in the model of Rose et al. (1983b, c). Rates of flow of sediment are represented by valve symbols. Symbol e represents rate of rainfall detachment, d rate of deposition, and r rate of entrainment of sediment. Fluxes in and out are sediment fluxes entering and leaving the element of flow by overland flow. The elementary section of overland flow is shown artificially elevated above the soil to clarify representation of the sediment fluxes between them. Arrows show the direction of fluxes, and the cloud symbols represent sources and sinks outside the volume of interest.

of d_i calculated separately for each sediment size class i with settling velocity v_i. It follows simply that:

$$d_i = v_i\, c_i \qquad (kg\ m^{-2}\ s^{-1}) \qquad (8)$$

where c_i is sediment concentration in size class i.

3. *Rate of Sediment Entrainment, r.* The entrainment process in overland flow has similarities to bedload transport in streams. It has been shown

that the rate of bedload transport can be related to the excess of "stream power" (Ω), above a threshold value (Ω_0) required to entrain sediment (Bagnold, 1977). "Stream power" is the rate of working of shear stress between sediment and the stream bed. An analogous approach can be developed for r using mass conservation of sediment in the elementary section of overland flow shown in Fig. 3. The fraction of the soil surface, C_r, unprotected from entrainment by overland flow, is introduced and plays a similar role to C_e in e (Eqn (7)).

The stream power can be calculated from the bed slope and the water flux q. Whilst the stream power is the maximum rate at which energy is available per unit area, not all this energy is employed in entraining and transporting sediment.

The stream power can be calculated from the bed slope and the water flux q. Whilst the stream power is the maximum rate at which energy is available per unit area, not all this energy is employed in entraining and transporting sediment. The efficiency of this conversion is denoted η, where $0 \leq \eta \leq 1$.

MODEL OF EROSION/DEPOSITION ON A PLANE

The model follows from considerations of mass conservation of sediment in the elementary section of overland flow (Fig. 3), combined with the marriage of the theories of sediment concentration and hydrology reviewed above.

From Fig. 3, mass conservation of sediment of size range class i and concentration c_i requires that:

$$\frac{\partial}{\partial x}(q\,c_i) + \frac{\partial}{\partial t}(\mathrm{D}\,c_i) = e_i - d_i + r_i \quad (\mathrm{kg\ m^{-2}\ s^{-1}}) \qquad (9)$$

where D is the depth of overland flow at any time and position on the plane, and the algebraic sum of rates on the right-hand side of Eqn (9) represents the net erosion rate.

With Eqn (7) (suitably modified) for e_i, Eqn (8) for d_i, and a more complex expression for r_i, it may be shown that to a good approximation the partial differential equation (9) can be reduced to an ordinary (first order) differential equation, which is readily solved. A result of this analysis, analytically summing c_i over all size range classes, yields the sediment concentration ($c(\mathrm{L},t)$) at the bottom of the plane of length L as a function of time t. The result is:

$$c(\mathrm{L},t) = (a\mathrm{C_e P^2/QI}) \sum_{i=1}^{\mathrm{I}} (1/\gamma_i) + \rho g \mathrm{SKC}_r(1 - x_*/\mathrm{L})\ (\mathrm{kg\ m^{-3}}),\ (\mathrm{L} > x_*) \qquad (10)$$

The first term on the right-hand side of Eqn (10) is due to rainfall detachment, and the second term to entrainment, both being net values over deposition. The previously undefined terms in this equation are:

- I = number of sediment size class ranges;
- γ_i = $1 + v_i/\mathrm{Q}$;
- ρ = density of water (1000 kg m^{-3});
- g = acceleration due to gravity (9.8 m s^{-2});
- S = land slope (sine of inclination angle);
- K = 0.276η where η is the efficiency of net sediment entrainment and transport;
- C_r = the fraction of soil surface unprotected from entrainment by overland flow; and
- x_* = the distance downslope from the top of the plane beyond which entrainment of sediment commences.

The variable distance x_* is related to Ω_0 (Rose et al. 1983c) by:

$$x_* = \Omega_0/(\rho g \mathrm{SQ}) \qquad (\mathrm{m}) \qquad (11)$$

and thus varies with time, as do Q, γ_i, and P.

SOIL LOSS FROM A PLANE

From Eqns (1) and (3), then at distance downslope x = L:

$$q_s(\mathrm{L},t) = c(\mathrm{L},t)\mathrm{QL} \qquad (\mathrm{kg\ m^{-1}\ s^{-1}}) \qquad (12)$$

The accumulated mass of sediment (M_s) from a plane of width W is thus given by:

$$\mathrm{M}_s = \mathrm{WL} \int_0^{t_\mathrm{R}} c(\mathrm{L},t)\,\mathrm{Q}\,dt \qquad (\mathrm{kg}) \qquad (13)$$

where t_R is the duration of the runoff event.

In applying Eqn (13), since sediment concentration $c(\mathrm{L},t)$ and runoff rate Q vary with time, the integral can be adequately approximated by summing over calculations of c repeated at some time interval Δt, which could be the time-averaging period used in some rainfall-rate measuring equipment. Summation may thus require the order of 10–20 calculations, which can be carried out by a hand calculator, though use of a microcomputer or programmable calculator has obvious advantages.

Methods for obtaining the data required to calculate $c(\mathrm{L},t)$ using Eqn (10) are given in Rose et al. (1983b).

If there is a decrease in slope of the plane, then net deposition will occur. The same theory as is given above can be modified to give an expression for the amount, location, and aggregate size distribution of such deposition.

Deposition which occurs in the channel formed by contour banks accumulates with erosion events, and can lead to the bank having to be reformed. Deposition of eroded soil in waterways, dams and other public utilities has a range of economic and social consequences.

Simplified Erosion Process Model

The general model given in the previous section can be much simplified and yet still provide a good approximation in many situations.

Let us write Eqn (10) as:

$$c(L,t) = A + B \quad (14)$$

where

A = net contribution to sediment concentration of rainfall detachment over deposition; and
B = net contribution of entrainment over deposition.

The larger the runoff event (i.e. the larger Q in Eqn (10)) and the better aggregated the soil (i.e. the larger the sedimentary units and so the larger γ_i in Eqn (10)), the smaller is term A compared to B in Eqn (14). Neglect of term A yields the simplified theory in which sediment concentration is given by:

$$c(L, t) = \rho g S K C_r (1 - x_*/L), \qquad (L > x_*)$$
$$= 2700\, S\eta\, C_r(1 - x_*/L) \qquad (\mathrm{kg\,m^{-3}}) \quad (15)$$

since $K = 0.276\eta$.

Concentration $c(L,t)$ in Eqn (15) is a function of time, t, only because x_* is time-dependent (through Q, Eqn (11)). Let x_* in Eqn (15) be replaced by a time-averaged mean value, $\bar{x}_*$, defined from Eqn (11):

$$\bar{x}_* = \Omega_0/(\rho g S \bar{Q}) \quad (16)$$

where $\bar{Q}$ = mean rate of runoff per unit plane area $\int_0^{t_R} Q\, dt/t_R$.

The only other term in Eqn (15) which might be time variable is η, the entrainment efficiency. Assuming this term represents its average value for the erosion event, then sediment concentration can be taken to be constant for a particular erosion event and given by:

$$c \equiv c(L) = 2700\, S\eta\, C_r(1 - \bar{x}_x/L) \quad (\mathrm{kg\,m^{-3}}) \quad (17)$$

The terms η and $\bar{x}_*$ (or Ω_0, Eqn (16)) in Eqn (17) are not generally known, and currently require experimental determination. If length L > 30 m very approximately, then $\bar{x}_*/L$ can be small compared to unity, in which case the theory simplifies further to:

$$c = 2700\, S\eta\, C_r \qquad (L > 30\,\mathrm{m}) \quad (\mathrm{kg\,m^{-3}}) \quad (18)$$

Under rainfall of constant rate there is experimental support for the constancy of sediment concentration indicated by Eqns (17) or (18) (e.g. Loch and Donnollan (1983), Kilinc and Richardson (1973).

Substituting for c from Eqn (18) into Eqn (13) gives:

$$\eta = \frac{M_s/WL}{2700\, S C_r \int_0^{t_R} Q\, dt} \quad (19)$$

where M_s/WL is the total soil loss per unit area, and $\int_0^{t_R} Q\, dt$ the total runoff per unit area during the erosion event. If both these total losses are measured, and L > 30 m, then η can be calculated directly from Eqn (19), provided C_r is also known.

If L < 30 m approximately, then $\bar{x}_*/L$ may not be negligible compared to unity, and the form of simplified theory given in Eqn (17) should be used. More fundamental than a requirement based on slope length L, would be a requirement that stream power Ω should be greater than approximately 0.5 W m^{-2} before Eqn (18) be used, where:

$$\Omega = \rho g S Q L \qquad (\mathrm{W\,m^{-2}}) \quad (20)$$

(Justification for the figure of 0.5 W m^{-2} will come later — see Fig. 4.)

Substituting for $\bar{x}_*$ from Eqn (20), it follows that:

$$c = 2700\, S\, C_r\, \eta\, (1 - \Omega_0/\bar{\Omega}) \quad (21)$$
$$= 2700\, S\, C_r\, \lambda \qquad (\mathrm{kg\,m^{-3}}) \quad (22)$$

where

$\lambda = \eta\,(1 - \Omega_0/\bar{\Omega})$, and $\bar{\Omega}$ a time average value of Ω. (23)

In general, neither η nor Ω_0 is known. Hence, only λ (Eqn (23)) can be calculated from runoff and sediment loss unless $\Omega_0/\bar{\Omega}$ is negligibly small compared to unity. One way in which Ω_0 can be determined is illustrated in the next section.

Plot Length L and Soil Loss

The length (L) of a cultivated plot is a most important variable that can be controlled in management. As the scale of mechanical cultivation and harvesting equipment has been increasing in many countries, so the length of cultivated slopes between effective barriers to overland flow (such as contour banks) has also been extending. However, especially where cultivation is not mechanised, or where the scale of mechanical equipment used is modest, then the length of slope between effective barriers to overland flow can be reduced to much smaller values. This is a common practice in Third World countries, and it can lead to substantial reductions in soil loss per unit land area.

The purpose of this section is to illustrate the application of Eqn (21), and to relate soil loss per unit area to L and other relevant variables.

Equation (21) will be illustrated using the data of Dangler et al. (1976), who measured runoff and sediment loss using a rainfall simulator on field soils on the islands of Hawaii and Oahu. Two plot lengths were investigated (10.7 and 22.9 m). Simulated rainfall rate was 2.5 in h^{-1} (63.5 mm h^{-1}), and experiments lasted approximately 120 min. The first experiment, at prevailing field water content, was sometimes followed some 18 hours later by a second 'wet run.'

The data analysed were for a Molokai series soil, a silty clay loam (Typic Torrox, or Oxisol). Prior to these experiments, sites had been used in continuous sugar-cane production.

The result of analysis of these data using Eqn (22) is presented in Fig. 4. Despite scatter apparently due to site-to-site variability, a tendency for λ to increase with Ω is evident. Such a relationship would be expected from the form of Eqn (23), shown fitted as a curve to the data, assuming η is a constant equal to 0.35, and Ω_0 to be 0.5 W m^{-2}. This value (0.05 W m^{-2}) corresponds to the value of Ω at which Loch and Donnollan (1983) found rilling to commence, accompanied by a quite rapid rise in sediment concentration; though it should be noted that their experiments were on quite different soil types to those investigated by Dangler et al. (1976). This raises the interesting possibility, requiring further investigation, that Ω_0 may not vary greatly with soil type for soils in a recently cultivated condition.

It follows from Eqn (23) that λ tends towards the (assumed) constant value of η as Ω increases. Whether or not for any particular bare soil η does have an approximately constant value independent of Ω requires further investigation.

Assuming κ is approximately constant, then despite the scatter in Fig. 4, the great importance of the factor $(1 - \Omega_0/\Omega)$ in interpreting soil loss from small- to modest-scale experiments is clear.

Let us now use the values of Ω and η obtained by fitting Eqn (23) to the data in Fig. 4 to examine how soil loss would be expected to vary with plot length for a particular suite of variables. From

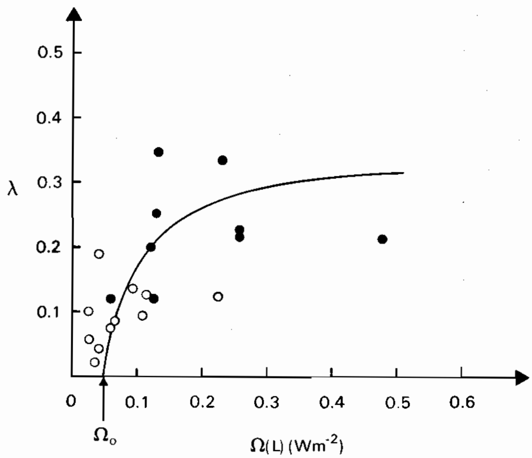

Fig. 4 The relationship between the term λ defined in Eqn (23) and stream power Ω (L) at exit from the field experimental plots of Dangler et al. (1976). Plots of varied slope but same soil type, exposed to simulated rainfall. Plot lengths either 10.7 m (35ft, 0) or 22.9 m (75ft, 0).

Fig. 1 and Eqn (1), the soil loss per unit land area ($m_a = M_s/WL$) is given by $\Sigma q_s/L$. Hence, from Eqns (13) and (17) and writing $\int_0^{t_R} Q\,dt$ as $\bar{Q}t$, the

$$m_a = 2700\ S\ C_r\ \eta\ (1 - \Omega_0/\bar{\Omega})\ \bar{Q}t_R \quad (\text{kg m}^{-2})\ (24)$$

Eqn (24) was used to calculate m_a for a range of values of L, the value of $\bar{x}_*$ corresponding to that length at which $\Omega = \Omega_0$. In addition to $\eta = 0.35$ and $\Omega_0 = 0.05$ W m^{-2} from Fig. 4, a slope S = 0.1 (or 10%) and $C_r = 1$ (bare soil) was assumed. The illustrative values adopted for the hydrological variables in this calculation correspond to a severe rainstorm: $\bar{Q} = 50$ mm $h^{-1} = 1.39 \times 10^{-5}$ m s^{-1}, and $t_R = 30$ min = 1800 s.

The values of m_a calculated from Eqn (24) using these values are shown plotted against L in Fig. 5. Notable is the quite rapid rise in m_a with increase in L beyond $\bar{x}$. (Note that in Fig. 5 m_a is expressed in tonne ha^{-1}, where 1 kg m^{-2} = 10 tonne ha^{-1}.) The indication in Fig. 5 that m_a is zero for $L < \bar{x}_*$ follows from the approximate form of the theory used, which neglects the first term on the right-hand side of Eqn (10). In practice, this term will ensure some loss, even for $L < \bar{x}_*$. The magnitude of this soil loss for lengths less than that at which entrainment becomes effective requires investigation, but is likely to be typically less than 1 tonne ha^{-1} for a single rainstorm.

For the particular runoff event and soil characteristics assumed in calculating Fig. 5, the simple theory predicts that soil loss per unit area would be less than 10 tonne ha^{-1} only if L < 6.5 m approximately. It is the determination of values of η and Ω_0, as is illustrated in Fig. 4, which permits this type of inference to be made. This type of inference can be used, in conjunction with information on tolerable rates of soil loss, to make recommendations on upper safe limits to plot lengths, and how such limits will depend on land slope for example.

From Fig. 5 it can be seen that the employment of contour banks or similar structures will reduce soil loss per unit area by reducing the effective value of L. In the context of agriculture employing large machinery, L may be of the order of 50 m (depending on slope). From Fig. 5 it can be seen that in this particular example the predicted value of m_a is not highly sensitive to values of L in this range. It is not until L is reduced to 7 m that m_a is reduced to approximately half its value at 40 m.

The highest value of η found so far is about 0.7 or 0.8 for cultivated vertisols (Pellusterts and Chromusterts), silt loams (mesic, Typic Fragiudalfs), and loess. Accumulation of the dependence of η (and Ω_0) on soil type is required, in the hope that some useful predictive generalisations can be reached. Further research is also needed on the effect of tillage, tillage type, and time from tillage on η and Ω_0. The effect of degree of rilling on soil loss also requires more investigation and a better understanding of the processes involved.

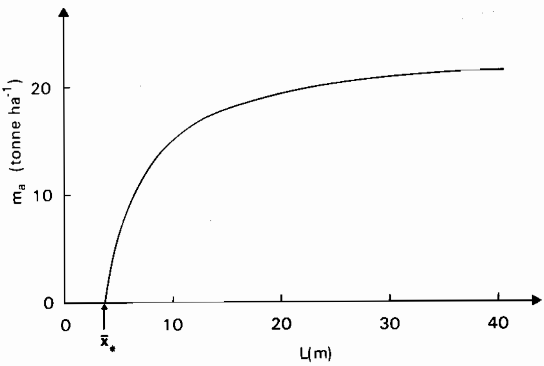

Fig. 5 Relationship between soil loss per unit area (m_a) and length of plot (L) for a particular suite of relevant variables given in the text.

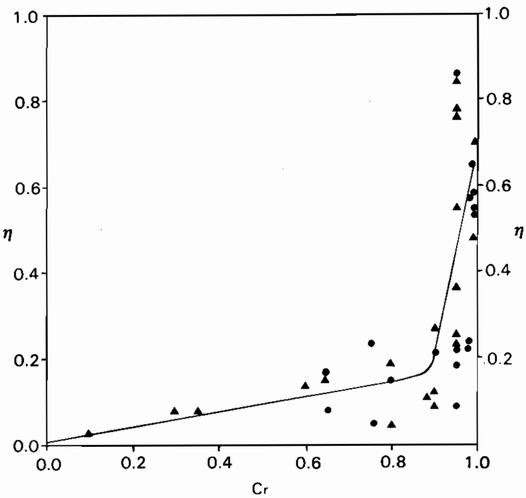

Fig. 6 Efficiency of entrainment (η) vs. soil surface exposure fraction for two vertisols in the Darling Downs, Queensland (△) refers to a Pellustert, 0 to a Chromustert. (Source: Rose et al. 1983b)

Effect of Contact Cover and Slope

In addition to slope length (considered in section 6), land slope (S) and the fraction (C_r) of soil surface not protected by cover in direct contact with it, are important factors affecting soil loss. This section considers the trade-off between S and C_r which exists in practice at the farm level if the objective of limiting soil loss to some tolerable rate is to be achieved. The tolerable rate of soil loss is often called a 'T-value'. If a T-value represents a soil loss rate which will not lead to soil deterioration and/or production loss in the long term, it is bound to be quite variable, depending for example on soil depth and all the factors affecting rate of soil formation. Perhaps partly because of the experimental difficulty in determining T-values, there is still argument about the utility of the concept. However, the concept will be used below to illustrate the trade-off between the maximum slope which should be cultivated and the level of cover ($1 - C_r$) which can be maintained, if soil loss rate is to be restricted to the T-value. It should be noted that only protective material (such as stubble mulch) in contact with the soil surface and protecting it from entrainment is considered as contributing to ($1 - C_r$).

To simplify discussion in this section, it will be assumed that L > 30 m approximately, so that the Eqn (18) can be used for c, instead of the more general Eqn (17).

The trade-off will be illustrated using the approximate relationship between η and C_r found by Rose et al. (1983b) and illustrated in Fig. 6. Data comes from two different soil types (see legend to Fig. 6), and there are other causes of scatter. A relationship similar to the type illustrated in Fig. 6 appears to hold generally.

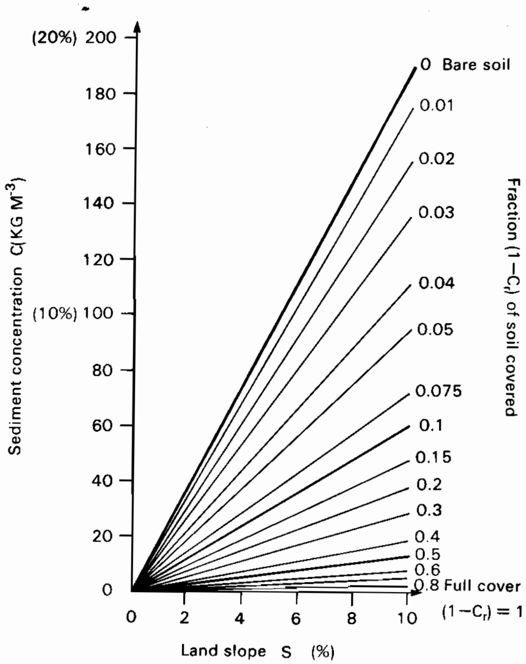

Fig. 7 Graph allowing sediment concentration c (km m^{-3}) to be read off as a function of land slope (S expressed in %), and fractional soil cover $(1 - C_r)$. Based on the relation shown in Fig. 6 and approximate Eqn (18) in the text. Percentages for sediment concentration are approximate only.

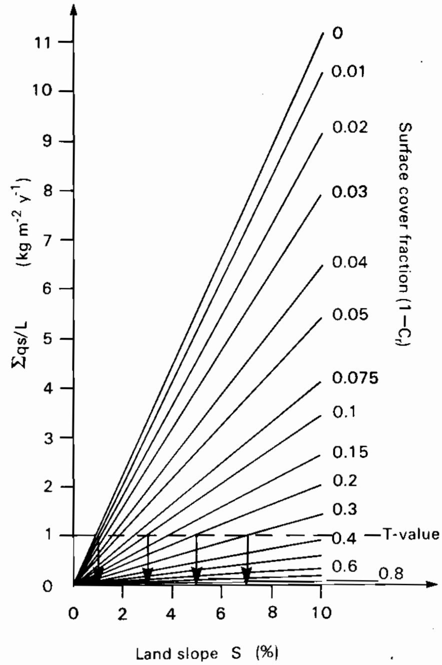

Fig. 8 Illustrating how, for a particular location in the Darling Downs, Queensland, the average annual soil loss ($\Sigma\ q_s$) varies with land slope S and the fraction $(1 - C_r)$ of the soil covered by mulch or other effective contact cover. The T-value is a tolerance level corresponding to 1 kg m^{-2} y^{-1} (or 10 tonne ha^{-1} y^{-1}). Arrows indicate various trade-offs between maximum cultivated slope and cover, if soil loss is not to exceed the tolerance value.

Accepting a relationship between η and C_r such as that shown in Fig. 6, then specifying C_r determines η for the particular soil (or soils) and cover type from which the data have been obtained. Thus, in this context, it follows from Eqn (18) that concentration c can be considered to depend on only two variables: S and C_r. The dependence of c on S is direct, but on C_r is more complex because of considerable non-linearity in the relation between η and C_r (Fig. 6). The relationship between c and these two factors for the situation from which Fig. 6 was derived is shown in Fig. 7.

It follows from Fig. 7 or Eqn (18) with Fig. 6 that for given slope and contact cover, c is constant. Thus, from Eqn (1), the total soil loss per unit width of plane, obtained by summing over the duration of the runoff event, is given by:

$$\int_0^{t_R} q_s\, dt = c \int_0^{t_R} q\, dt \qquad (\text{kg m}^{-1}) \qquad (25)$$

where $\int_0^{t_R} q\, dt$ is the total runoff for the event.

For any given site, in general there is an effect of fractional cover $(1 - C_r)$ not only on c but also on total runoff. Hence, total soil loss is influenced by cover through its influence both on term c and total runoff in Eqn (25).

For a specific site at Greenmount in the Darling Downs, Queensland, Freebairn (personal communication) has obtained the following relationship for average annual relationships between runoff and cover:

$$\int_0^{t_R} q\, dt = 59 - 29(1 - C_r) \qquad (\text{mm y}^{-1}) \qquad (26)$$

Substituting the suite of values shown in Fig. 7 for the surface cover fraction $(1 - C_r)$ in Eqn (26) yields a corresponding suite of values for average annual runoff. Multiplying these by the corresponding value of c (Eqn (25)) gives the average annual soil loss per unit area ($\Sigma\, q_s/L$) expected at this site for any combination of fractional cover $(1 - C_r)$ and land slope S. Such calculations have been restricted to S = 0.1 (or 10%), since somewhere beyond this limit, landslides or other mechanisms involving gravity which are ignored in this theory may become important. The results of these calculations are given in Fig. 8.

Figure 8 also shows a T-value of 1 kg m^{-2} y^{-1} (or 10 tonne ha^{-1} y^{-1}) which has been used in some situations. Simply accepting this T-value as a desirable upper limit to $\Sigma\, q_s$, then the trade-off can be explored between the maximum land slope which should be cultivated and the fractional cover which can be maintained. Consulting the intersection of the adopted T-value line with the relations in Fig. 8, it can be seen that $\Sigma\, q_s/L$ not greater than 1 kg m^{-2} y^{-1} can be achieved for the following illustrative combination of values:

Fractional cover $(1 - C_r)$	0	0.1	0.2	0.3
Maximum slope S for cultivation (%):	1	3	5	7

The fractional cover which can be maintained depends on many crop and management factors. In mechanised agriculture, cover can be maintained at much higher values if suitable stubble-handling machinery is available which minimises the burial of stubble from the previous crop. Less intensively mechanised agriculture would appear to be generally compatible with maintaining a high surface cover by stubble; and in suitable climates, intercropping, for example with a shrub legume, can also be an effective soil-conserving practice.

Conclusions

Practical reasons are given for the desirability of moving on from erosion models which summarise a large base of experimental data to models which aim to represent the processes at work in erosion and deposition.

A process model of soil erosion and deposition processes is outlined which has received a significant amount and range of testing with field data. This full model can be substantially simplified and yet maintain adequate accuracy in most situations of significant erosion. Predictive use of this simplified model requires experimental determination of the physically defined parameters η and Ω_0.

The simplified model, especially, appears suitable for use in interpreting experimentation on soil erosion and in the design and assessment of soil-conserving management systems for agriculture at any location, of any cultural type, and for any scale and type of cultivation. The challenge remains to expand experience on values of η and Ω_0, and to seek alternative ways in which these parameters can be measured or predicted.

Acknowledgments

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Appendix Table 1. List of major symbols

Greek/Roman symbol	*Description*
a	Detachability of the soil by rainfall
A, B	Terms defined in Eqn (14)
c	Sediment concentration
c(L)	Sediment concentration at x = L
C_r	
C_e	Fraction of soil surface unprotected from raindrop detachment
C_r	Fraction of soil surface unprotected from entrainment by overland flow
d	Sediment deposition rate
D	Analytic approximation to depth of overland flow
e	Rainfall detachment rate
g	Acceleration due to gravity
i as a subscript	Refers to a particular sediment size range
I	Number of sediment size ranges, infiltration rate
K	0.276 η
K_p	A coefficient depending on the length, slope and roughness of a plane
L	Length of plane
m_a	Equal to M_s/WL
M_s	Accumulated mass of sediment leaving the plane of width W as x = L
P	Rainfall rate
q	Volumetric water flux per unit width of plane
q(L)	Value of q at x = L, the bottom of the plane
q_s	Sediment flux per unit width of plane
Σq_s	Average annual soil loss per unit area
q_s(L)	Value of q_s at x = L
Q	Runoff rate per unit plane area
$\bar{Q}$	Time mean value of Q
r	Sediment entrainment rate
R	Excess rainfall rate
S	Slope of the plane (the sine of the angle of land surface inclination)
t	Time
t_R	Duration of runoff event
v_i	Settling velocity of sedimentary particles of size range i
W	Width of plane
x	Distance downslope from the top of the plane
x_*	Value of x beyond which $r > 0$
$\bar{x}_*$	Time average value of x_*
γ_i	$(1 + v_i/Q)$
η	Efficiency of net entrainment by overland flow $(0 \leq \eta \leq 1)$
λ	A paramenter = $\eta\,(1 - \Omega_0/\Omega)$ (Eqn (23))
ρ	Density of water
Ω	Stream power
Ω_0	Threshold value of Ω

Assessment of Some Soil Erosion Prediction Models for Application to the Philippines

Romeo C. Bruce*

THE erosivity of the soil, raindrop impact, and runoff all play a part in the degree of erosion likely to take place (Foster and Meyer 1975). The extent of erosion can be predicted by mathematical expression of the relationship of soil loss by measuring rainfall and runoff erosivity and of a soil's susceptibility to erosion. Erosion is a function of climate, soil, topography and land use (Bruce 1980), and is greatest where rainfall is intense and high, typical of the Philippines. Some soils are naturally more erodible than others. Steeper and longer slopes are also more erodible. Land use has by far the greatest impact on soil erosion, so disturbance and/or removal of cover by land-use must receive primary emphasis in evaluating erosion problems and selecting erosion control practices.

When the vegetative cover is removed, the rate of loss of soil material, at least initially, increases rapidly. This principle is well known and hardly needs elaboration.

If we are to focus our attention on any individual watershed, large or small, and a question is asked as to the rate of soil erosion, a quantitative answer is not easily obtained. The possible error in the calculation of sediment yield from any given watershed is considerable. Significant variations have been observed in sediment production from two adjacent watersheds which appear to be generally similar. Even more difficult is making a quantitative evaluation of the change in the rate of soil erosion when the natural vegetation is disturbed. Our lack of ability to answer what seems to be so simple a question is due to many reasons.

Measuring Erosion Rate

Sheet erosion cannot be accurately measured by observing directly the gradual lowering of the ground elevation as a function of time. The process is slow in terms of the human life-span. On a microscale, soil erosion is offset by deposition.

To determine the amount of erosion in terms of loss of a certain portion of soil profile which was supposed to have originally existed is crude, and hardly satisfies the desire for an objective, quantitative measure.

It is possible to measure the rate of landscape degradation by gully erosion through computation of the volume of the stream network. But these data do not exist in the Philippines. Such estimates are plagued by the importance of local depostion of eroded material in fans near the mouth of the gully. In addition, there is no assurance that at least some of the gullies did not exist prior to the start of the peiod under consideration.

Theoretically, it is possible to estimate the rate of soil removal from a watershed on the basis of sediment load of the main stream draining the area. However, present techniques measure only the suspended portion of the load, and only if the material is not coarser than sand particles. The portion of the load moving along or close to the river bed is not measured because of the absence of proper techniques and equipment. The load of gravelly streams cannot be accurately measured in the channel at all. The part of the load moving along or close to the bed constitutes about one-third of the total debris in many streams. Data on sediment load are virtually absent in many important stream channels in the country.

Sediment yield from watersheds is an indirect indication of erosion. However, one should also consider that sediments are often deposited within a watershed. Sediment yield may therefore be more a result of transport capacity of overland flow and stream channels than of sediments resulting from erosion (Foster and Meyer 1975). In addition, stream channels can delay the transport of sediments so that present sediment yield may actually indicate erosion that occurred several years earlier (Trimble 1975). Therefore, an equa-

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tion that estimates erosion at the field site is preferred as a practical tool for quantifying soil erosion.

The rate of sediment deposition in a reservoir provides the best measurement of total load and therefore of the average soil loss. Although some suspended sediment does not settle in the reservoir but passes over the spillway or through the gates, this spill can be estimated. But the number of reservoirs in the country is not adequate to describe the diversity of watersheds in the river basins in the Philippines. Moreover, sedimentation study of reservoirs does not furnish information on the relative amounts of debris from various parts of the basins upstream. The constituents dissolved in the runoff water may be a significant part of the total load. Measurements of reservoir sediments do not include the dissolved fraction.

Measurements of rates of soil loss from experimental plots and watershed are almost non-existent in the Philippines. And if available, it is very difficult to extrapolate from these measurements on small areas to large river basins. Experimental plots and watersheds represent only a small fraction of the many possible combinations of soil type, slope and vegetative cover.

Land Use Effects

Experimental data from a limited number of studies conducted by the Bureau of Soils and U.P. Los Baños indicate that changes in land use have a greater effect on sediment yield than on total surface runoff or runoff intensity (Palis 1977). However, these data do not permit quantitative generalisations about the effect of human activity on land degradation due to soil erosion. Cultivation and grazing have, without question, increased sediment yield. But the amount is variable and highly dependent on local conditions. The survey made by the National Environmental Protection Council (NEPC) on crops grown on slopes greater than 3% in Cebu, Batangas and La Union only evaluated the tenanted farms in terms of susceptibility to soil erosion. The results obtained in the study can be considered nothing better than general approximations. Data on the relations of land use types to sediment production of streams are not available in more than 90% of the total number of cultivated watersheds in the Philippines. Attempts to generalise relations of human activities to sediment contribution can do more than indicate the complexity of the problem. The validity of estimating the change in sediment yield resulting from a change in land use depends on the relative magnitude of the anticipated consequences of, and the error inherent in, describing the original condition of the watershed.

Use of the land can have a marked effect on sediment production. Since measurements of initial conditions of the watersheds are not available it is extremely difficult to evaluate this effect. We have no data on which to base our goals in soil erosion control. The greatest floods during the rainy season are the most effective in eroding the soil and we can easily see this by the muddy condition of our streams. Our goal, therefore, is to make this water as clear as possible during the rainy season.

The need is to look at our watersheds feeding the river basins, the watersheds upstream in particular. But because of financial and time constraints we can only make approximations of the rate of soil erosion.

USLE Equation

The soil erosion scientist is responsible for generation, collection, and evaluation of data for the development of technology to predict and control soil erosion. Much scientific soil erosion knowledge has been generated by USA erosion scientists and their efforts resulted in the development of a soil loss equation popularly known as the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978).

The USLE is widely used to estimate erosion. It is an empirical equation that is based on an extensive data set of more than 10 000 plot years of data from natural rainfall and rainfall simulators (Foster 1979). It is simple to use and applicable in the determination of soil erosion at the farm level or at the local planning level. For larger or global scale assessment, FAO developed a provisional methodology in 1979 which can be used in the soil erosion determination over large areas. Because of the severity of the problem and lack of research data, there is a lot of interest in transferring USA or other technology for prediction and control of soil erosion to the Philippines.

In selecting a particular model to estimate erosion, the intended purpose of the model should be identified. The expected use of soil erosion prediction in the Philippines is to identify erosion problems relative to some allowable limit, and to evaluate control practices for each site that will reduce erosion to a level below the allowable limit. The selected model is successful if it accurately identifies erosion problems and provides information leading to a wise selection of management practices. The soil erosion problems are quantitative but the selection of practices is qualitative. The error limits when applied to Philippine conditions must be compatible with the use of the model and available data. To demand a very precise equation for the country where basic data on soil, rainfall, and land use is lacking might hinder wise application of available technology. Improvements in predictive techniques must be made as knowledge grows and basic data become more available.

Limitations in USLE

FAO PROVISIONAL METHOD

The FAO erosion prediction equation appears as:

$$D = F(C, S, T, K)$$

where

D = soil degradation, i.e. soil erosion
C = climatic factors; rainfall in terms of yearly total
S = soil factor
K = constant, representing the standard conditions for natural vegetation, land use and management factor.

The equation involves multiplication of factors to obtain the result in terms of soil erosion. FAO set the soil erosion classes as:

Erosion class	Soil loss (t/ha/yr)
None to slight	<10
Moderate	10-50
High	50-200
Very high	>200

The climatic factor, C, refers to the amount of annual rainfall received by a particular area. The rainfall erosivity values are as follows:

		Imputed value
Slight	<50 mm/yr	0.5
Moderate	50-500	1.0
High	500-1000	2.0
Very high	>1000	3.0

The soil factor, S, or soil erodibility is determined by taking into account soil erodibility classes and soil textural classes on the basis of soil mapping units listed on 1:5 million scale FAO/UNESCO World Soil Map. A soil mapping unit has equivalent soil erodibility classes as:

Erodibility class	Description	Imputed value
I	Slight	0.5
II	Moderate	1.0
III	High	2.0

The ratings for the textural classes are as follows:

Class	Description	Imputed value
1	Coarse texture (<18% clay and >65% sand)	0.2
2	Medium texture (<35% clay and <65% sand) or (<18% clay and <82% sand)	0.3
3	Fine texture (>35% clay)	0.1

The derived values of soil erodibility and soil texture are multiplied to get the soil erodibility composite value.

Topographic factor, T, takes into account the dominant slope with categories as follows:

Slope range		Imputed value
0-8%	Level to nearly level	0.35
8-30%	Rolling to hilly	2.0-0.35
>30%	Steeply dissection to mountainous	8.0-11.0

Land use factors refer to land cover types (vegetation) and per cent ground cover. This is included with factor K in the equation.

The FAO erosion equation is discussed in detail in the FAO Bulletin of 1979. The model is based on scientific principles and empirical data. The mathematical relations used in the model are not exact representations of what is actually happening in nature, but mere approximations of the influence of the various environmental factors on soil erosion. The model is an approximate indication of the likely magnitude of degradation in terms of soil erosion.

The model can be applied in the Philippines to a limited extent because of the small scale of the World Soil Map by which soil erodibility class of each major soil type is based. For national, regional and provincial levels the model will suffice particularly if the goal is to stir up the minds of the people to become concerned with the problems of soil erosion.

If data on organic matter, permeability, structure and texture for soil types in the Philippines area are available, soil erodibility can be estimated from Wischmeier's nomograph (Wischmeier and Smith 1978) and used as the soil factor in the model. However, there is a question whether Wischmeier's nomograph can be applied to tropical soils since most data from which the nomograph was prepared have been on medium textured soils in the midwest United States.

Another major limitation on the use of the FAO erosion model is related to the erosivity of the rainfall. The erosivity rainfall factor in the model was based on annual precipitation without considering the intensity. With more information on rainfall intensity in many parts of the country the model could give an overall picture of rainfall erosivity based on annual data.

The constant factor, K, for natural vegetation, land use and management practices requires careful evaluation and application related to the types of crops grown and natural vegetation.

UNIVERSAL SOIL LOSS EQUATION

The USLE is as follows:

$$A = RKLSCP$$

where

- A is the average annual soil loss in t/acre
- R is the rainfall erosivity
- K is the soil erodibility
- L is the slope length
- S is slope steepness
- C is the cropping and management factor
- P is the supporting conservation practices such as terracing, strip cropping and contouring.

The limitations for USLE use in the USA have already been identified (Wischmeier 1976). These limitations may also apply to the Philippines.

Unit Plot Concept The unit plot concept, defined as a slope 22.1 m long with a uniform steepness of 9%, isolates complex interactions so that individual factors in the equation can be evaluated. The plot is maintained in continuous fallow with periodic cultivation up and down slope to break the crust and to control weeds. The 22.1 m slope length and 9% steepness represent the midpoint of much of the USLE data. Continuous fallow separates the soil effect from cover and management effects and perhaps the simplest management and least variable conditions possible (Wischmeier and Smith 1978). Another unit plot could be designed for the Philippines but it is important to recognise that all USLE variables except R are in terms of this definition. Except R, all the USLE variables are absolute. Consequently, a new R variable requires that a new K also be defined. A new slope steepness relationship must be relative to the 9% slope or K must be adjusted. This is true for other factors in the equation relative to the unit plot.

Land use type		Imputed value
Cropland	— areas with very seasonal rains	0.8
	— humid areas (tropical forest areas) without long dry season	0.4

Pasture, grassland, rangeland and woodland/forest. Imputed values depend on percentage ground cover as follows:

0–1	*1–20*	*20–40*	*40–60*	*60–80*	*80–100*
Pasture, grassland, and rangeland					
.45	.32	.20	.12	.07	.02
Woodland with appreciable undergrowth					
.45	.32	.16	.18	.01	000
Woodland without appreciable undergrowth					
.45	.32	.20	.10	.06	.01

Rainfall Erosivity, R The rainfall erosivity, R, includes the erosivity of both rainfall and runoff. Rainfall erosivity at soil surface depends on canopy and ground cover. Runoff erosivity depends on runoff volume and rate. Volume and rate of runoff depend on rainfall, infiltration, ground cover, surface roughness and runoff flow pattern, which are influenced by soil, cover-management and supporting conservation practices. The factor R reflects a basic climatic input.

The erosivity factor, R, was based on an empirical evaluation of several potential erosivity measures (Wischmeier 1972). One might question the applicability of extrapolating this empirical factor to the Philippines. However, the R factor contains the basic information required of an erosivity factor. Since unit rainfall energy as a function of intensity varies with location over the world (Hudson 1971), the USLE unit energy-intensity relationship now used in the USA may not be accurate for the Philippines. When drop size measurements show this to be the case, the unit energy intensity relationship can be modified to reflect local conditions. Developing erosion index maps by USLE procedure requires extensive data to compute for R values. These data are virtually absent in the Philippines. However, a few long-term and some short-term intensity records can be used to augment storm volume data.

Soil Erodibility, K Perhaps the most difficult USLE value to transfer is the soil erodibility factor, K. Most K values in the USA have been derived on midwestern, medium-textured soils. Experimental values are available for some Hawaiian soils (El-Swaify and Dangler 1977), Puerto Rico (Barnett et al. 1971) and Ivory Coast (Roose 1977). El-Swaify and Dangler reported that K estimates from the USLE nomograph were significantly in error for several Hawaiian soils while Roose found good estimates for nine Ivory Coast soils.

Early in the development of USLE, K values were selected by comparing properties of soils with those of benchmark soils having known K values. The same procedure can be followed for the Philippines if K values of some benchmark soils established by University of Hawaii-PCARRD Benchmark Soils Project are known. Unfortunately, such value is not available in any Philippine soils. Experimental values of K should be established in several major soil types of the Philippines using rainfall simulator and plots 20 m or longer. Long-term baseline plots (20 m or longer) should be established to obtain best estimates of K under natural rainfall. Many of these plots would also be needed for the development of a new erosivity factor. Soil scientists who are familiar with both Philippine soils and USA mainland soils should select K values if USA mainland values are adapted. This requires considerable judgement. Errors in selecting K are less than the range of effects of cover and management. Nevertheless, reasonably accurate estimates of soil erodibility are required. The intent in K is to define a relatively constant soil factor.

Length of Slope, L The slope length factor is given by,

$$L = \left(\frac{l}{l_1}\right)^m$$

where l = slope length of field site and l_1 = slope length of unit plot. Recommended values for m increase with steepness up to 5% and then become constant at 0.5% (Wischmeier and Smith 1978). The USDA Soil Conservation Service at Hawaii adopts the values of $m = 0.5$ if slope steepness is 5% or greater, 0.4 if slope is 4%, and 0.3 if slope is 3% or less. It was also noted that the effect of slope length and steepness are not independent of soil erodibility, cover or erosivity (Roose 1977; Lombardi 1979; Wischmeier 1972).

Steepness of Slope, S The USLE slope steepness should apply well to the Philippines for slopes up to 25%. Application to steeper slopes is an extrapolation. Obviously, research is needed to verify the relationship for steep slopes. The relationship of erosion to slope is influenced by row directions and types and amount of crop residues but research is needed to define the effects.

Cover-Management, C Cover-management factor has the greatest range in effect on erosion and generally can be most readily changed by the farmer to control erosion. Therefore, accurate evaluation of C should be given careful attention in transferring the USLE to the Philippines. This is complicated by the variable distribution of the rainfall-erosion potential during different periods of canopy provided by the crop during seedbed preparation and growth stages, and before and after harvesting.

Soil loss ratio for factor C is the ratio of soil loss from the given cover management condition to that from the unit plot. Soil loss ratio includes the effect of canopy and ground cover as well as effects from soil conditions. The influence of cover-management on infiltration and runoff and their effects on erosion is also described by soil loss ratio. Soil loss ratios for cover-management practice not previously evaluated can be estimated by comparing characteristics of the practice with those of practices having known soil loss ratios. This is done using factors described by Wischmeier (1973, 1975) for canopy (Type I), ground cover in contact with the soil (Type II), and within soil effect (Type III). Type I and II can be applied directly without adjustment. But Type III may require adjustment for tropical soils. A continuous tilled soil is much more erodible than a soil immediately after it is ploughed out of crop cover. This residual effect decreases with time after continuous tillage begins. Our soil scientists need to assess the extent and rate of this soil degradation considering the differences between Philippine climates and USA climates. This degradation is included in factor C because it is a direct effect of land use. Protected tropical soils have high infiltration rates (Greenland 1977). When the cover is removed, surface increases significantly. This should be accounted for in C since such increase is the effect of management.

Supporting Practices, P The supporting practices factor reflects the influence of practices like contouring, terracing, strip cropping and contour furrowing which augment the protection provided by crop rotation, canopy cover and residue mulches. Standard USLE values for P can be transferred to the Philippines except for vegetative strips that infiltrate large runoff from tilled areas upslope. The P values would be less for the Philippines than those for USA strip cropping. A well-constructed and well-maintained grass buffer strip can trap considerable sediment in runoff from upslope tilled areas. The trap sediment is a deposition process that the USLE cannot describe.

Soil Loss Tolerance

Soil loss tolerance is the maximum long-term average annual erosion rate that a particular soil can tolerate without excessive degradation of the soil for continued crop production. The concept of soil loss tolerance used in connection with equations like USLE is a valuable tool for identifying erosion problems and selecting appropriate erosion control practices.

The tolerable soil losses in the USA range from 5 to 11 mt/ha/yr (Wischmeier and Smith 1978). The USA soil loss tolerance should be carefully evaluated before adapting it for Philippine soils because factors like soil depth and loss of organic matter may be quite different in tropical climates. We need to set soil loss tolerance based on research. The concept of soil loss used in connection with equations like USLE is a valuable tool for identifying erosion problems and selecting appropriate erosion control practices.

Conclusion

Basic erosion prediction and control principles apply universally. With appropriate adaptations, the USLE or a similar simple and easily used soil erosion equation can be a useful planning tool in the Philippines. The influence of soil cover and the intensity of Philippine rainfall are major factors to consider in applying the USLE. Political, social and economic factors may limit the utilisation of conservation tillage and management for effective soil erosion control.

Erosion control practices that sufficiently reduce the amount of rainfall, the erosivity of rainfall and the susceptibility of the soil to erosion are most effective. Cover that protects the soil surface from direct impact of raindrops and slows runoff velocity is the best single factor for reducing erosion. Any practices that work well in other countries in controlling soil erosion might work well in the Philippines with appropriate modification.

Design procedures used for terraces, contours, buffer strips and others apply elsewhere. Although erosion control principles are applicable anywhere, they must be adapted to the local conditions. It would be unwise to adapt a wholesale transfer of other countries' soil erosion control practices to the Philippines. While the practices we observed in other places suggest ideas, imaginative soil scientists and technicians are needed to adapt the ideas to the Philippines. Many factors other than erosion consideration may decide the feasibility of a given practice.

PARAMETRIC MODEL

The two basic principles involved in using parametric models for assessing soil erosion and soil erosion susceptibility are:

(1) Soil erosion susceptibility is determined by climatic aggressivity, resistance of the land, and human action. This states that soil erosion susceptibility is influenced by climate (rainfall amount and intensity), soil characteristics (texture, depth, structure, etc.), topography (which includes steepness and length of slope) natural vegetation (forest, grassland), human activities such as land utilisation and soil management. The rate of soil erosion is determined by the way human action (land-use type) modifies the balance between climate aggressivity and resistance of the land.

(2) Soil erosion susceptibility determination is effective if all modifiable factors (land use and management, existing natural vegetation) are eliminated and assumed to be standard, and the risk evaluated that would be involved in certain alternative uses of the land.

SCALING-WEIGHTING

The scaling-weighting method operates by assigning weights according to the relative importance of the variable. Scales are formulated in determining a variable numerical value which is then multiplied by the relative weight assigned to that particular variable. An example of this method is shown.

Variable	*Weight (Wi)*
Slope	35% W1
Rainfall characteristics	15% W2
Soil characteristics	15% W3
Land Use	35% W4

Scores of variable (Pi):

Slope	
0–3% steepness	20
3–9% steepness	40
9–18% steepness	60
18–30% steepness	80
>30% steepness	100
Land Use	
Bare soil	100
Cropland	80
Residential pasture	60
Irrigated farmland	40
Plantation forest	20
Natural forest	10
Soil type (based on texture of surface soil)	
Mountain soils	100
Fine sands/sandy loams	80
Silt loams, sandy clay loams, silty clay loams	60
Clay loam, silty clays	40
Clay	20
Hydrosol	0

The scaling-weighting method is simple and easy to use since it employs simple arithmetic. The degree of soil erosion can be computed by the equation:

$$SE = W_i P_i$$

where

SE = degree of soil erosion

W_i = relative importance weight of concern i

P_i = the numerical value or score of parameter i.

This method, however, provides only an approximation of the degree of soil erosion and is not as accurate as USLE and the FAO methods. The method gives only the static values of soil erosion and does not provide the dynamic status of the rate of soil erosion.

REMOTE SENSING

For years remote sensing techniques have been used as one of many tools in characterising and mapping soils. Aerial photographs have become a standard tool in national soil surveys. The use of remote sensing techniques for soil erosion studies in the country is in terms of giving information on three of the four factors that influence soil erosion, namely, land use, slope and soil characteristics. The technique has reduced the amount of field work considerably.

The type of land use in any area is clearly visible on aerial photographs. Information on soil is normally taken from existing soil reports and maps or by interpreting the aerial photographs if soil information is not available.

Interpretation of soil from aerial photos begins with the identification of landforms having similar shapes and topographic positions that represent materials deposited by geomorphic processes. By interpreting the visible elements such as surface drainage pattern, characteristics of gully erosion, topography, vegetation, land use and micro-relief, soil surveyors will be able to make general statements about the soils, namely, texture, depth and parent materials. Although field verification is always necessary, the use of aerial photographs in soil study considerably reduces the amount of field work and manpower. One of the most important contributions of remote sensing in soil erosion study is in terms of assessing the forest cover in the country.

Landsat imagery has been providing land use data for the Philippines since 1976. This is utilised in evaluating vegetative cover in the country and used for national soil erosion susceptibility studies. One very important characteristic of an earth resources satellite is its 18-day repetitive coverage of the earth surface. With this we are able to monitor the change of vegetation of a particular place on macro scale level every 18 days.

The utilisation of remote sensing techniques for soil erosion studies in the Philippines is limited by high costs of acquiring aerial photographs, and also the age of some of the imagery.

CONVERGENCE AREA APPROACH

Soil erosion susceptibility is a land quality that results from the interaction of land use, soil slope and rainfall characteristics, whereby soil particles are detached by rainfall impact and runoff. In practice, it is necessary to arrive at an expression of soil erosion susceptibility by interpreting more easily observed and measured characteristics. The convergence area approach involves study of each of the four factors — land use, soil, slope, and rainfall, and determine their influence on the susceptibility of the land to erosion (Bruce 1984). The next step is to prepare single factor soil erosion susceptibility maps of common scale, namely: (1) due to land use effect; (2) due to soil effects; (3) due to slope effect; and (4) due to rainfall effect.

The final step is to prepare a land use/soil slope/rainfall/soil erosion susceptibility interaction map by superimposing the four maps and drawing the converging areas.

The convergence area approach developed by Bruce (1982) is limited by the accuracy of the basic data of land use, soil, slope and rainfall. The method considers only the total monthly amount of rainfall and the number of wet months (rainfall exceeding 200 mm/month). Rainfall erosivity is a function of intensity, duration, amount and rain drop characteristics. The approach provides an estimate of the proportion of the land area susceptible to soil erosion.

Soil erosion susceptibility studies of 15 provinces have been completed by the National Environmental Protection Council (NEPC) since 1982 (Bruce, 1980, 1982, 1983 and 1984). The factor which had overriding effect on the susceptibility of the soil to erosion was rainfall followed by slope in nine provinces and rainfall followed by land use in the remaining provinces.

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Mechanical Structures for Soil Erosion Control

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TODAY, soil erosion is nationally recognised as a serious threat to the Philippines (NEPC 1982). This is shown by the fact that most of the government agencies charged with the administration of the land are now engaged in supporting programs on soil conservation. Most of these programs stress soil erosion control through proper land use and management of crops and animals, such as proper planting schemes, cropping patterns, agroforestry and reforestation strategies, and grazing systems. There are very few mechanical protection structures in spite of the numerous gullies or streambanks cutting into the country. The constraints may be the high cost of establishing and maintaining these mechanical structures.

Although the vegetative or bionomic control measures are very efficient and productive, they are not completely appropriate for all types of erosion. In more advanced erosion where mass wasting is active, such as gully formation, channel bank or bed scouring, and slumping of slopes or road banks, mechanical structures are required to provide effective protection against elements causing erosion. Mechanical structures are generally necessary, especially in areas where vegetation cannot be immediately established. The principles of correct land use, and techniques of scientific farming, grazing, or logging may be applied later.

Types of Erosion Control

Soil erosion control is generally classified into (1) vegetative, (2) mechanical, and (3) biophysical, which is a combination of the two measures.

The vegetative or bionomic measure refers to the use of vegetation to provide the soil with protective cover to minimise or prevent acceleration of erosion.

Mechanical measures are ground works, which include terracing, contour furrowing or contour bunding, and structural measures, such as the construction of check dams, riprap, gabions or masonry to control erosion.

Structural measures are erected for the following purposes: (1) to divert runoff where it can be safely disposed; (2) to reduce velocity of runoff and prevent scouring of the land; and (3) to provide an effective barrier or sieve for moving soil and promote reclamation of eroded area for vegetation to grow.

Mechanical structures are generally used in places where vegetation cannot be immediately established, and in gullies, channels, or rivers and road banks that have to be stabilised and protected.

Gully Control

Gullies are formed by excessive surface runoff flowing with high velocity and force that is sufficient to detach and carry away soil particles. Gully and channel erosion frequently occur because of increased water flowing from denuded areas. The water can start from bare lands, livestock trails of overgrazed pasture, faulty drainage from roads, neglected rills and furrows in farm lands, logging trails and log landing, or clogged drainage canals.

In controlling gully erosion, the following considerations are important: (1) improvement of the catchment area of the gully to reduce and regulate the quantity of runoff; (2) stabilisation of the gully head to prevent the gully from further scouring the head; (3) safe conduct of water through the gully, if it is part of the natural drainage; (4) reclamation of the gully area if it is not a part of the natural drainage system.

IMPROVEMENT OF CATCHMENT AREA

Experience shows that complete gully control cannot be made without proper treatment of the drainage area, as well as the gully itself. No gully caused by poor watershed conditions can be controlled without first properly treating or protecting the area above it.

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If gully formation is caused by a denuded watershed with excessive runoff, the vegetative cover should be reestablished. Grasses, shrubs and trees increase infiltration and water-absorbing capacity of the soil. In critical conditions, surface runoff can be reduced by contour bunds or trenches which are small earth dams made from trenches along the contour, behind which surface runoff can be retained and gradually absorbed into the soil.

STABILISATION OF GULLY HEAD

Before control measures are attempted within the gully, runoff should be diverted above the head of the gully. The principle generally applies to all gullies, except those having a small drainage area with negligible runoff.

A diversion canal is a ditch-dike combination with the ditch on the upper side. The ditch can be 'V' or 'U' shape. The 'U' or flat-bottom ditch has better flow characteristics and carries water at low velocity.

Diversions are used to cut runoff away from gully heads, serve as spillways to lead water out from small earth dams, protect critically planted areas from washing, and flood irrigated dry sites.

The location of diversion canals should be in headwater areas, dealing with small quantities of runoff. Large flows of more than 500 l/sec should be avoided. The canal should be located on stable slopes above the overfall, far enough to prevent sloughing into the gully overfall. The diversion ditch is dug above the gully head at a distance of once or twice the depth of the gully.

Diversion ditches should be wide and shallow with a regulated grade to produce low runoff velocity. They should be large enough to carry all the water that will discharge from contributing drainage areas during periods of maximum runoff from a 5-10-year highest rainfall. The ditch should empty its flow on spreading areas which are or can be made resistant to erosion, like rock cropping out of the soil surface, sod or brush areas. Water spreaders of wire, rock, or brush, or combination of these materials may be prepared for this purpose.

GRADING GULLY HEAD

To check the gully from scouring backward, the gradient of the gully head is first reduced to 45°. The surface of the gully head is then stabilised by either sodding, brush cover, riprap interplanted with cuttings, pole structure or solid structures of riprap, gabion and concrete, depending upon their availability in the locality.

STABILISATION OF GULLIES

After treating and improving the watershed and stabilising the gully heads, the gully beds have to be treated to prevent further deepening and widening. This is primarily achieved by (1) earth plugs, (2) brush fills, or (3) check dams from available materials.

Earth plugs are a series of small earth fills placed across small or medium gullies. Spacing is determined by running a line from the water level of the earth dam upstream to the channel bottom where another plug should be placed. The earth fills are raised above the ground level, and short diversion ditches are sometimes used to lead overflow away from the ends of the fill to prevent erosion damage and to spread the water.

Brush fills are brush packed into small gullies not exceeding 1 m × 1 m in size starting at the very head. Shrubs, brush, and small trees need not be trimmed to permit compost placement. The gully should be lined first with small branches to protect the soil. The objective is to obliterate the gully with soil held by the brush. Live branches or limbs that may later grow are preferred.

Check dams are constructed in small or medium gullies if water cannot be kept out of the gullies by either infiltration in the soil or by diversions. Check dams can be temporary or permanent. If the volume of the runoff conveyed through the gullies is not greater than what can be controlled by well-established vegetation, a temporary structure for check dams may be used during vegetation establishment. Permanent structures should be resorted to only if the runoff volume cannot be controlled by vegetation. They should be used only when less expensive measures are impractical, but should still be supplemented by vegetation as much as possible.

Temporary Check Dams

Temporary structures do not require very good materials nor much precision in construction. The main purpose of temporary check dams is to hold soil and moisture at the bottom of the gullies until vegetation can be established. Low check dams are less likely to fail and after they silt up and rot away, vegetation can control the low overfalls much easier than in high dams.

Temporary check dams should not exceed 0.5 m high. The average effective height of 30 cm is more desirâble. Effective height is the vertical distance from the original gully bed to the spillway crest of the structure. This type of dam is more successful in gullies with small drainage areas. Location and spacing of check dams are determined at strategic places where plant growth can be protected and facilitated. This way, fewer dams can produce more effective results.

Check dams should be anchored well in the ground to prevent washout underneath or around ends of the structures. They should have sufficient spillway capacity to convey runoff at the maximum expected rate during the life of the structure. A spillway apron will be necessary to prevent undermining of the structure. It is desirable to have the notch length several times greater than the depth (Table 1).

There are several methods of check dam construction. The selection of a method primarily depends on the available material, size, and characteristics of the gully.

TYPES OF CHECK DAMS

Brushwood dams are temporary and are constructed in areas where stones are not available. They are best suited for gullies with small drainage areas and with soil conditions that permit the driving of posts. Several types of brushwood dams are in use depending upon the materials available.

The brushwood, sprouting or non-sprouting, is placed between two rows of pegs or posts driven into the soil 40 cm apart across the gully bed with the foundation dug well into the banks. The distance between rows of pegs or posts is about 1 m for a 5-m gully. The brushwood is packed firmly between the two rows of posts and tied by wire. Any type in use should provide a spillway at the centre lower than the ends to avoid damage by water. On the lower side of the dam, branchwood is placed lengthwise to serve as an apron to prevent scouring by overflow.

Log or pole dams are constructed of poles or logs. Two rows of vertical poles are driven into the bed of the gully extending to the sides above flood level and spaced at 60 cm to keep the horizontal poles in place. In a wide shallow stream, it is best to drive all the posts to more than 0.5 m above the ground, so that the top of the posts follows the surface of the stream bed. If the gully has steep sides, it is better to make a rectangular notch at the center, big enough to allow flood passage.

The second method is a simple structure of a single row of posts driven side by side to form a wall of logs secured by horizontal poles. Some of the poles are placed lengthwise below the check dams to serve as an apron.

Stone or loose-rock dams are commonly used in gully control as dry-rock wall. The construction of a loose-rock dam starts with the smoothening of the gully banks of the dam site to about 45° or 1:1 slope. Then the foundation of 30–50 cm deep extending well into the banks is dug and the excavated soil piled upstream to be used for refill. The largest rocks are laid at the bottom. This is followed by another layer in rows across the gully with sufficient overlap to produce a shingle effect until the dam is built to the required height. The center of the dam is kept lower than the sides to form the spillway.

The large flat rocks are countersunk below the spillway flush with the channel surface to serve as an apron.

Periodic inspections, repair, and maintenance of these erosion-control structures must be made, particularly after heavy rains to ensure proper functioning.

Table 1. Approximate discharge capacity for rectangular notches in small dams.

Depth of notch (ft)	Discharge capacity (cfs) of spillway having lengths (feet) as shown							
	3	4	6	8	10	12	14	16
0.5	3.0	4.0	6.5	8.5	10.5	12.5	15.0	17.0
1.0	9.0	12.0	18.0	24.0	30.0	36.0	42.0	48.0
1.5	16.5	22.0	33.0	44.0	55.0	-	-	-
2.0	-	34.0	51.0	68.0	-	-	-	-

Adopted from USDA-FS Handbook Category 2, No. 2534, 1958.

Note: Above table for use where expected flows do not exceed about 50 cfs. Values were computed to nearest 0.5 cfs by formula.

$$Q = 3L \times D^{3/2}$$

where

Q = discharge in cubic feet per second
L = length of spillway notch in feet
D = depth of spillway notch in feet

Caution: L and D are not interchangeable.

Conversion:
1 ft = 0.3048 m
1 cu. ft = 28.32 l
1 cu. ft/sec= 0.472 l/sec

Permanent Check Dams

As much as possible, gully control should be achieved by vegetation and by the use of simple structures. However, there are cases where only permanent dams or structures can solve the problem. Permanent dams are constructed from durable materials, such as reinforced concrete, masonry, and earth with permanent spillways.

Permanent dams may be recommended for the following gully conditions: (1) the volume of runoff cannot be controlled by vegetation; (2) in adverse conditions when soil is very unstable; (3) the area is remote and regular maintenance is difficult; and (4) temporary dams are either inadequate (cannot withstand floods) or impractical (have a short life span).

Permanent check dams are located in such a way that the line of discharge from the spillway is parallel to the centerline of the gully immediately below the dam. This will prevent side-cutting of the drainage channel below the structure.

These check dams are named according to use or materials used for construction.

SILT TRAP DAM

When an excessive sediment load threatens water supply downstream, a silt trap dam is necessary. Trapping the silt in sufficient quantity by existing vegetation may be slow and uncertain. A fast and positive reduction of sediment movement can be achieved by constructing permanent silt trap dams. The requirements and design of such dams are similar to those of the water storage dams.

Maximum storage capacity at minimum cost should be the main consideration. Storing water in a few large dams is usually more economical.

GULLY-HEAD CHECK DAM

To check the advance of the gully headcut, a permanent check dam will be necessary to stop the active head from eating its way steadily upstream and before it threatens a road or bridge. This dam is also used to elevate the grade to a silting grade of 0.5–3% from the spillway crest to the rim of the gully head.

MASONRY CHECK DAM

These dams are used in gullies or small stream channels with high rates of runoff or where vegetation cannot be established. This dam is recommended only when rocks or stones are available. Concrete hollow blocks, tiles, or any hard and durable materials may also be used. The minimum thickness of all walls should be 30 cm. The slope of the downstream side of the dam below the spillway should be at least 1:2 or 200%. The thickness of the base must not be less than three-fourths of the height of the dam.

CONCRETE CHECK DAMS

Concrete dams are recommended when there are inadequate materials for masonry check dams. The same general specifications given for masonry dams can be used for concrete dams. The disadvantages of masonry and concrete structures in erosion control is that they are very inflexible. Once damaged, they are not easy to repair.

GABIONS

Gabions is an erosion control technique that originated in Italy. They are large rectangular wire crates filled with stones. They are flexible, permeable, and economical in places where stones are abundant. Besides stabilising gullies, gabions can also be used in flowing water, for land reclamation along shores, for retaining walls, etc.

Gabions may be constructed from locally available mesh wire with a diameter not less than 2.5 mm. A gabion 2 × 1 × 1 m in size requires 10 m^2 mesh wire, 12 m iron rod 7 mm in diameter, and 10 m tie wire. The mesh wire is formed into a rectangular basket by tying its edges. The iron rod is tied around the basket for reinforcement. Cross ties are made to keep the gabion in shape during filling.

Before the gabion is filled with stones, it is placed in position to form the check dam or retaining wall. Stones used for filling must be larger than the mesh. Stones should be riprapped in front of the gabion while it is being filled. The back or inner side can be roughly filled.

After filling, the cover of the gabion is sewn along the front edge and sides. Gabions placed side by side or on top of one another are connected with a strong galvanized wire. The main advantage of this structure is its flexibility to settle slightly without any loss of strength if scouring takes place.

Riverbank or Streambank Erosion Control

Streambank erosion is frequently associated with gully erosion because it is essentially a process of lateral cutting. Gullies often begin at the banks of natural water courses and by waterfall erosion, and move back into adjacent lands. In addition, portions of bottom land are frequently damaged by bank cutting that occurs along many of the streams. This is particularly noticeable at the bends of winding channels.

In controlling bank cutting in small streams, it is seldom necessary to use heavy timber, concrete, or masonry structures which are ordinarily required for control on large streams. Before vegetation can be established, temporary jetties, wing dams, fences, tree and cable revetments, or other types of deflectors are usually necessary along the eroded bank to slow down the water and start silting deposition.

In large channels, bank protection works should always incorporate vegetative measures with structures added as necessary. Plans should always include plantings, and separate planting plans should be made if they are not shown in the structure plan. Conservation measures on a watershed have a direct bearing on the success of the treatment installed downstream to protect channels and banks. Channel stabilisation works can never give the maximum protection if abnormal floods and sediment from the upper watershed continue to rip out or clog the channel.

Before selecting the type and design of bank protection, the technical feasibility should be determined. Causes of instability should be determined early and removed or treated.

Bank protection and channel stabilisation works are accompanied by means of mechanical structures and vegetation. Vegetation is always considered as supplement to mechanical control devices. Plantings should be as carefully planned as the mechanical structures used in river control work.

Several methods have been developed to reclaim or prevent erosion damage along riverbanks. They can be temporary, emergency or permanent structures (Unkel and Endangan 1975; USDA-FS 1958).

'RAUHBAUN' METHOD

Dense and well-branched trees or tree tops are placed along the bank with the butt ends pointing upstream and anchored by strong pegs and wire or ropes. The posts to which trees are tied must be anchored firmly in the riverbed, and braced if necessary. To protect longer banks, several rows of brushy tree crowns or branches have to be placed in a single-file formation. The function of the tree crowns is to reduce the velocity of flow along the banks. During floods, the Rauhbaun method may be the only possible measure that can be adopted.

TEMPORARY GROYNES

This method is used in wide and shallow riverbeds and streams. With the help of groynes the direction and velocity of the current, and partly the deposition of sediments, can be influenced.

Temporary groynes are installed by driving posts of about 15 cm in diameter into the riverbed. Trees or branches of trees are placed horizontally on the upstream side of the posts and anchored firmly. To resist flood the posts must be reinforced by supports or braces.

REVETMENT

Revetment is a structure which may be built in contact with the bank, near the bank, or at various moderate distances from it, but running roughly parallel to, the bank, throughout the length of the damaged channel. Revetments are built to protect the bank from erosion but not to change the direction of flow or regimen of the stream, except in the immediate vicinity of the structures. Revetments may be made of tree and cable, log and cable, piles of floating logs, tetrahedrons, gabions, double posts, brush rock, fascine slope mattress, masonry or concrete linings, and bank riprap.

JETTIES

A jetty is a structure built to direct the current of a stream away from a bank. Ordinarily, a jetty begins in the bank and extends out into the stream for a short distance in a downstream direction. Jetties are set at various angles with the current, ranging from as small as 10–15° to a right angle. To be effective, jetties created at larger angles with the current must usually be more impermeable than those set at small angles. Jetties can be made of rock, concrete, pile and lumber, steel pile, brush rock, or gabions.

Other structural measures are available for water and sediment storage, such as the various forms of dams. Their designs are similar to any water impounding dams with due consideration to the conditions of the channel or stream.

Research Findings and Needs

Research on structural measures is wanting, and studies on soil erosion as influenced by slope under Philippine conditions are very limited. A study by Bayotlang (1978) showed that runoff per unit area was greater from shorter plots than from longer ones in both bare and grass plots. Another by Salvador (1981) indicated that soil loss and runoff per unit area increased with slope grade, but decreased with increase in slope length. These results may be considered as indicative of the behaviour of soil loss and runoff under plot conditions.

There is a dearth of studies on structural measures. Only one study in Cebu is ongoing aimed at determining the effectiveness of different types of check dams in controlling gully formation using local materials. No results are yet available.

The control of soil erosion by structural measures should not be overlooked as an inevitable remedy where vegetation fails to establish. More economical methods using endemic resources for structures may be used to reduce cost.

The preventive measures should be emphasised in erosion control, in favour of cheaper measures instead of expensive rehabilitation or reclamation techniques.

Problems and Recommendations

There are several methods which can be modified to suit local conditions. Many of these measures have been adopted in the Philippines, but the common problem is that they are expensive and not economical in lands of low value. Hence, farmers and land administrators prefer to use the less expensive vegetative measures, where possible, to control erosion. Preventive measures are cheaper and should be emphasised in erosion control.

Mechanical structures should not be considered as a complete remedy for erosion control, but only as a complement to vegetative measures. These structures can be more effective if the drainage area or watershed conditions above them are improved and properly used.

Many of the stream channels have become unstable largely because of improper land-use practices within the watershed, such as poor upland farming practices, overgrazing, poor logging practices, fire, mining, and poorly constructed or maintained roads. In mountain areas, raw vertical banks and deeply cutting channels are indicative of unstable stream or river channels. This points to the fact that the problem of soil erosion is caused more by high volumes of water runoff than by structural features. Soil erosion in the Philippines is generally caused by excessive water overland. If rains can be held back in the drainage areas and flood peaks reduced, erosion can be minimised.

Research Opportunities

The recommended research areas to form a basis for policy formulation to control erosion are prioritised according to their importance and availability of resources for conducting the research:

1. Studies of measures to increase infiltration capacities of various soils under different plant cover or land use.

Surface runoff or overland flow is the primary factor causing erosion in the Philippines. Increased infiltration and water-holding capacity of the soil will reduce surface runoff. Soils with infiltration rates greater than rainfall rates are more stable and can conserve more water.

Various land uses may either increase the infiltration rate of the soil or reduce it through compaction. The proper land treatments or appropriate plant cover for the various soil types must be known to improve the soil condition and increase infiltration capacities.

2. Studies on cropping patterns in uplands to reduce tillage and soil exposure during rainy season without reducing income of farmers.

Soil erosion generally occurs during rainy days. Without rain, erosion is minimal. Since natural rainfall is beyond the control of man, rainfall effects on erosion can only be minimised by maintaining protective cover on the soil. Economic crops, which can provide protection on the soil during the rainy season and serve as substitute to preferred rice, corn or other open crops inducing erosion, should be used to minimise accelerated erosion.

3. Studies on the effects of various land-use practices, such as logging systems, grazing intensities, agroforestry schemes, road construction and maintenance, etc. upon streamflow characteristics and sediment yield.

The main causes of soil erosion on uplands are the various land uses which cause disturbances to the soil. These lands are primarily forest lands, but the resources therein are used to produce goods and services for human needs. In the process of using the upland resources, these land-uses accelerate erosion if improperly done. These land-use practices or methods must be improved to avert accelerated erosion.

4. Studies to determine the appropriate plant species and methods of establishment in bare areas particularly on low pH soil.

Many barren areas, which are erosion hazards, must be protected or rehabilitated. Vegetation establishment could be the most efficient means of protecting the area, if the appropriate species adapted to the site are used. Failure to establish vegetation in several project areas was due to the wrong choice of species and improper establishment methods. This problem is better addressed to acidic soils, and in areas with low rainfall or a long dry season.

5. Studies on alternative crops or on vegetation conversion for water control or water conservation.

One important product of the land is water. All uplands are part of a watershed draining to streams or rivers as source of water for use in domestic, irrigation, industries and power generation. The water flowing in the streams or rivers must be of acceptable quality and quantity in order to meet public demands.

Through the use of appropriate vegetative cover on the land the desired characteristics of water can be produced.

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Methods for Measuring Soil Erosion: Some Results from Subtropical and Tropical Queensland

R.J. Loch and D.M. Freebairn*

IN Australia, soil erosion research is a comparatively recent development. A sharp increase in awareness of soil erosion problems in the early 1970s brought increased funding for soil conservation work and related research, a trend that has carried through to the present.

Soil conservation authorities in each state are responsible for planning and implementing soil conservation measures and are, therefore, the main 'users' of results from soil erosion research. Faced with a general lack of data on soil erosion/conservation, these state authorities have now established substantial research activity and are responsible for most of the soil erosion research in Australia, especially field studies that require large and costly field resources. Increases in research funding have prompted some growth in soil erosion research by CSIRO and universities, but resources limit those bodies to mainly process or modelling studies.

In Queensland, unlike some other states, soil conservation planning, extension, and research are carried out by branches of the state Department of Primary Industries (QDPI), i.e. by the Soil Conservation Services, and Soil Conservation Research Branches. This administrative structure ensures that soil conservation is not studied as a separate, isolated issue, but as part of an effort to produce stable, profitable farming systems. Other research and extension work by various branches of QDPI includes crop and pasture agronomy, soils, entomology, plant pathology, animal production, and agricultural engineering. There is, therefore, considerable scope for multidisciplinary research.

The development of soil erosion research in Queensland has been a process of self-education, as there was little existing Australian research prior to the 1970s to give guidance on methodolgy or equipment. During the last 10 years, we have developed research programs in a wide range of environments. This paper describes the research methods adopted and some of the results obtained.

Environment

The climate of Queensland is classified as tropical to subtropical. Rainfall is summer-dominant, and high intensities are not uncommon. Rainfall is highest in coastal regions, declining inland. By world standards, reliability of rainfall is low.

Sugar cane and horticultural crops are grown in the wetter, coastal areas. Inland, grain cropping occupies more than 1.8 million ha in central and southern Queensland, and the area under crop is increasing by about 100 000 ha/annum. Grazing of sheep and cattle is a major land use, sometimes in combination with grain cropping.

For the east coast of Australia, available data show a general increase in erosion from south to north, with annual soil losses as low as 2 t/ha at Wagga Wagga in southern New South Wales and as high as 380 t/ha at Innisfail in northern Queensland. This trend appears to be a function of rainfall erosivity, and clearly, the potential for soil erosion in Queensland is extremely high.

Concepts

Erosion research can generally be divided into two groups: management research, and process research.

MANAGEMENT RESEARCH

This typically refers to field studies under natural rain with catchment sizes ranging from 0.01 ha (row crops), to 1-10 ha (contour bays) to 12 ha natural catchments. The definition of experimental conditions and the measurements made are not detailed, and generally the processes operating are not considered explicitly. Common treatments are a range of management strategies, either in current practice, or experimental systems such as zero tillage.

The *advantages* of this type of research are the

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following: (a) results are 'real,' being derived from field scale areas under natural rain; (b) results give a good measure of the existing situation; (c) a wide range of measurements can and should be made, e.g. runoff, soil loss, soil water storage, crop yield; (d) the results indicate the most promising management approaches, thus identifying areas for more detailed research; and (e) trials can also be used as demonstration areas, making this type of research particularly useful for extension efforts.

The *disadvantages* of this type of research are as follows: (a) results are site specific; (b) the range of treatments studied is often small, due to logistic constraints; and (c) variability in rainfall may be such that trials need to be run for long periods if they are to give an adequate measure of long-term results, though Freebairn and Boughton (in press) show that it is possible to assess whether a trial has adequately sampled the range of storms likely to occur over a longer time period.

PROCESS RESEARCH

This typically refers to studies of some part of the overall runoff/erosion system, e.g. effects of surface cover on infiltration (Glanville et al. 1984) or slope length on erosion (Loch and Donnollan 1983a). Conditions are generally more precisely defined or controlled, and measurements made can be relatively detailed, e.g. sediment size and density (Loch and Donnollan 1983b) or nutrient enrichment in sediments (Dalal and Loch 1984). Simulated rain and/or run-on water is commonly used, and plot sizes are small, ranging from 1 m^2 to 90 m^2 depending on the type of rainfall simulator used. There is greater emphasis on understanding the processes contributing to a particular result, especially as sampling intensity can be greater. For example, Loch and Donnollan (1983a, b) measured sediment size and concentrations at 1-min intervals compared with the measurements ot total soil movement for each runoff event from 'management' studies. Process research generally has three main purposes: (1) increasing understanding of the processes of runoff and erosion, aiding development of the runoff/soil loss models needed to extrapolate data from both management and component research to a wider range of environments; (2) gathering resource data, e.g. infiltration characteristics and soil erodibility; and (3) examining potential management techniques in greater detail, to identify refinements or alternative approaches that could be considered.

It should be noted that process research does not produce 'real world' data, and Loch (1984) has shown that gross misconceptions or misuse of data are not uncommon. However, it is possible to use data from process research as inputs to single-event soil loss models to obtain good prediction of erosion in the field (Silburn et al. 1984).

INTEGRATION

Management and process research obtain very different data, and the combination of these two approaches can be very effective if it is recognised that they are complementary.

For any research effort, management research is the obvious starting point. It gives not only some definition of the environment, but also a broad indication of likely good management systems. It arouses public interest and has the very important attribute that soil erosion is not the only parameter measured. Runoff, soil water storage, crop yield, insect pests, crop pathogens, soil properties, and economics can all be assessed. Such data can be essential in 'selling' a change in management systems to farmers; and management-type erosion research in Queensland is typically a team effort where agronomists, soil scientists, plant pathologists, and entomologists are involved in varying degrees.

Process research can provide an understanding of the results of management research; and then, through the development of predictive models, allow data and/or recommendations to be extrapolated to a wider range of local environments.

Measurements

Once the aims, experimental approach, and intended use of data obtained are defined, there remains the problem of making useful measurements.

Interestingly in Queensland, the measurement of runoff occupies a major proportion of the time, capital, and technology inputs in most field studies of erosion; and therefore, some brief discussion of runoff measurement is included.

There are reasons for our apparent preoccupation with runoff. Runoff amount and peak runoff rate are two of the many factors influencing soil loss, and both are strongly affected by management practices (Freebairn and Boughton, in press). Particularly in the inland grain-growing areas, soil water is a major limitation to crop yield; and the reduction of runoff is a worthwhile objective in itself, being reflected in increased soil water storage and crop yields (Freebairn and Wockner 1983). Also in some experiments, measurement of runoff is essential for the calculation of soil erosion.

Runoff

MICROPLOTS

Small plots in the order of 1–10 m^2 can be enclosed by metal strips, and the relatively small volume of runoff either collected in drums or measured by, for example, a small tipping bucket. Bligh (1984) gives a detailed description of the use of this approach, which gives a measure of runoff amount, but not of catchment hydrology.

LARGER CATCHMENTS

Discharge from larger catchments is usually measured by some form of control structure at the catchment outlet. Exceptions are the use of large tipping buckets to measure flow from small, row-crop catchments (Sallaway and Prove 1984), or of rated cross sections for catchments >100 ha. A cross section of natural channel is 'rated' by obtaining a relationship between flow depth and discharge, which involves measurement of velocity profiles at various flow depths. Rated cross sections may be used where any disruption of flow is undesirable, but rating curves can vary considerably with channel conditions, e.g. length of grass or reeds.

Generally, control structures give more accurate measurements, though tipping buckets can be effective when catchments are small and sediment loads are low. Depending on catchment size and the type of installation, costs of control structures vary considerably. Small V-notch weirs cost little, but large flumes can be expensive and take a lot of work to install.

Measurement of flow height is traditionally based on a float in a stilling well, though alternatives to frequency water level sensors are available, such as pressure transducers or capacitance.

Data storage systems range from clockwork-driven charts, punched tape, or electronic data loggers to systems linked by radio or telephone to a central computer.

Most equipment is available 'off the shelf'; and fairly reliable systems can be developed, provided the components are well matched to the environment. For example, electronic equipment has not always been a success in humid climates; nor is it tolerant of lightning strikes in adjacent areas. One of the most reliable systems used for recording water levels is based on a simple clock and a direct trace of float height (Freebairn 1984b), which is simple, inexpensive, and easily serviced by untrained staff.

Potential problems with all equipment are endless, as mud hornets, ants, and even rodents with a taste for electrical wiring can cause equipment failures. Therefore, it pays to have dual measurement and data storage systems, and regular servicing is critical, so good access to a site is important.

SOIL EROSION

The definition of soil erosion can be contentious. For example, one definition is that for soil to be truly eroded, it must reach the sea. However, in studying soil erosion we are usually only concerned with measuring the movement of soil from some defined area. The defined area may be a 1 m^2 plot, or a 1000 ha catchment, depending on the purpose of the experiment.

The size of experimental area studied is an important consideration. For 'management' studies in particular, the experimental area selected should allow erosion to be studied at the scale at which it is greatest. An example of changes in the erosion process and sediment concentration with increasing area would be: rain-flow < rill >> contour bank channel ≤ waterway. This is a common pattern in the grain-cropping areas of the Darling Downs. Integration of a range of studies at various scales can also be useful (Loch et al. 1984).

There are, essentially, three approaches used to measure erosion: (1) estimating soil loss from changes in elevation of the soil surface; (2) trapping all soil removed so that it can be measured; and (3) sampling sediment in runoff as it passes some measuring point.

These approaches differ both in the type of data produced, and the situations for which they are best suited, but can be used either singly or in combination.

Measuring changes in elevation of the soil surface
This technique is particularly suited to row crops, where there is a pronounced ridge and furrow shape running up and down the slope (Sallaway and Prove 1984), and has been used in sugar cane, pineapple, and cotton-growing areas in Queensland. A range of bar-and-pin type instruments (Fig. 1) has been developed, including microprocessor-controlled automated versions (Radke et al. 1981; Grevis-James 1984).

Pegs can be inserted in the rows (Fig. 1) to serve as semi-permanent reference points, and soil loss is calculated as:

$$\text{Loss} = \frac{BD \times \triangle A}{W}$$

where BD = soil bulk density
$\triangle$ A = change in cross-sectional area
W = furrow width

Readings can be taken at a number of points up and down a row, and at various times during a season. A large number of readings are required to achieve accurate results. Major advantages of the method are the following; (a) it is well suited to row crops; (b) it can identify sources and sinks of sediment; and (c) although not highly accurate, it is well suited to areas where soil losses are large. Limitations are: (a) it is not suitable for areas receiving frequent cultivation; (b) if not automated, it can be a very laborious technique; and (c) it is not suitable for swelling clay soils.

Trapping all soil removed This covers a wide range of possibilities, many of them being relatively simple and inexpensive. As a general rule, this approach is most effective when the sediment is relatively coarse and readily deposited.

Catch troughs (Gerlach troughs) are a widely-used approach. They are dug into the ground to intercept overland flow; so that although water flow is not greatly affected, most of the sediment in the runoff is deposited in the trough. Because troughs have to be carefully dug into the soil so that they do not cause localised erosion or deposition, their use is generally restricted to situations where soil disturbance (tillage) is rare or absent, e.g. grazing, zero tillage.

In some catchments, a sharp decrease in bed slope can cause most of the sediment to be deposited. For example, Freebairn and Boughton (1981) describe catchments on a 6–7% land slope, where runoff is intercepted by a contour bank (terrace) of 0.3% slope. Runoff is measured

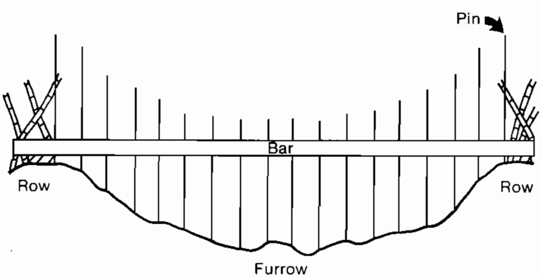

Fig. 1. Profile meter placed across a cane furrow on permanent pegs, with pins lowered to ground level.

through a flume at the end of the bank channel, and most of the sediment is deposited in the channel.

In other catchments, bed-load (i.e. coarse sediment) is trapped in ponds immediately upstream of the flume or weir, with flow restriction by the control structure encouraging deposition. Often, a change in bed slope restriction of flow is used to ensure deposition. However, because not all the sediment is deposited, stage samplers are installed at the flumes and have been found to give a good measure of suspended sediment leaving the catchment (Freebairn 1984a).

A range of survey techniques has been used to measure the amounts of deposited sediment; and accuracy of ±5 t/ha is possible, provided both volume and bulk density of the deposited sediment are measured carefully.

An alternative used in some studies of erosion plots is to use a flow splitter, so that a fixed fraction of the total runoff and soil loss is collected in a tank. Flow splitters vary in complexity and accuracy, and calibration would be essential. The sediment collected settles out in the collecting tanks; and there can be difficulties in cleaning out the tank, as well as measuring the sediment. General attributes of measurements based on trapping of sediment are the following: (a) very reliable; (b) can be inexpensive and require little maintenance; (c) reasonably accurate, especially if combined with some measure of suspended load; (d) very suitable for 'management' projects; and (e) gives a measure of total soil loss per event, not of erosion through time.

It should be noted that catchment size, or at least the amount of soil to be trapped, should not be too large, or the task of removing large volumes of sediment from a pondage area becomes prohibitive. Also, the size of the pondage area must be consistent with the volume of soil likely to be trapped.

Sampling sediment in runoff In some cases, this can be relatively simple, e.g. manually taking samples of runoff from experiments in which simulated rain is used. At larger discharges, even manual sampling becomes more difficult, as sediment is not evenly distributed through the depth of flow; and in general, this type of soil loss measurement requires the greatest inputs of money and technology.

In field studies, equipment is needed that will automatically sample runoff at selected time intervals. Essentially, there are two components: a

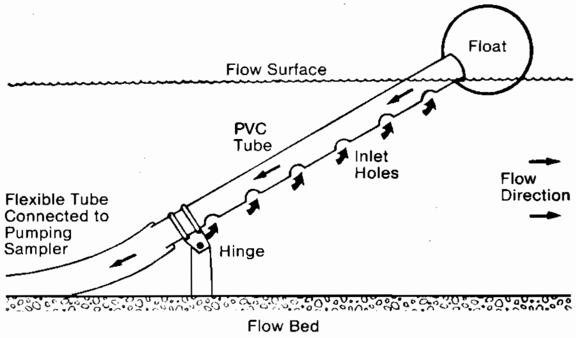

Fig. 2. Typical method of sampling flow.

pump and control system, and some means of obtaining a representative sample of the runoff water and sediment.

Reliable and sophisticated pumping samplers can be purchased, and it is well worth spending a little extra money to gain reliability.

Unfortunately, obtaining a representative sample of flow is not always easy. Pumping samplers in Queensland have typically been linked to a length of PVC tubing with holes on the underside, hinged at the bed, and with a float at the end of the tubing; so that the PVC tubing can sample evenly between the bed and the flow surface (Fig. 2).

However, it seems that this method of sampling only works successfully for very fine sediment. A recent assessment of this method used a length of PVC tube with 5 mm diameter holes on the underside, installed in a small flume. Water carrying high concentrations of coarse sediment was passed through the flume, and results showed that sediment > 0.250 mm diameter was grossly underestimated.

Most Queensland situations in which this sampling system is used are such that sediment would be < 0.250 mm, as considerable deposition would occur well upstream of the sampling point. However, there are situations where high concentrations of coarse bed-load need to be sampled, e.g. single-rill studies (Ciesiolka and Freebairn 1982), studies of sugar cane rows (Truong and Wegener 1984), or catchments where the flumes used do not cause deposition of sediment (Sallaway et al. 1983) and alternative approaches are needed. At present we are evaluating the GUTSS sampler (McTainsh and Rosewell 1984) and initial results have been promising.

Hardware Our experience with measuring and sampling equipment has not always been the happiest. We have wasted a lot of time and money by trying to make our own electronic equipment cheaply. Where reliable equipment can be purchased 'off the shelf,' it is well worth the extra expense, but testing and calibration of equipment is always necessary.

Results

Over the last 10 years, the quantity and range of data collected by QDPI have grown rapidly. Two examples of such data are presented in detail.

GRAIN-GROWING AREAS OF THE DARLING DOWNS

Rainulator studies (Loch and Donnollan 1983a) showed that rills formed in bare soils at very low discharges. Rills carried quite high sediment concentrations, and further increases in discharge did not cause any increase in sediment concentrations in the rills. Loch (1984) showed that this pattern of response could, in the long-term, give a gradual increase in erosion with increasing slope length, but noted that under Australian rainfall patterns, slope length was unlikely to be very important.

A further conclusion was that because rills formed at such low discharges on vertisols, contour banks (even at very close spacings) would not prevent rills, and would probably have little effect on erosion between the banks.

Among extension officers who saw their primary role as the establishment of contour banks, these conclusions were not well received. Because these conclusions were essentially a 'modelled' result, they may not have been accepted; but Freebairn and Wockner (1983) confirmed that on bare soils, annual rates of erosion between contour banks were indeed high (30–50 t/ha).

Consequently, a review of extension priorities was necessary. Fortunately, Freebairn and Wockner (1983) also showed that stubble retention between contour banks gave drastic reductions in inter-bank erosion (Fig. 3). This led to some questioning of the role of contour banks in the system. Were they needed at all? However, it was realised that by shortening slope lengths, contour banks prevented rills from becoming gullies, and reduced the volumes of overland flow sufficiently for stubble mulches to be effective in preventing rill initiation. Both locally and overseas, there have been observations of 'mulch failure' on long slopes or at high discharges

(Foster et al. 1982). Therefore, it was concluded that the combination of stubble mulches and contour banks was essential; and that either practice on its own was likely to be relatively ineffective.

Although the need for a more balanced approach to soil conservation had been 'sold' to the soil conservationists, there still remained the problem of persuading farmers to adopt a change in management practices. Interestingly, as far as the farmers are concerned, soil conservation may not be the major reason for retaining stubble. Instead, they are prepared to retain stubble because a number of studies have shown that stubble retention increases soil water storage and crop yield. In fact, the need to retain stubble and increase moisture storage is now regularly proclaimed in advertising by farm machinery and chemical companies.

This example shows clearly the value of management studies which, by the range of parameters measured, provide excellent extension material. The complementary nature of management and component research is also illustrated.

SUGAR CANE AREAS

Experience in sugar cane areas reinforces the lesson that soil conservation measures are often adopted by farmers for reasons other than soil conservation.

Sallaway (1979a) showed that annual soil losses under sugar cane on Queensland's central tropical coast could be as high as 227 t/ha. Soil loss was reduced by a reduction in cultivation (Sallaway 1979b). Subsequently, trials have shown dramatic reductions in soil loss when trash is retained and tillage eliminated (Truong and Wegener 1984). These management techniques are now being widely adopted, but at the farmer level, the reasons for adoption are other than the prevention of erosion.

In the drier, southern areas where soil moisture can limit cane yield, improvements in rainfall infiltration, soil moisture storage, and crop yield are the major reasons farmers have adopted trash retention techniques. In the northern, high rainfall areas, tillage was a major cost; and the reduction in costs with trash retention and reduced tillage is the major reason for adoption of these management techniques.

Data management, interpretation and modelling

Research efforts involving a number of scientists, with trials at various locations, can become

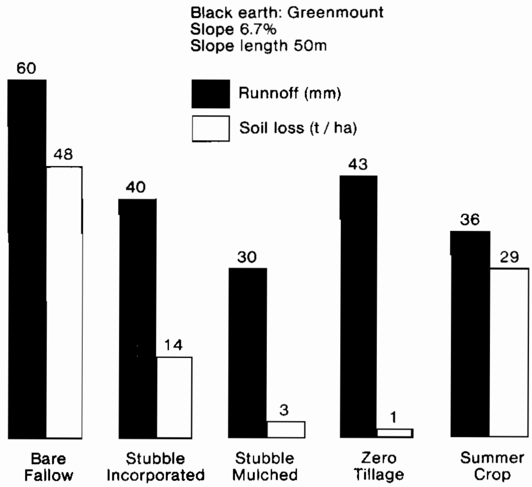

Fig. 3. Annual runoff and soil loss at Greenmount for the six years 1976-77 to 1981-82 (Freebairn and Wockner, 1983).

fragmented. As this makes it more difficult to develop a large, easily accessible data base, it is important that data be collected and stored in a common format.

Although each researcher is usually responsible for interpreting and reporting results from his own experiments, in time there will be a need for integration and interpretation of results from the whole research program. This can be considered a modelling exercise, and it may take 5–10 years before sufficient data are available. Our experience is that data organisation and model development should occupy at least one full-time scientist. (It is also at this stage that the value of common data formats becomes obvious.)

A range of runoff/soil loss models is available, and we are evaluating a number of these at present. Runoff/soil loss models are being incorporated into a larger model, with other components including water balance and crop growth.

Conclusions

1. Management research is the obvious starting point in a programme of soil conservation research. It requires simpler methodology, and produces short-term data that are ideal for extension work.

2. Management and process research should complement each other. Process research supports management research, providing understanding of relevant processes and a sounder basis for extending and extrapolating results.

3. Beware of false economies when purchasing equipment.

4. In the longer term, integration and extension of data can be a considerable challenge.

5. Practices that conserve soil are seldom if ever 'sold' on their conservation merits alone.

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Farming Systems Approach to Soil Erosion Control and Management

Andres F. Celestino*

IN THE Philippines, as in most Southeast Asian countries, the lack of sufficiently flat lands or lands having slopes within the accepted limit of less than 18% for safe cultivation, and the need to intensify food production in order to stave off hunger, have forced farmers to use the slopelands for agricultural production. They plant their annual crops in rows on steeper and steeper upland slopes. Moreover, shifting cultivators have reduced fallow time to the detriment of the regeneration of sufficient ground cover. The result is a rapid and continuing denudation of many hillside areas which were once fertile.

Soil erosion in these areas is mainly caused by surface runoff. The degree of surface runoff generally varies with the intensity of cultivation and rainfall, especially during the early periods of low cover, i.e., the time from seedbed preparation to the early stages of crop growth when the soil surface is directly exposed, to a greater degree, to the beating of raindrops. Rain splash causes detachment and dispersion of soil particles (Ekern 1950; Kirby and Morgan 1980; Al-Durrah and Bradford 1982 a and b: Singer et al. 1982; and Woodruff and Siddoway 1965).

Shifting land use from grassland or woodland to crop production has almost always resulted in greater soil loss (Grant 1975; Pereira 1973; and Nye and Greenland 1964). This is especially true where the farming system used produces a radical change in vegetative cover. For example, in the Philippines, erosion in logged-over areas which are planted to coconut, rubber, falcataria, coffee, cacao or other tree crops is not as serious as in similar logged-over areas planted to cultivated row crops. The former system does not cause a radical change in vegetation, since the lands planted to such tree crops are not entirely cleared of their vegetative cover and the soil is not tilled except in spots where the trees are planted.

El-Swaify and Dangler (1982) reported that erosion trends in the humid tropics are quite dependent on the extent of disturbance by people. Lands in these regions display low erosion by water when the natural protection provided by abundant vegetation is undisturbed. However, when vegetation is disturbed, heavy rainfall can cause severe erosion.

Various methods of controlling soil erosion by water have been reported, both mechanical and agronomic measures. Mechanical measures include the construction of bench terraces, stone walls, contour bunds, hillside ditches with benches and similar other systems (Chan 1981; Sheng 1982). Agronomic measures include: (1) planting cover crops to protect the soil from the impact of raindrops which causes soil detachment and dispersion (Singer et al. 1982; El-Swaify and Dangler 1982) and to increase permeability and water infiltration rate through the biological loosening effect of the root system (Kemper and Derpsch 1981); (2) addition of organic matter to improve the aggregate stability of the soil and thereby increase its resistance to erosion (Unger 1982); (3) proper soil tillage and management to increase water-stable aggregates to resist or minimise soil dispersion and maintain higher infiltration rates, thus decreasing runoff and attendant erosion (Johnson et al. 1979; Unger, 1982). This method includes the use of the no-tillage (or 'conservation tillage') system (Lal, 1982) to avoid stirring the soil which predisposes it to erosion; and (4) application of appropriate cropping systems and crop management practices such as multiple cropping, intercropping or mixed cropping, relay cropping, crop rotation, mulching, plant spacing, etc.

Agronomic measures affect both soil detachment and transport processes while mechanical measures influence transport but have little effect on detachment. Agronomic measures are more

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effective than mechanical measures in controlling soil erosion on their own, and even more effective when combined with good soil management. But mechanical measures are rarely effective without agronomic measures to support them. Agronomic measures offer more advantages than mechanical control of erosion in that they are less costly, frequently require no special equipment or machinery, need less maintenance, and are more easily incorporated into an existing farming system.

Conservation-Effective Farming Systems

There is still no satisfactory and universally accepted definition of the term 'farming system'. The Technical Advisory Committee (TAC) of FAO's Consultative Group on International Agricultural Research in Farming Systems (as quoted by Lal 1982) defines a farming system as 'an interwoven mesh of soils, plants, animals, implements, workers, other inputs and environmental influences with the strands held and manipulated by the farmer who, given his preferences and aspirations, attempts to produce output from inputs and technology available'.

The above definition means that a farming system includes and considers all the component technologies or 'sub-systems' that deal with the individual 'sub-sets' (namely, crop production, animal production and secondary or non-agricultural production systems) of a farming system (Zandstra et al. 1981). Tillage methods, planting patterns/systems, fertilisation, pest control and management, etc. are examples of component technologies or sub-systems that may form part of a specific farming system (Lal 1982).

Some of the potential farming systems and sub-systems used for soil and water conservation are discussed below.

CORN/LEUCAENA

The corn/leucaena farming system involves the establishment of leucaena vegetative terraces planted at intervals in double-row hedgerows along the contour lines. The leucaena hedgerows provide a biophysical infrastructure within which cropping methods using existing practices or new cropping systems can be carried out (in the strips) without danger of massive soil erosion (Celestino 1984). Through their deep root system, leucaena trees check soil erosion. The strips between hedgerows tend to flatten over the years, becoming a series of terraces with the leucaena hedgerows serving as risers (Fig. 1). This increases the stability of the soil and makes farming operations easier and more convenient.

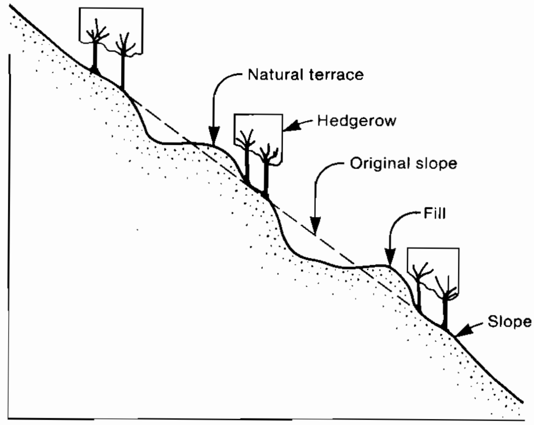

Fig. 1. Natural terrace formation with leucaena hedgerows serving as risers.

The corn/leucaena farming system is a very appropriate approach toward the efficient and effective management of hillylands where soil erosion and degradation are serious problems. Apart from checking erosion, the leucaena trees also provide a renewable source of organic fertiliser, fuelwood, feed for livestock, and wood to meet local construction needs.

Pacardo (1982, 1983) studied the extent of erosion in hillylands planted with leucaena hedgerows. He reported that soil loss followed the same trend as that for runoff water: bare plots lost more soil than plots planted to corn alone which in turn lost more soil than plots planted to corn/leucaena with stubbles removed. The latter plots in turn lost more soil than plots planted to corn/leucaena with corn stubbles retained. Plots with leucaena hedgerows with or without corn stubbles showed much less than plots without leucaena hedgerows: 63 times less in the area where surface soil was thicker and 3 times less in the area where surface soil was thinner.

AGROFORESTRY (TREE-BASED)

Agroforestry is the growing of perennial trees and shrubs along with ephemeral food plants. Agroforestry is based on the concept that soils in the wet tropics not only have generally low fertility, but are also unstable and easily degraded (Spath 1979).

Agroforestry is particularly suitable for hilly areas where soil erosion and degradation are serious problems whenever the land is planted to cultivated food crops. By combining perennial trees and shrubs with short-term food crops (Fig. 2 and 3), the soil is better protected and its degradation diminished.

Perennial trees and shrubs have a double function. Primarily, they protect the other cultivated plants and the soil from strong insolation and concentrated rainfall, thus minimising the destructive effects of rain splash. Through their leaf fall and deeper root system, trees improve the soil's physical structure and infiltration capacity. They also supply fruits or shoots which serve as food for people or livestock, and provide wood as a source of fuel energy to meet local needs.

Agroforestry is perhaps the best approach to rationalising soil conservation and management in slopelands. In the Philippines, however, there are many constraints, both physical and social, to its application. For one, many of the farmers in the hillylands do not own the land they till, hence, they do not have a strong incentive to adopt erosion control measures. Also, landholdings are highly fragmented and small. Thus, it is almost impractical to get the farmers to plant forest tree species because this reduces the area for food crop production.

Evidently, there is an urgent need for more research on agroforestry as an approach to erosion control and management, but the approach must cover a much wider front than the technical aspects.

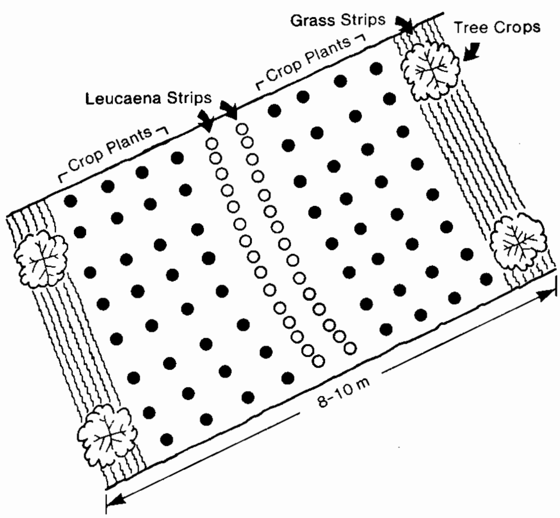

Fig. 2. Suggested tree-based farming system for sloping lands.

LEGUME-BASED PASTURE LIVESTOCK

This particular farming system shows promise as a strategy for marginal erosion-susceptible areas because it provides continuous cover to protect the soil against erosion, provided it is not over-grazed.

Sanchez (1982) reported that on well-managed pastures in Northern Australia, the organic matter content of alfisol was maintained. Soil erosion on properly managed pastures, with controlled grazing, is generally speculated to be not as serious as on arable lands planted to open-cultivated row crops (Lal 1982). However, there are no quantitative data available to support this argument.

On the other hand, excessive grazing resulted in denudation of the vegetative cover and accelerated soil erosion (Greenland and Lal 1977). Pereira (1973) reported 40% of rainfall lost as runoff from heavily grazed watersheds in East Africa. Rainfall penetration in overgrazed soils was shallower than in soils with controlled grazing.

TILLAGE

It is widely recognised that tillage, as a 'subsystem' of any farming system, significantly influences the magnitude of soil erosion. Rough cloddy surfaces increase infiltration and decrease soil erosion compared to smoother surfaces (Johnson et al. 1979). Rough surfaces decreased runoff by 77% and soil erosion by 89% of that from smooth surfaces. Tilling compacted soil (or wet soil) results in greater cloddiness than tilling uncompacted soils. To be effective as an erosion control measure, soil clods must be large enough and stable enough to keep infiltration at a high level until the crop canopy covers the surface soil.

Unger (1982) reported that one-way disk tillage resulted in significantly more water-stable aggregates than sweep tillage in both wheat-fallow and continuous wheat cropping systems. Johnson and Moldenhauer (1976) found that under wet to very wet conditions, chisel-ploughed plots had 50% less soil loss than moldboard-ploughed plots.

Despite the above claims, conventional methods of mechanical seedbed preparation have not been effective in controlling soil erosion even of terraced plots. Lal (1982) reported that the sediment load in water runoff from terraced and mechanically tilled plots was five times that from no-tilled plots (Fig. 4). No-tillage plots had higher organic matter content and infiltration rates than ploughed plots; thus, runoff and erosion losses were minimal (Lal 1976). Unger (1982) also found that the no-tillage cropping system resulted in sufficiently large and stable dry aggregates which were primarily responsible for reduced erosion.

Zero-tillage can reduce erosion if adopted along with a package of recommended cultural practices that may vary with different crops and soils (Lal 1982).

CROPPING

Cultural practices that support good crop growth go a long way toward reducing soil erosion. Farm practices such as optimum plant population, fertiliser application, and adequate crop protection minimise soil erosion problems (Hudson 1971).

Multiple cropping, intercropping or mixed cropping, relay cropping and rotation cropping minimise soil erosion. These cropping systems offer better and continuous vegetative cover which protects soils against direct raindrop impact.

Aina et al. (1977) observed a significant decrease in runoff and soil loss from a field of intercropped corn and cassava as compared to runoff and soil loss in a field where corn and cassava were planted separately (Table 1). Lal (1980) also observed significantly less runoff and soil losses from combined cropping than from monocropping. These findings indicate that the multi-storey canopy structure resulting from combined cropping offers an effective mechanism for cushioning raindrop impact. The upper canopy layer serves as the first intercepter and absorber of raindrop impact. As rainwater drips off the leaves, it is intercepted by the lower canopy layer so that when the rainwater reaches the soil surface, it is no longer erosive. Moreover, the roots of the component crops hold more soil particles in place, thus reducing erosion.

Moldenhauer et al. (1967) reported that land planted continuously to corn was significantly more susceptible to erosion than land planted to corn followed by a good grass-legume meadow, particularly in the seeding stage of the corn year. Lal (1976) stated that a suitable system of crop rotation combines those which leave adequate residue with those which leave inadequate residue to minimise soil erosion. Crops that do not leave a significant amount of residue on the soil surface cannot be grown continuously without causing deterioration of the physical properties of the soil.

Different crop species vary in their effects on

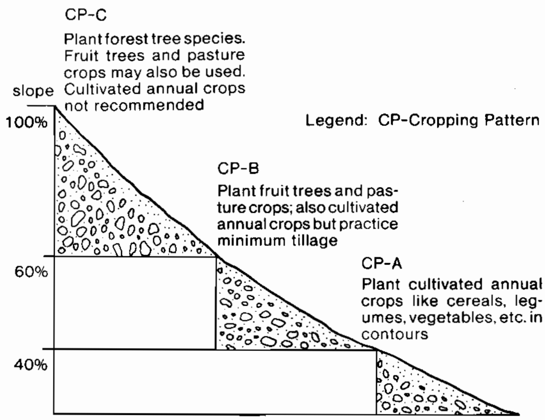

Fig. 3. Suggested cropping patterns for various degrees of hillside slopes.

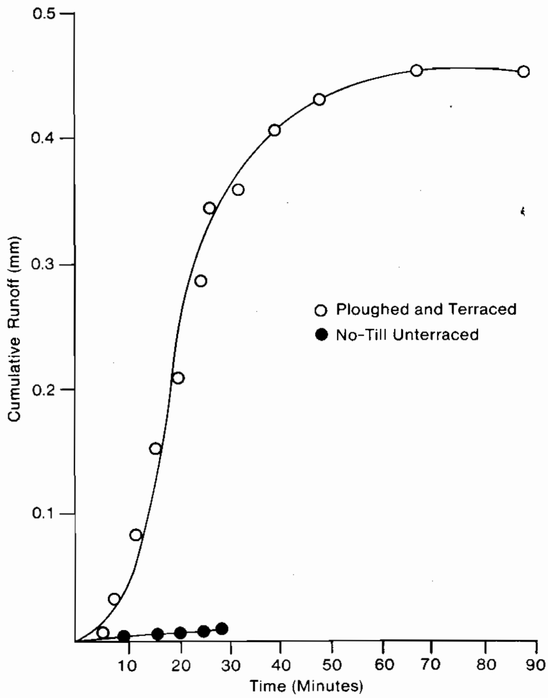

Fig. 4. Effects of tillage systems on runoff from a 23-mm rainstorm recorded at Ibadan, Nigeria, on 17 June 1979. Conventionally tilled 5-ha watershed is terraced whereas no-till watershed is not.

soil erosion, a fact attributed to differences in canopy and other morphological characteristics which result in varying degrees of roughness of the ground surface. Van Doren and Baver (1946) observed less runoff and soil loss in plots planted to soybean than in plots grown to corn because soybean developed an effective canopy earlier than the corn plants. A high amount of soil loss occurred during the first 2 months of corn growth. In another study, Gumbs and Lindsay (1982) found that monocrop corn and cowpea both reduced soil loss (<1 t/ha/annum) under low to moderately intense rainfall. Under more intense rainfall, however, cowpea was more effective than corn.

Bocato (1981) reported the following amounts of runoff for the various crops, as percentages of the total rainfall: sweet potato, 2.69; natural vegetation, 3.38; paragrass, 4.56; guinea grass, 6.61; centrosema, 7.04; stylo, 11.13; corn + stylo, 21.58; corn, 36.30; bare plot, 44.86.

Bare plots had the highest soil loss, with 22.87 t/ha for 3 months; corn plots came next, with 14.78 t/ha. Paragrass was the most effective in reducing soil loss, with only 0.07 t/ha.

Palis (1977) and Colting (1981) observed no significant differences in runoff and soil loss during the stages of crop growth. However, after 2 months the plots planted to grasses, grass-legume mixture, and sweet potato started to reflect less runoff and soil loss compared to the plots planted to legumes and bare plots. Orr (1970) reported that runoff and erosion rates decreased until cover density reached 60% (live vegetation + litter). This implies that a density of 60% is the minimum level needed to control runoff and erosion.

All these studies indicate that the rate of canopy development directly influences soil erosion. While soil loss is generally high during the early growth of the crop, it decreases slowly but steadily as the canopy develops and covers a greater area of the ground surface.

Crop spacing and other crop management systems such as mulching, changing the sowing dates of different crops, returning green and animal manure to the land, etc. are the other means of reducing soil loss (Schiller et al. 1982; Singer et al. 1982; Hudson 1982; and Sheng 1982). Singer et al. (1982) observed that soil loss decreased as straw mulch was increased from 0 to 96%.

At 96% cover, soil loss by splash transport was reduced to less than 8% of the bare soil loss, while interrill (rainflow) transport was reduced to 24%. Reduction in sediment loss by interrill flow was the result of reduced detachment by rain splash.

Table 1. Soil losses and runoff under cassava monoculture and mixed cropping of cassava and maize at Ibadan, Nigeria (Aina et al. 1977).

Slope (%)	Soil loss (MT/ha/annum)		Runoff (% of rainfall)	
	Cassava	Cassava/ Maize	Cassava	Cassava/ Maize
1	3	3	18	14
5	87	50	43	33
10	125	86	20	18
15	221	137	30	19

Spacing also plays a role in reducing soil loss. Adams et al. (1978) observed that sorghum planted in rows 50 cm apart established a more complete canopy earlier than sorghum planted in rows 100 cm apart. The former spacing arrangement provided more ground cover for much of the growing season. Narrow-row spacing increased ground cover significantly 35 days after emergence. At 63 days, ground cover was 81 and 46% for the narrow-row spacing and conventional spacing, respectively. Runoff and soil loss from the narrow-row spacing were 45 and 39% less, respectively, than runoff and soil loss from the conventional spacing.

Research Needs

Research information on the farming systems approach to soil erosion and control and management under Philippine conditions is scant. On the other hand, there is much information on the farming systems approach to soil management in termperate regions (Lal 1976). But while the principles of erosion and erosion control in temperate regions are transferrable and applicable worldwide, the application of conservation measures cannot be extrapolated to local conditions because of fundamentally different environmental and socioeconomic circumstances (Hudson 1982). Hence, more research must be conducted under local conditions.

Research is urgently needed in the following areas:

Development of acceptable agroforestry farming systems Scientifically, agroforestry is the best approach to rationalising soil conservation and management in slopelands. Changing intensive types of land use to less intensive ones like tree crop production can reduce erosion. However, the physcial problems (e.g. fragmented and small landholdings) and social problems (e.g. the urgent need to produce food crops for daily subsistence) involved demand that research cover a much wider front than the technical aspects.

Legume-based pasture/livestock farming systems research Legume-based pastures are a promising strategy in marginal erodible areas because they provide continuous cover to protect the soil against erosion. They also provide a cheap supply of feed for cattle. Studies are needed on optimum stocking rates; selection and/or breeding of productive, persistent and compatible pasture grass and legume cultivars tolerant to marginal soil conditions; and appropriate pasture management practices.

Evaluation of tillage techniques as sub-systems of a given farming system Seedbed preparation procedures and techniques must be evaluated in relation to the use of mulch and other simple conservation practices such as contour cultivation, grass strips, etc. Bench terracing would probably be the most effective practice, but it cannot be justified when the cash value of the produce is a fraction of the cost of constructing the terraces.

There is also a need to develop a package of cultural practices that will meet the requirements and exploit the potentials of zero-tillage as a method of seedbed preparation. Along with this, there is a need to develop tools which can make working and seeding on trashy uneven soil surface easier and convenient.

Cropping systems management research Cropping systems management has the greatest potential effect on erosion, and can generally be most readily changed by the land user to control erosion.

Location-specific farming systems must be developed to ensure a supply of crop residue mulch for continuous ground cover that will protect the soil against raindrop impact. Development of farming systems involves among others, research on innovative mixed cropping and relay cropping techniques; selection/development of compatible, fast-growing crop cultivars that develop canopies fast enough to cover the ground surface and leave adequate residue; and development of other appropriate cultural practices that support good crop growth and provide luxuriant and continuous ground cover.

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Upland Agriculture Development: The Central Visayas Regional Project-I Experience

Ed Queblatin*

THE Central Visayas region consists of the provinces of Cebu, Bohol, Siquijor, and Negros Oriental. It has a population of 4 million. The terrain is rugged; less than 15% of its total area has a slope below 18% and is ideal for agriculture. Central Visayas is an atypical region in the sense that its major source of income is industry, not agriculture.

Most of the people live in the rural areas. Sixty percent of the farmers derive their income from the uplands, and the average farm size ranges from 0.5 ha in Cebu and Siquijor to 2.0 ha in Negros Oriental and Bohol.

Farming systems have changed minimally from the traditional kaingin and lowland monoculture techniques adopted by early settlers. Cropping patterns are based mainly on corn, and, in some areas, upland rice. Intensive cultivation because of high population density, short fallow periods, and the absence of on-farm soil conservation measures contribute to the low productivity of the land (annual yield of 0.5 t of shelled corn from two crops is common). In addition, Central Visayas is one of the most severely eroded areas in the Philippines.

Institutional constraints to the adoption of appropriate upland farming practices include land tenure insecurity, highly centralised planning and budgeting, general lack of resource management awareness among farmers as well as government personnel, and jurisdictional problems over upland farming areas, particularly between the Ministry of Agriculture and Food (MAF) and the Bureau of Forest Development (BFD).

The Central Visayas Regional Project-I is a 5-year project, launched in July 1984 and supported by the World Bank (World Bank 1984). It represents the largest investment to date in upland agriculture and resource management. Concurrently, it is regarded as an acid test for regionalisation. Success or failure could spell the government's final attitude towards decentralisation.

The CVRP-I seeks to achieve the following objectives: (1) to assist forest occupants and marginal upland farmers and municipal fishermen in selected pilot areas; (2) to foster community-based resource management in these areas to arrest rapid environmental degradation; (3) to reinforce the government's regionalisation program to ensure greater administration/budgetary autonomy for the region, direct the timely flow of development funds, and maximise participation of local officials and project clients.

Upland Agriculture Component

The project's Upland Agriculture Component is implemented in four watershed areas†. The major goal is to assist upland farmers in a sustained transition from monoculture of staple crops to stable systems utilising perennials, livestock, etc.

Key activities of the component include: (1) deployment of a site management unit in each project area that will live and work with farming communities, provide on-farm technical assistance (utilising simple technologies), and assist in community building; (2) provision of planting materials, farm tools, and other basic farm inputs and improvement of farm-to-market roads; (3) provision of land tenure security through stewardship contracts; (4) strengthening of relevant support service units of the regional offices of the Ministry of Agriculture and Food and the Bureau of Forest Development through greater delegation of administrative authority and budgetary support for incremental manpower and logistics; and (5) farming systems research to back-up on-site implementation problems.

Strategies and Initial Experience

While many of CVRP's individual staff have had substantial experience in agroforestry-related

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† The other CVRP-I components are nearshore fish habitat management and social forestry which involves community-based forest resource management and utilisation.

projects, the CVRP's experience itself is limited. The CVRP started as a small pilot project in Barangay Magsaysay, Talibon-Bohol in August 1983. Full implementation is to begin in July 1985 concurrent with the deployment of trained Site Management Unit (SMU) staff.

During the almost 2 years of project preparation, CVRP gained insights into the successes and problems of on-going projects within and outside the region. Some of these projects within the region are the following: (a) BFD reforestation projects, particularly the Southern Cebu Reforestation Project, Argao, Cebu; (b) World Neighbours Soil Conservation Project in Guba, Cebu City and Suyac, Argao; (c) MAF corn-ipil-ipil cropping systems in Barili and Catmon, Cebu; (d) ViSCA Agroforestry Extension Projects in Eastern Visayas; and (e) Philippine American Timber Corporation Agroforestry Operations in Ayungon, Negros Oriental.

The following discussion, while largely reflecting the CVRP experience and strategies being contemplated, will also include lessons learned from other projects in the region. Discussion will focus on the following critical issues: (1) extension strategies for soil conservation; (2) cropping systems development; (3) land tenure; (4) decentralisation and devolution; and (5) personnel deployment.

PROMOTING SOIL CONSERVATION

While CVRP-I is being implemented in four watershed (open, upland) areas, project activities are not primarily meant to support irrigation projects. The decision to implement the project in watershed areas was made to demonstrate the effect of upland resource management on lowland activities, e.g. nearshore marine fish habitat management. There is no specific investment in irrigation. This allows project design, particularly at the site level, to be aligned closely with situation-specific needs at the community and farmer level.

There is no attempt at the moment to neatly assign specific land uses or zones within the watershed, as this is almost futile. For instance, right now no one can convince the farmer who plants corn on a 100% slope to shift to ipil-ipil immediately as this is a survival issue. The project recognises that the upland farmer makes the day-to-day decision that will eventually affect the upland resource—not the policymaker miles away in Manila or Cebu. Project operations, therefore, focus on the individual farmer and his farm.

Project-sponsored technologies are deliberately made simple. Technologies revolve around: (1) *soil conservation*—using an A-frame to determine contour level lines and constructing vegetative hedgerows, stonewalls, contour ditches on the farm; (2) *soil fertility enhancement*—composting, green manuring, etc.; (3) *farm diversification*—incorporation of legumes, livestock, and trees in the farming system.

The project shares the view of many that the upland farmer has taken care of himself longer than development agencies have focused on his concerns. Thus, while recognising that hillyland development will eventually include many components, the project has opted to begin by setting two or three targets and concentrating on these targets until a reasonable degree of accomplishment has been attained. The project hopes to make a mark in community mobilisation, so that succeeding stages in the development process, i.e. social services, may be best identified and resolved by the farmers themselves.

By limiting and simplifying the technology, the project hopes to increase adoption rates. The A-frame, for instance, is very easy to learn and easily adopted by the critical mass of project clientele. In Barangay Magsaysay, Talibon, Bohol, more than 80% of farmers have adopted soil conservation measures using the A-frame, within a year and a half. In Barangay Cang-apa, Larena, Siquijor, a 35% adoption rate was reported within 4 months of extension work.

Having successfully promoted soil conservation activities in Barangay Magsaysay, the project is now promoting the second level set of technologies, e.g. organic manuring and crop diversification.

The early enthusiasm shown by CVRP-I clientele in adopting soil conservation measures may be attributed to a lot of factors:

(1) The farmers are involved in defining their own problems and identifying solutions.

(2) The farmers are made to understand the value of soil conservation not so much to lowland concerns, e.g. irrigation and flooding, but more to the actual farmer.

(3) Available solutions being promoted (such as using A-frames, ipil-ipil hedgerows, etc.) are evidently simple and can easily be mastered by farmers.

(4) The farmers do not have to adopt a whole set (package) of technologies at once. Rather, technology is promoted on a step-by-step basis, e.g. soil conservation, first; organic manuring, second; crop diversification and livestock, third; tree crops, fourth; etc.

(5) Technologies promoted use available resources in the community. In the Bohol site, madre de cacao leaves, not ipil-ipil, are promoted as organic manure; ipil-ipil does not grow well in acidic soils. Inorganic fertilisers and chemicals are not recommended.

(6) Soil conservation technology is tied up with other farming concerns, e.g. using napier grass with ipil-ipil as hedgerows which is very attractive among smallhold livestock raisers. In fact, in two project barangays, it is suspected that farmers have adopted soil conservation because field implementers made it a condition for receiving napier grass.

(7) The project avoids a strong identity, so that field personnel assume the role of catalysts in the identification of community problems and the formulation of barangay action plans by client communities. CVRP-I objectives are incorporated in these action plans prepared by the community.

(8) Field personnel stay at the project sites to live and work with the farmers. Personnel credibility is built primarily by consistency in work and action. This includes participation in farmwork. Farmers in two areas (one of which was not a project area), when asked why they adopted soil conservation practices in spite of their insecure land tenure, explained that their extension agents sweated it out with them in farm work.

(9) The project avoids the creation of new farmer organisations unless the farmers feel and demonstrate a concrete need for them. The project is building the barangay development council for planning and management, as well as indigenous farmer groups called alayons, which involves labour exchange for land preparation. Each member of the alayon spends 1-2 days a week to help in backbreaking soil conservation work.

(10) Early adopters who are articulate are tapped to convince and train other farmers. This year, advanced farmers are being asked to train other farmers on soil conservation. This allows project personnel to give more attention to promoting the second set of technologies, i.e. organic manuring.

(11) Demonstration farms are carefully selected so that they do not belong to just one farmer. Otherwise field personnel run the risk of being accused of favouritism by other farmers. Project personnel avoid being associated solely with the more advanced, articulate farmers. There is a conscious effort to reach out to the silent types.

(12) Particularly in areas where there are fears that land planted to trees may eventually be taken over by government, the project has initially avoided a strong emphasis on tree crop development. Rightly or wrongly, the image projected by SMU personnel as agriculturists and not as foresters appears to help diminish the prejudice against tree crops.

CROPPING SYSTEMS IMPROVEMENT

Soil conservation is only the first solution to the problem of low productivity. CVRP-I recognises the need to promote farm diversification that is both 'productive and protective' (Sajise 1984). Gains achieved in cropping systems improvement are the best incentive for farmers to maintain their soil conservation structure.

Project plans call for the SMU to appraise existing cropping systems and design cropping improvements appropriate to farming conditions. A rapid rural appraisal method is used by the SMU to diagnose the farming situation in the area.

The rural appraisal method is derived largely from farming systems research (FSR) methodologies developed by several international agricultural research centres. These surveys are not done just to gather data for planning and research purposes. They are also used as opportunities for building community enthusiasm. For instance, farmers feel very challenged when consulted in plotting out rainfall data and existing cropping patterns.

The rapid rural appraisal surveys being conducted by the SMUs are problem-oriented. The appraisal is designed to yield only the most useful data needed by the SMU to gain a reasonable understanding of the farming situation in a shorter period than what it usually takes with the use of the formal socioeconomic surveys. This strategy enables the SMU to make its first concrete contributions to the community as early as possible.

The design for possible improvements in existing cropping systems is done according to several guidelines, among which are: (1) not tampering with the staple crops; rather introduce other crops that may be intercropped, relayed, or rotated with the staple crop (Celestino 1983); (2) determining periods of lean food supply and high labour surplus and designing a cropping calendar so that food and income from the farm is evenly distributed throughout the year (Raros 1984); and (3) ensuring that every existing farm practice has a good motive; this must be captured and reflected in the farming system design. For example, in Cebu, corn is usually grown farther apart than the recommended distancing. A hill, however, would contain up to five plants. The farmers gave three reasons for this practice: (1) land preparation is very laborious (the only tool used is a crowbar); (2) farmers expect only one to two cobs from a hill; and (3) the stubble from unproductive plants is needed for livestock fodder.

Particular care is taken to explain to the farmers that these promising technologies, while successful in other sites, may not be applicable in the area and must therefore be tested first. The community then decides which of the innovations they would want to try out. A site is subsequently selected by the community as an area where mature technologies, like soil conservation, are demonstrated and where promising cropping improvements are tried out on a small scale (e.g. on a 20 × 5 m plot).

The tests are done within the strips to be stabilised and involve only two treatments: the existing practice as control and the proposed innovation as the second treatment. Tests conducted so far include: (1) the use of madre de cacao leaves (*Gliricidia* sp.), ipil-ipil (*Leucaena leucocephala*) as organic manure for upland rice and corn; (2) testing of new crops, like kadios (*Cajanus cajan*), mungbean, and peanut; (3) testing of improved varieties of upland rice, corn, and sweet potato; (4) improvement of plant density for corn; and (5) additional trials involving intercropping, relay cropping and more complex innovations (which will eventually be conducted with the assistance of the MAF research staff).

Why would farmers want to try out innovations they have never seen work before? Credibility of project personnel has a lot to do with this. Also these innovations do not involve credit or huge capital inputs and are tried out only in a small area.

A key indicator of future project success would be for farmers themselves to eventually acquire the interest and skills in conducting their own testing and innovations and to sustain productivity even after the withdrawal of project personnel.

LAND TENURE

The relation between the land tenure insecurity and reluctance of farmers to adopt appropriate practices requiring long-term investment is well documented. Many Central Visayas upland farmers occupy timberland areas. Farm parcels are 'owned' by 'pseudolandlords' which largely include both influential and ordinary residents in the lowland areas or town proper. These landlords pay real estate taxes to the local government in the hope of future land release and titling. Accepting real estate taxes on lands within timberland is illegal (P.D. 705), but it is apparently being tolerated for obvious reasons.

Government policy (LOI 1260) today recognises those who were once considered illegal forest occupants as partners and stewards in forest resource management. Fifty-year stewardship contracts are provided to actual tillers of the open upland areas nationwide without prejudice to existing relations between pseudolandlord and tiller.

CVRP-I facilitates the application of stewardship contracts in its project areas under the following assumptions and guidelines: (1) stewardship contracts are unpalatable not only to pseudolandlords but also to local governments. The latter could lose income from taxes which pseudolandlords are now paying. In this connection, CVRP is presently gathering hard data that will quantify how much the local government stands to lose from unpaid taxes versus the potential increase in farm income from farmer beneficiaries of stewardship contracts; (2) stewardship contracts should not be awarded in a hurry but hand in hand with the building of the farmer's interest in the potential of his land and the confidence that he can actually achieve this potential (Gapas 1984); (3) recognising the need for immediate tangible evidence of security, certificates of land occupancy will be issued immediately and until the farmer is ready to enter into stewardship contract (see item 2). Concurrently, the timing of other project activities is being reviewed to complement this process. For instance, road construction which could spark renewed speculation among lowlanders in timberland areas will be kept at low levels until existing occupants have acquired their tenure security.

For instance, the project team at the Cebu project site had decided to postpone discussion on stewardship contracts for several reasons: (1) the pseudolandlords occupy the barangay leadership; a good number are relatives of some tenants themselves; (2) landlords are perceived as benefactors particularly in times of cash shortage; (3) most farmlands are marginal; many farmers are resigned to their low corn yields and the infertility of the soil; (4) the project team has yet to prove that the land can be improved and is therefore worth protecting and fighting for; (5) the team has yet to prove that it can be relied upon by farmers in the case of land conflicts.

DECENTRALISATION AND DEVOLUTION

CVRP-I is also designed to pilot a model for the government's regionalisation program. Region VII was chosen because at the time the government started to think seriously about a regional pilot project, the project had already prepared its regional development and investment program (RDIP). Regionalisation requires both decentralisation of government authority and devolution. The latter involves an increase in the capability of regional offices to assume greater responsibilities.

The atypical regional economy requires decentralisation, since many national programs have a limited application in the region. For instance, a predominantly rugged topography limits Masagana 99 coverage. In the fisheries sector, the Biyayang Dagat program encountered the problem of a very low repayment rate because the local fishery resource was already depleted.

Decentralisation is also badly needed in resource allocation. One of the World Bank loan conditions to CVRP-I is for Ministry of Natural Resources and Ministry of Agriculture and Food to delegate to the regional offices such powers as the authority to issue permits and leases to enter into service contracts, receive budgetary allocations directly, and to issue licenses and permits for forest product utilisation.

Decentralisation to the regional level will make possible further delegation of authority to the district level. The implications are wide-ranging. A small farmer in a remote barangay in Siquijor, for instance, hopes that the next time he cuts down a tree for house repair, a tree which he planted himself, he does not have to undergo the tedious process of tree inspection and having his permit approved by the subdistrict office and finally by the district office in a separate island (Merced 1984).

On the other hand, having been entrusted with additional powers, regional offices are aware that the national offices are keenly observing how they are faring. Mistakes could cost a reversal to centralisation.

The following steps are being taken to hasten devolution: (1) the Regional Development Council is being sustained as a regular forum for continuing interaction between line agencies and local governments; (2) the Provincial Agricultural Councils are being mobilised as mandated under P.D. 803; (3) ad hoc interagency technical committees, such as those under the umbrella of the Philippine Council for Agriculture and Resources Research and Development (PCARRD) Technopack Project, are being sustained, particularly along the areas of upland agriculture and mangrove management; (4) the CVRP-I management seeks to reduce the volume of foreign technical assistance requirements and implement a policy of attraction for technical personnel who are natives of the region, but currently employed elsewhere; and (5) a substantial investment in manpower training is being undertaken.

PROJECT PERSONNEL

CVRP has invested substantially in training the people who now compose the core staff of its site management units.

SMU trainees were trained on community development management, as well as on concepts and skills in upland agriculture development. Training on community development focused on social preparation and included a list of 'do's' and 'don'ts.'

On the whole, the training was probably more of an unlearning experience for the trainees. For instance, many of the assumptions on which development programs for lowland agriculture was based were scrutinised from new perspectives, such as from those of ecological balance and economic nationalism.

Recommended Research Areas

The following areas provide fertile ground for future research:

(1) *What would be an appropriate research methodology for hillyland farming systems?* Such methodology should include: *a.* a rapid community appraisal technique that can be appreciated and mastered by field level personnel, particularly field level researchers and extensionists. This technique will be used to obtain and analyse community and farm level data as a basis for making recommendations appropriate to the community situation; and *b.* simplified techniques for on-farm experimental design and testing to allow maximum farmer understanding and participation.

(2) *What kind of field implementing personnel would be needed for community-based upland projects?* Professional community development workers who will be trained on technical tasks or technical people trained on community development.

(3) *What specific strategies must be undertaken to attract and retain the best talents to run foreign-assisted upland agriculture projects, considering that foreign assistance does not shoulder personnel services and that the government of the Philippines (GOP) wage ceilings are unrealistic?*

(4) *How much would MAF gain or lose if it went all out to support upland development in the predominantly upland Region VII instead of implementing national commodity program, M99, which has limited application due to small lowland areas?*

(5) *How much do local governments expect to lose if pseudolandlords stop paying their taxes when stewardship contracts are issued to actual occupants?*

(6) *How do relationships between the hillyland farmer and his landlord really work?* Why and how should tenurial relationships in uplands be differentiated from those in lowland rice-growing areas.

(7) *What cropping systems can tolerate and eventually alter acidic conditions in cogon-dominated areas without necessarily resorting to liming?*

(8) Additional information is needed on native species that can be used simultaneously as soil conservation hedgerows, organic manure, and livestock feed, e.g. madre de cacao, *Desmodium*, napier grass, salago (*Wikstroemia* spp.), katuray (*Sesbania* sp.), malunggay.

(9) *How can livestock be best integrated into marginal hillyland farming systems? In addition to utilisation of farm wastes, how can improved pastures be actually incorporated into existing cropping systems?*

Conclusions

CVRP-I innovativeness stems from the following key features: (a) it is a *resource management* project, not just a *resource utilisation* project; (b) the farmer is recognised as the *de facto resource manager*; (c) *simple appropriate technologies* within the capability of project clients will be applied to achieve resource management objectives; (d) the authority to plan, make decisions, and implement these decisions will be *decentralised* from Manila to Region VII. Decentralisation will make it possible to achieve integration of government services at the local level; and (e) project implementers will no longer be accountable solely to central ministries, provincial governors, and regional directors. They will also be *directly accountable to project clients.*

CVRP-I is obviously only the first phase of a long-range program for resource management vis-a-vis regionalisation. Success or failure can spell future government policy on regionalisation. At the moment, funds earmarked for a similar regional project in two other regions are being held until CVRP-I yields favorable results.

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Farming Systems and Soil Management: the Philippines/Australian Development Assistance Program Experience

Terence E. O'Sullivan

ZAMBOANGA DEL SUR (ZdS) is, for the most part, geologically recent. Much of its agricultural land is steep and of volcanic origin. Ridge and V-valley land forms and basalt hills make up two-thirds of the land surface. The area has been cleared since World War II. Today, only 16% of its forest remains. This is grossly excessive exploitation. The national target for areas under natural forest is 42%. Rainfall exceeds 3000 mm/year in the eastern part of ZdS and is around 2000 mm/year in the west.

Farmers testify to a decline of 80% in corn yield over a period of 15 years. A comparison of the present and former levels of soil on exposed boulders or core stones shows a loss of up to 1 m of soil.

These recent limestone, basalt, and andesitic soils constitute a vast resource which is disappearing at a frightening rate.

Land Resource Study

The Zamboanga del Sur Development Project of the Philippine Australian Development Assistance Program (ZDSDP/PADAP) commissioned a land resource study in April 1982 which included rephotographing the province. The study was completed by the Bureau of Soils under the guidance of John McAlpine of Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO). This study places the province in a strong position to plan resource utilisation. The implementation of such plans is, of course, quite a different matter. Nevertheless provincial planners are using the data and agriculturalists have found it very useful in determining priorities. Studies such as this must be prerequisites to any development planning.

AGROFORESTRY PROJECT

In 1981, a project was initiated which recommended that farmers plant ipil-ipil (*Leucaena leucocephala*) in contoured rows while conducting their farming in the intervening bays. The idea was used elsewhere in the Philippines and about 20 demonstrations were set up.

In mid-1982, a project was planned based on experiences at the Rural Life Centre, Kinuskusan, Bansalan, Davao del Sur. The system at Bansalan is called Sloping Agricultural Land Technology (SALT). Two counterpart agencies were identified, the Bureau of Forest Development (BFD) and the Ministry of Agriculture and Food (MAF), because the responsibility for land development in the Philippines is divided between BFD and MAF on the basis of slope.

Lands under 18% slope are deemed 'alienable and disposable.' These lands are classified and declared not to be required for forest purposes. Lands over 18% are deemed 'not alienable and disposable' and are held by the BFD under various forms of tenure.

Recently, the BFD introduced a system of tenure for lands with a slope of over 18% under the National Integrated Social Forestry Program. This system is called the stewardship lease. A stewardship lease is granted for a maximum of 7 ha and may be inherited but not sold. It is renewable at the end of 25 years. The stewardship lease is meant to stabilise the nomadic farming of kaingeros (kaingin-swidden) and strengthen food production and reafforestation efforts.

The agroforestry project of the BFD and the Hillside Farming Project of MAF have similar farming components. Both promote the production of corn, mungbeans, and peanuts in contour bays between double-row hedges of ipil-ipil. The crops are mulched with cuttings from the hedges and the process is called alley cropping.

The projects are implemented by a staff of 50 who conduct a major BFD project, while a staff of less than 10 run a minor MAF Project. There are more than 200 half-hectare demonstration

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farms, supported by a vigorous extension program.

Research Program

A long-term experiment was begun in May 1981 to determine the effect of alley cropping corn with ipil-ipil. The latest harvest was the seventh, coming from the first cropping season for 1984. The yield of corn planted after peanuts was also measured. The eight treatments used are described in Table 1.

The plot size was 8 × 8 m. In the alley-cropped plots, rows of ipil-ipil containing around 80 plants/m were grown at plot edges and between replications. Interrow spacing of corn was 75 cm.

Eleven rows were harvested from treatments 3 to 8 while eight rows were harvested from treatments 1 and 2. Corn was harvested from 48 m^2 in treatments 1 and 2 and from 64 m^2 in treatments 3 to 8. Thus, in the alley cropping system represented by treatments 1 and 2, the ipil-ipil hedges occupied 25% of the plot.

A separate area was set aside to produce ipil-ipil for use on plots which were not alley cropped.

At intervals the hedges were pruned to a height of 45 cm, and the clippings weighed and spread uniformly along the rows in the mulch treatments. The current practice is to apply the first lot of clipping during land preparation and the second lot just prior to the hilling-up operation.

Fertiliser was applied to half the treatments at the rate of 100 kg N/ha and 40 kg P_2O_5/ha on corn and 20 kg N/ha and 20 kg P_2O_5/ha on peanuts.

Yield data are expressed in terms of system yield. Thus plot yield from treatments 1 and 2 has been adjusted to full plot size (64 m^2) and expressed in tons per hectare. A table of actual yields from treatments 1 and 2 is not included. This gives an accurate measure of the outcome from applying ipil-ipil mulch. The figure for actual yield can be determined from the yield figures in Table 1 by applying a factor of 0.75 to the figures for treatments 1 and 2.

Table 1. Effect of intercropping and mulching ipil-ipil on corn yield.

	1982[a]				1983[a]				1984[b]	
	First crop[c]		Second crop[c]		First crop[c]		Second crop[c]		First crop[c]	
Treatment (t/ha)	Ipil-ipil	Corn yield	Ipil-ipil	Corn yield	Ipil-ipil	Corn yield	Ipil-ipil	Corn yield	Ipil-ipil	Corn yield
Corn-Corn Intercropped with ipil-ipil										
1. + N, P	36.17	1.03	14.26	3.29	11.20	3.25	7.70	2.38	14.68	2.13
2. − N, P	27.43	0.30	11.46	1.58	11.50	1.74	6.70	1.00	14.01	1.00
Corn-Corn Transported ipil-ipil										
3. + N, P	12.53	1.64	6.22	2.93	6.10	3.11	2.60	1.98	5.58	2.11
4. − N, P	11.24	0.24	5.70	0.99	5.40	1.27	2.30	0.42	6.18	0.34
Peanut-Corn (no mulch)										
5. + N, P	nil	(3.67)	nil	2.95	nil	(1.35)	-	1.62	-	n.a.
6. − N, P	nil	(3.63)	nil	1.50	nil	(1.20)	-	0.42	-	n.a.
Corn-Corn (no mulch)										
7. + N, P	nil	1.52	nil	2.57	nil	2.95	-	1.58	-	1.93
8. − N, P	nil	0.30	nil	0.90	nil	0.81	-	0.32	-	0.30
L.S.D. (P=0.05)	3.47	0.29	1.80	0.46	6.9	0.3	0.7	0.26	2.3	0.37
C.V. (%)	10.0	23.0	12.0	15.0	12.0	10.7	10.0	14.1	14.3	18.8

[a] Source: Dofeliz and Nesbitt (1984).
[b] Dofeliz and Nesbitt (unpublished data).
[c] Corn yield from treatments 1 and 2 are multiplied by factor 1.33 to account for plot size differences between treatments 1 and 2 and treatments 3 to 8.
( ) Figures in parentheses are peanut yields from first cropping period.

Results

There were no significant differences among the treatments until the fourth phase which was the second cropping of 1982 (Table 1). From that time, corn yields were consistently higher in treated plots than in control plots. This could be attributed to the mulching effect of ipil-ipil. Results obtained from 1982 to the present are summarised in Table 1.

The last two cropping phases, phases 6 and 7, showed that trimming ipil-ipil hedges twice during a corn crop and using these trimmings as mulch resulted in a three-fold increase in yield over the control. A further treatment provides comparative data on corn following peanuts.

Soil Conservation

Cropping system trials were complemented by soil conservation studies. Observations showed that runoff water was depositing its silt load on the bottom side of the cropping alleys. Indeed, some older demonstration areas showed that terraced profiles were developing quite rapidly. On some sites, the difference in level from the upper side of a *Leucaena* line to the lower side was as much as 1 m.

The demonstration provided a working base for a soil conservation study undertaken in October 1984 to assess the effectiveness of contour hedges of ipil-ipil as a soil conservation method.

The Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) was used to compare alley cropping with the conventional cropping pattern of corn-corn, the most common cropping pattern in Zamboanga del Sur (Denning, 1980).

The equation was applied to a representative slope of 23.6% selected from 10 demonstration sites. The site consisted of seven alleys. The contour strips of ipil-ipil were established in June 1982.

A typical alley on this slope is 4.5 m wide with the ipil-ipil strips 1.5 m wide (Fig. 1). The depositional area covers the lower 1.5 m of the alley.

The slope is even and slightly convex in the transverse section. There has been little concentration of runoff down the slope and little run-on water at the top. The soil is a friable red-brown gradational soil formed on basalt.

Corn was planted on April 15 and on September 1. The crop was mulched with *Leucaena* prunings at 2 weeks and 8 weeks from planting. Each application was 600 kg DM/ha.

Table 2. Computed values of LS, C and P[a]

USLE factor	Cropping system	
	Conventional	Alley cropping
LS	17.3476	15.8313
C	0.4846	0.2222
P	1.0000	0.9500
LSCP	8.4066	3.3418

[a] Source: Shepherd 1984 (unpublished data).

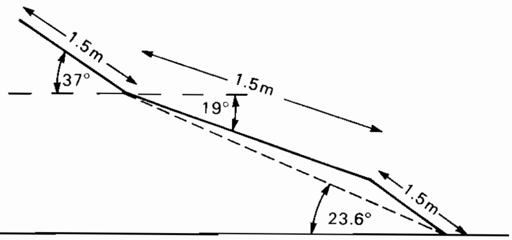

Fig. 1. A longitudinal section of a typical alley.

The use of the USLE is justified on a comparative basis. Absolute quantities were not computed because of the absence of data on rainfall intensity (R) and soil erodibility (K) which are site specific. The equation was applied to analyse the remaining factors, all of which could be either measured or reasonably estimated.

Table 2 shows the computed values from the USLE, $A = R\ K\ L\ S\ C\ P$ where

A = the computed soil loss per unit area
R = the rainfall and runoff factor — measure of rainfall, i.e. Energy times Intensity (E.I.)
K = the soil erodibility factor, and is the erosion rate per unit of rainfall, E.I.
L = the slope length factor
S = the slope gradient factor
C = the cropping management factor
P = the erosion control practice factor

Results showed that under the alley cropping system with mulching, soil erosion is reduced by 60.2%. Of this, 48% can be attributed to the land covered by ipil-ipil, the depositional area introduced into the system, and the mulching effect. The remaining 12.2% is attributed to the changed profile caused by deposition (7.75%) and contour working (4.43%).

Two other soil conservation techniques have been used in Mindanao, and these were included in a desk study. The techniques are zero tillage and companion cropping. The soil conservation study showed that zero tillage results in a reduction in erosion comparable with the reduction that results from the alley cropping system (60.9%).

Companion cropping with a dense ground cover of hetero (*Desmodium heterophyllum*) dramatically reduces soil erosion. A technique of cutting a swathe through the hetero sward at 1 m intervals and planting corn in the clean area without tillage is being used at the Rural Life Centre, Bansalan, Davao del Sur. Yields comparable with that of alley cropping have been obtained.

A table of erosion susceptibility under different cropping patterns and management practices was developed using data gathered in ZdS. The ratings (Table 3) were made when the conservation methods were imposed, i.e., alley cropping, zero tillage and, in the case of corn-corn, companion cropping with hetero. Ratings were based on a scale in which areas under native rain forest are least prone to erosion, and a bare fallow in weed-free seedbed conditions is most susceptible to erosion. All combinations of cropping patterns and management practices must lie between these limits.

Table 3. Erosion susceptibility of areas under different cropping patterns and conservation practices.

Rating (%)	Land use option
0.1	Native rainforest
0.7	Permanent grass/legume pasture
1.7	Corn/corn, zero-till planted into a companion crop of hetero + contoured ipil-ipil
2.0	Corn/corn, zero-till planted into a companion crop of hetero
9.1	Corn/corn, zero-till planted and contoured ipil-ipil
9.1	Upland rice/corn; conventional rice; zero-till planted corn and contoured ipil-ipil
9.1	Upland rice/legume; conventional rice; zero-till planted legume and contoured ipil-ipil
13.3	Legume/corn; zero-till planted and contoured ipil-ipil
13.4	Upland rice/corn; conventional tillage and contoured ipil-ipil
16.3	Mungbeans/peanuts/corn; conventional mungbean, zero-till peanut and corn and contoured ipil-ipil
17.5	Upland rice/legume; conventional tillage and contoured ipil-ipil
18.9	Corn/corn; zero-till planted
18.9	Upland rice/corn; conventional rice and zero-till planted corn
18.9	Upland rice/legume; conventional rice and zero-till planted legume
19.3	Corn/corn; conventional tillage and contoured ipil-ipil and crop mulched with ipil-ipil
21.9	Corn/corn; conventional tillage and contoured ipil-ipil
25.3	Legume/corn; conventional tillage and contoured ipil-ipil
28.7	Legume/corn; zero-till planted
29.1	Upland rice/corn, conventional tillage
35.5	Mungbeans/peanuts/corn; conventional mungbean zero-till planted peanut and corn
38.3	Upland rice/legume; conventional tillage
48.5	Corn/corn; conventional tillage
56.6	Legume/corn; conventional tillage

Source: Shepherd 1984 (unpublished data).

The Future

PADAP has attempted to develop stable and productive farming systems for Zamboanga del Sur. There are several useful options resulting from the PADAP agronomic research and soil conservation studies.

The project presently offers farmers credit-backed cropping patterns based on local research and experience. This program is called the Multiple Cropping Production Program. Credit is offered to client farmers. Crops and practices that the program considers creditworthy are defined. A repayment rate of between 80 and 90% over 11 cropping seasons has been achieved for 1000-1500 farmers per cropping.

Maisan 22 is being considered for credit. Maisan 22 is a program for growing corn, alley-cropped with ipil-ipil, over three seasons. In the first season, the farmer plants the ipil-ipil contours and grows corn with two bags of fertiliser provided on credit. In the second crop, he will cut some ipil-ipil; so he will be provided with seeds and one bag of fertiliser on credit. In the third cropping he will receive seeds only. On Shepherd's scale (Table 3), this mix of cropping patterns and management practices receives a rating of 19.3%.

Assuming this scale provides an acceptable level of erosion control, all better land use options must rate less than 19.3%.

The cropping pattern of mungbeans, peanuts, and corn rated 16.3%, has been tested in farmers' fields. This cropping pattern is very profitable and is particularly appealing because the second and third crops can be planted without tillage. With further testing, this pattern may become creditworthy.

All the cropping patterns beginning with upland rice and followed by a zero-till crop are very attractive. Investigations with HYV rice have shown that a zero-till second crop is subject to unacceptable weed population. More recently, the production program has switched over to a local rice variety which is tall. Weed growth underneath a tall local variety is less than with HYVs, and prospects for zero-till may be better.

Perhaps the most interesting variation at present is companion cropping with a prostrate but not viny legume. Two corn crops have been produced with hetero at Bansalan, Davao del Sur. On Shepherd's scale (Table 3), ratings of 1.7% with ipil-ipil strips included and 2.0% without ipil-ipil are extremely attractive. Even more appealing is the prospect of disposing of the cumbersome ipil-ipil hedges and removing the labour-intensive and very demanding task of trimming and spreading the hedges.

Zero tillage and companion cropping could be the most intriguing aspects to be considered in the future. The 1978 PADAP livestock survey in ZdS showed that 51.6% of the farmers did not own a carabao. Zero-till is therefore a relevant option. One of the challenges for future research is to consider various species of legumes which could be used for companion cropping in various agro-environments.

Until then, alley cropping with ipil-ipil will be a most effective erosion management tool.

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Soil Erosion and Ecological Stability

Enrique P. Pacardo*

SOIL EROSION is defined simply as detachment and transport of soil. It is inevitable in the tropics whenever natural vegetative cover is replaced by commercial farming (Lal 1979), consumed by grazing animals, or removed by engineers undertaking construction work.

Some indigenous systems of upland farming in the Philippines result in minimal erosion. Examples are the Ifugao rice terraces in Mt. Province and those farming systems which involve perennial crops. Other systems that use annual crops such as rice and corn usually result in high soil losses.

Soil erosion is a destabilising factor in all agroecosystems, for when the soil goes, so do the soil nutrients. The effect of soil erosion can be felt upstream and downstream, particularly in lakes, dams, and low-lying fields.

In spite of the serious environmental problems posed by erosion. I am not aware of any concerted effort at the national level to develop and implement an aggressive program on erosion control in the Philippines. One of the reasons may be the limited perception of the causes and consequences of erosion by farmers, farm managers, policymakers and researchers. Most people are generally not aware that agricultural technologies affect not just the land being exploited but the rest of our environment as well.

This paper presents a conceptual model showing the interrelationship of technology, environment and society. It also cites specific cases of traditional and modern technologies wherein such an interrelationship leads to the stability of an agroecosystem.

A Conceptual Framework

An agricultural enterprise represented by management has certain responsibilities to itself and to its stockholders. To discharge these responsibilities, management adopts strategies based on organisational structure and policies.

The enterprise has a set of objectives. The fundamental one is survival, but in a changing world, growth is imperative. Growth may be qualitative or quantitative. Such growth depends on profit or surplus. To realise these objectives, management undertakes certain activities in order to generate products. The environment in which these farming activities take place is initially the technological environment, but soon these activities create an impact on the economic environment.

The erosion caused by the technology and the demand for more resources affects the biophysical environment, e.g. the nutrient balance in the soil (Fig. 1). When certain activities in the biophysical environment are curtailed, the cultural environment is also affected. Eventually, the effects of the technology filter down to the social environment. Through individuals or various active groups, the technology produces an impact on the political environment which in turn puts pressure on technological choice.

Because of this projected impact, agricultural

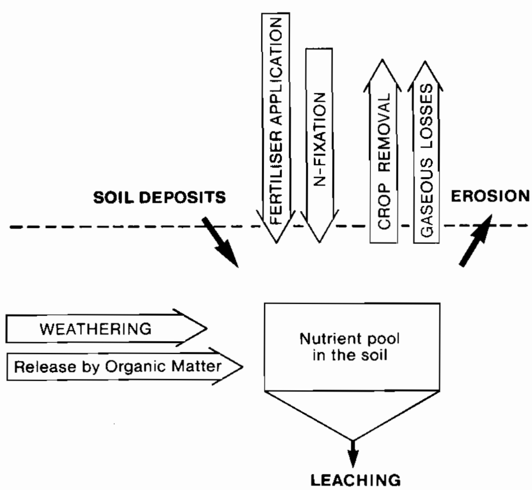

Fig. 1. Nutrient gains and losses in soils.

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management must conduct an environmental impact assessment before undertaking projects. Management must also conform with erosion legislation if there is any.

Projects may be constrained by resource shortages and land use regulations. Agricultural products can be threatened by product liability legislation. Thus, the whole gamut of activities of the management can be imperiled and its objectives of survival, growth and profit threatened. In response, management must be able to change its attitude and values towards the environment, and introduce elements of environmental concern in its policies and organisational structure. This approach can lead to the evolution of agricultural technologies which are not erosive but productive and ecologically stable.

The University of the Philippines at Los Baños Program on Environmental Science and Management (UPLB-PESAM) has documented a number of cases of cropping systems in the Philippines, where the unified concept of agriculture and environment is being practiced. One such system is the Bontoc Paddy Rice System in Northern Luzon.

BONTOC PADDY RICE SYSTEM

The Bontoc Paddy Rice System has existed in the Bontoc area for hundreds of years but the level of productivity is still high. Essentially the technology package of the Bontoc Paddy Rice System (BPRS) includes the construction of stone-walled terraces on the hill or mountainside in order to save water and soil. Rice is grown on terraces and fertilised with compost derived from pig manure. No pesticides and organic fertiliser are applied to the paddy. The pigs which are an essential component in Bontoc's religious rituals are raised in pens and fed grain husk and human feces.

Omengan (1981) studied the nitrogen and phosphorus cycle in the Bontoc Paddy Rice System. Results showed that nutrients moving in a cycle from one agroecosystem component to another, i.e. from soil to rice to people to pigs and back to the soil, are close to a steady state (Table 1). In fact, a net gain of 3.72 kg N/paddy and 4.28 kg P/paddy was observed. Omengan suspected that other sources of N and P such as azolla and blue-green algae may also be contributing to the system. The picture of nutrient cycle in such system may be seen in Table 2 where nitrogen and phosphorus losses from the soil by some

Table 1. Nitrogen and phosphorus budget in Bontoc rice paddy system for dry season rice crop (Omengan, 1981).

System component	N	P
	*kg/paddy**	
15cm paddy soil	68.8	1.8
Recycled from previous crop's residue	0.16	0.04
Recycled from previous crop's weeds	0.02	0.02
Added through seedlings	0.07	0.01
Recycled from weeds during weeding	0.60	0.12
Recycled from crop during weeding	0.11	0.04
Loss through crop retransplant	−0.05	−0.02
Lost through soil attached to retransplanted crop roots	nil	nil
Added through precipitation	0.07	0.02
Added through irrigation	2.26	3.17
Loss through drainage	−1.62	−0.87
Lost in panicle harvest	−2.20	−0.50
Stored in crop residue	1.50	0.43
Stored in paddy weeds	0.04	0.01
Net gain (Input-Output)	3.72	4.28

*A paddy unit is equivalent to 200 m^2.

Table 2. Runoff and soil losses during 7 months at Dapdap, Carcar, Cebu. Total rainfall was 1114 mm (Pacardo and Montecillo, 1983).

Treatment	Runoff (*mm*)	Soil loss (*g/plot*)
Bare	87	3156
Corn alone, stubbles removed	30	680
Corn/Ipil-ipil, stubbles retained	2	14
Corn/Ipil-ipil, stubbles removed	4	8

Table 3. Runoff and soil loss in 6 months from erosion plots in Patupat, Barili, Cebu (Pacardo and Montecillo, 1983).

Treatment	Runoff (*mm*)	Soil loss (*g/plot*)
Bare	56	5667
Corn alone, stubbles removed	33	2214
Corn/Ipil-ipil, stubbles retained	13	712
Corn/Ipil-ipil, stubble removed	16	820

Table 4. Yield of corn DMR Comp 2 in erosion plots in Carcar and Barili, Cebu (June crop) (Pacardo and Montecillo, 1983).

	Carcar (*kg/ha*)	Barili (*kg/ha*)
Corn alone	130	1242
Corn/Ipil-ipil, stubbles retained	499	1771
Corn/Ipil-ipil, stubbles removed	483	1738

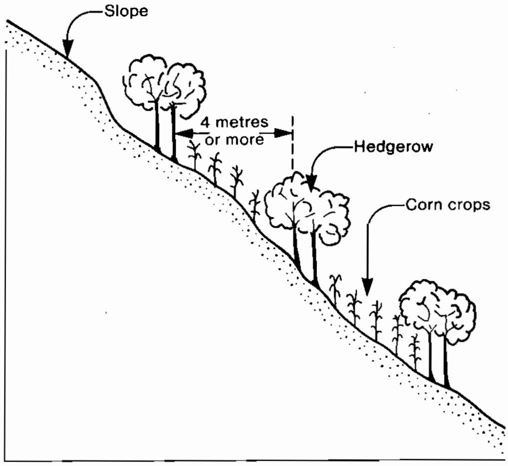

Fig. 2. Arrangement of corn and leucaena in double hedgerows across the slope.

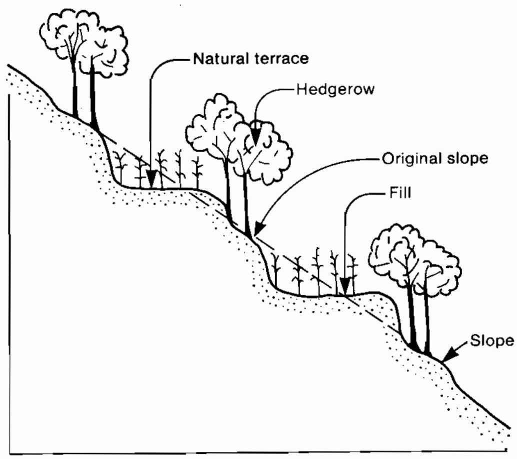

Fig. 3. Formation of natural terrace across the slope after 3 years of continuous cultivation.

erosion, crop removal, leaching and denitrification are replenished from organic matter and nitrogen fixation. The yield obtained using the traditional variety for BPRS was 621 g of clean rice per square metre which is equivalent to 6.2 t/ha.

CORN/LEUCAENA CROPPING SYSTEM

The leucaena — or ipil-ipil-based corn cropping system is another technology which appears to be ecologically stable. In this system, leucaena seeds are sown in double strips across the contour alley (Fig. 2). When the plants are fully grown, they are cut periodically about every 60 days at a cutting height of 40 cm. The cuttings are chopped into smaller pieces and returned to the soil to decompose.

The space between the double strips of leucaena is cultivated using the carabao to prepare the land for corn. With the leucaena trees firmly established along contour alleys, the farmer has to plough along contour lines — a deviation from the usual practice of ploughing up and down the slope. Continuous ploughing along contour lines results in the formation of natural terraces (Fig. 3).

An experiment using the corn-leucaena cropping system was conducted in Carcar and Barili, Cebu, to determine corn yield, surface runoff and soil losses from the ecosystem. Compared with bare soils, plots with ipil-ipil had very low surface runoff and soil losses (Tables 2–3). Corn yield under ipil-ipil also improved (Table 4). Measurements of N, P, K balance suggest that most of these elements are lost through leaching rather than by erosion. The high infiltration rates (August 1983, 0.96, and November 1983, 0.15 cm/min) in Carcar and Barili (1.64 and 0.30 cm/min respectively) may have facilitated high levels of leaching (Pacardo and Montecillo, 1983).

Conclusion

Agriculture, environment and society are interrelated components of an ecosystem. To preserve our environment is to promote the stability and productivity of our agricultural enterprise. Soil erosion is one of the most serious environmental problems that threaten society today. Its control or management hinges on the choice of technology to be used in our agricultural enterprise, and the political and institutional structures that will legislate and implement erosion control measures.

Some appropriate technologies do exist. Although there is a need to conduct more research on the fundamental aspect of soil erosion, the most urgent need today is to save our soils. Otherwise, we may discover the best methods for erosion control too late, when 'the removal of top soil and the creation of gullies has produced an infertile desert from the potentially productive lands of the tropical forest' (Greenland and Lal 1977).

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Soil, Climate, and Soil Erosion Control: State of Knowledge

Severo R. Saplaco and Petronila A. Payawan*

SOIL EROSION is almost universal. The extent of soil erosion is largely dependent on climate, soil types, and land use. Normal soil erosion may not pose a serious threat to man's well-being. However, when soil erosion is accelerated such that soil loss is greater than soil development at any given time and place, then man's very existence can be seriously threatened. Studies on the effect of erosion have shown that the downfall of many flourishing empires was primarily caused by soil degradation (Lowdermilk 1953).

The major soil-related factors affecting soil erosion include slope, texture, and structure. The climatic factors affecting soil erosion include the amount, intensity, and duration of rainfall. Water is a major factor causing accelerated soil erosion. The effects of soil and climate on soil erosion are compounded by the type of land-use practices. These practices include sloping cultivation, uncontrolled burning, overgrazing, improper road design and construction, and others. The uncontrolled effects of these three major factors on soil erosion may bring substantial adverse impact, not only on the soil but also on other valuable resources.

Soil and Climatic Types

Undoubtedly, soil and climate are important factors affecting soil erosion. Various soil types have varying susceptibility to soil erosion. Generally, fine-textured soils (clay, silt) are more resistant to soil erosion than coarse-textured ones, such as sand. This trend is largely due to the high water-holding capacity of fine-textured soils.

The texture of the soil is a general indication of the water-holding capacity and erodibility of the soil. Substantial areas in the Philippines are potentially erodible as given below (PCARRD 1980):

HIGH WATER-HOLDING

1. Clay: Burias Island, Bukidnon, some parts of Bataan, and Masbate
2. Clay loam: Nueva Vizcaya, Cabugao, Sulu Island, Camarines Norte, Northern Samar, Iloilo
3. Sandy clay: Marinduque

MEDIUM WATER-HOLDING

1. Loam: Baler, Quezon, Batangas, Sta. Cruz, Tuguegarao, Kidapawan, North Cotabato, Mati, Davao Oriental
2. Silty clay loam: Some parts of Iloilo, Davao, Calapan
3. Sandy clay loam: Some parts of Isabela

LOW WATER-HOLDING

1. Silt loam: South Cotabato, Bacolod City, and others
2. Sandy loam: Agusan del Norte, Dipolog City, Zamboanga del Norte, Surigao del Sur

VERY LOW WATER-HOLDING

1. Loamy sand: Some places in Pangasinan, Surigao de Sur
2. Sand: Some places in Abra, Pampanga
3. Stony land: Lingayen, a portion of Cabanatuan City

OTHERS

1. Complex: Camarines Sur, Pagadian City, Zamboanga del Sur
2. Hydrosol: Roxas City, some places in Agusan del Sur
3. Filled-up soils: A portion of Cabanatuan City
4. Undifferentiated: Abra, Ilocos Sur, Quirino, Mindoro Occidental, Sultan Kudarat, Agusan del Sur, Leyte, and others

Philippine soils have been ranked according to their relative susceptibility to erosion (Alcasid and Recel 1984). Susceptibility is classified in terms of estimated annual soil loss by weight per unit area. The estimates are reflected in the land-capability classification of Philippine soils by the Bureau of Soils. The classes are as follows:

(1) slight erosion with less than 3.5 t/ha;
(2) moderate erosion with 2.5–10 t/ha;

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(3) severe to very severe erosion with more than 10 t/ha.

Land Classes

Land classes have also been identified as follows:

Class Be Lands: good croplands, nearly level to gently sloping that are slightly to moderately eroded. They occupy 2.06% of the land area with a total of about 618 000 ha.

Class Ce Lands: croplands that are moderately good land; moderately sloping, and *moderately to severely eroded*. These lands cover about 3.94% of the total land area which is about 1 183 000 ha.

Class De Lands: fairly good croplands, strongly sloping, *severely to very severely eroded*. They comprise about 7.82% of the total land area numbering about 2 347 000 ha.

Class Cs Land: moderately good croplands, slightly eroded comprising about 0.23% of the total land area or about 67 000 ha.

Class Ds Land: fairly good croplands, *slightly eroded* comprising about 0.81% of the total land area or about 241 000 ha.

Out of a total land area of 30 M ha in the Philippines, the total cropland area is estimated to be about 8 348 662 ha, about 53% of which is eroded in various degrees (Alcasid and Recel 1984). A total of 4.46 M ha of upland area, or about 15% of the total 30 M, is eroded to various degrees. The extent of soil erosion in 50 provinces of the Philippines needs to be reevaluated.

Climate Types

Philippine climate is classified into four types according to the Coronas climate classification:

First Type: two pronounced seasons—dry from November to April and wet during the rest of the year. Provinces—Ilocos Norte, Abra, Tarlac, Pangasinan, Pampanga, Cavite, Bataan, Antique, and others. Average monthly rainfall—178 cm.

Second Type: no dry season, with a very pronounced maximum rainfall from November to January. Provinces—Polilio Islands, Camarines Norte, Sorsogon, Samar, Surigao del Norte and del Sur, Davao, and others. Average monthly rainfall—280 cm.

Third Type: seasons are not very pronounced; relatively dry from November to April and wet during the rest of the year. Provinces—Romblon, Capiz, Cebu, Zamboanga del Norte, Mt. Province, Cagayan, and others. Average monthly rainfall—150 cm.

Fourth Type: more or less evenly distributed rainfall throughout the year. Provinces—Bohol, Zamboanga del Sur, Davao del Sur, and other places in Mindanao. Average monthly rainfall—171 cm.

Substantial areas in the Philippines receive more than 1000 mm of annual rainfall. In general, areas receiving this much rainfall are particularly susceptible to erosion. Consequently, Philippine lands, particularly the sloping lands, are potentially prone to accelerated soil erosion. This situation is largely caused by the combined effects of soil types, climate, and land-use practices. It is no wonder, therefore, that one observes vast areas of open or grassland watersheds in the country today. These grass-covered watersheds are living indicators of the slowly, but continuously, degrading effects of soil erosion on these areas.

Soil Erosion Control

There are three major approaches that may be employed to control accelerated soil erosion. These approaches are (1) vegetative; (2) engineering; and (3) a combination of both or 'vengineering'.

The *vegetative approach* refers to the use of vegetation in minimising or preventing the occurrence of severe soil erosion. Bringing back forest vegetation which was originally absent (afforestation) or is originally present (reforestation) is the traditional and most commonly used strategy for soil erosion control. Any form of vegetation (grasses, herbs, shrubs, trees) as long as they are established, can minimise or control severe soil erosion. Living plants and plant parts found on the land or soil surface largely help in trapping soil particles and minimise their transport from one place to another. The filtering effects of plant biomass also contribute in holding detached soil particles *in situ*. Hence, the land (specifically the soil) is conserved while being used for productive purposes at the same time.

The *engineering approach* to land or soil conservation makes use of structural measures. Although these measures are primarily designed to minimise if not control severe soil erosion, they are not meant to replace vegetative measures totally in soil erosion control. Instead, they are designed to supplement vegetation in the process of controlling excessive soil degradation.

Some structural measures used for soil-erosion control include terraces, ripraps, contour paddies, check dams, and others.

Terraces are constructed channels or levelled surface areas along sloping lands. Terraces are usually constructed in series on the slopes and may have graded or levelled channels depending on the purpose for which they are constructed. Graded terraces drain into a natural or constructed outlet which carries away excess surface water-flow (runoff) at safe velocities. Level terraces are used mostly in light-textured permeable soils with an absorptive capacity allowing the infiltration of runoff without overflowing the ridge of the terrace.

Ripraps are soil-stabilising structures constructed in such a way that sloping land surfaces are completely covered by the ripraping materials, such as stones, bricks, or cement. Ripraps are constructed along the slopes without levelling the surface area. These structures are installed primarily on important and problem areas including road banks, bridge approaches, stream banks, and other high-hazard erosion areas.

Contour paddies are essentially elevated soil surfaces (paddies) constructed along the slopes. Like terraces, they minimise or control the downward velocities or runoff. They are also constructed in a series along the slopes. Unlike terraces, contour paddies do not require levelling or flattening of the land surface along the slopes.

Check dams are structures constructed in a series along streams and gullies primarily to check or trap the downward movement of water and eroded soil materials. When properly designed, check dams are intended as 'settling' ponds wherein the eroded soils are trapped or deposited. As the upper dam is filled with eroded soils, a relatively flat land surface emerges which can be used for vegetation growth. The next lower check dams will absorb the excess eroded soils from the filled-up check dams upstream until the gully is stabilised.

The *'vengineering' approach* makes use of both vegetative and engineering measures at the same time. The vegetative approaches (reforestation, afforestation, etc.) and cultural practices (crop rotation, strip cropping, etc.) are used to complement structural measures (check dams, contour paddies, etc.) in minimising or controlling excessive soil erosion. On the other hand, engineering approaches can be used to complement the established vegetative cover in soil-erosion control. This complementation scheme is accomplished by installing check dams which act as 'settling' ponds where eroded soil particles are deposited. As soon as the check dam is silted or filled up, it provides an area for the growth of natural or planted vegetation which will further stabilise the silted area or the gully.

Soil Erosion Control

To arrest soil erosion in the Philippines, the major activity being undertaken by the government primarily through the Bureau of Forest Development is reforestation of denuded and overlogged forest areas and rehabilitation of critical watersheds.

The Forest Research Institute (FORI) takes the lead role in conducting research on large watershed areas. Results of the research conducted in Magat, Nueva Vizcaya, showed that soil loss in a rice plot was 73 t/ha/yr, 69.7 t/ha/yr in a corn plot, and 0.04 t/ha/yr in an ungrazed grassland plot and 0.5 t/ha/yr in a grazed grassland plot (Atabay 1976). Due to the infancy of research, however, there is not much information available from the FORI research. Most of their research is still underway.

Pilot projects are also being conducted by different colleges and universities. Sajise (1983) conducted a study in Negros and found out that soil erosion in 29% cultivated slope amounted to 218.5 t/ha/yr. As cited by the same author, bare plots with 27% slope lost 22.9 t/ha/yr of soil in Guinobatan, Albay, while in Benguet with a slope of 29% soil loss amounted to 62.3 t/ha/yr.

Intercropping coconut with pineapple in sloping land is a destructive cropping pattern (Serranor 1983). Using this cropping system, soil loss was 14.5 t/ha/yr. Observations at UPLB-PESAM in Mt. Makiling hillsides (Sajise 1984) showed that soil loss in kaingin area is 15 t/ha/yr.

Among our ethnic communities, and other private groups, traditional soil and water conservation practices have evolved. The Tagbanuas of Palawan arrange logs across the slope in the process of clearing an area. This slows down the velocity of runoff water, thus reducing soil erosion (Sajise 1984).

Terracing is also a traditional practice. The people in the Cordillera area maintain these structures to provide irrigation water in their farm at the appropriate time. Unknowingly, they are controlling soil erosion by the use of these structures.

The farmers in Bulacan make use of terraces also. In effect, the terraces are used not only as contour but for the control of soil erosion as well. Recently, the sloping agricultural land technology (SALT) has also been developed.

Conclusion

The seriousness of the soil erosion problems in the Philippines cannot be denied or consciously ignored. The government as well as the private sector including the farmers are aware of this problem. Quite a number of conservation practices have been undertaken. However, there is a substantial gap in packaging and publishing this information. The need for updated information on the extent of soil erosion in the country indicates that more inventory and survey activities must be done. There should be a group of individuals or an agency which should collate the available information, publish and disseminate the information to policymakers, researchers, academicians, and even to farmers. Such action will assure utilisation of available technologies and conservation of the widely used non-renewable resource, the soil.

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Socioeconomic Considerations in a Soil Erosion Management Program: Case Study of Two Provinces in the Philippines

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LAND resource allocation in the developing countries of the world is a major concern of scientists and development planners. The rapid increase in population and the need for food and income have necessitated the cultivation of previously forested hillylands. Some of these lands have been tilled by these farmers for many years. Some either inherited their farms from their parents or purchased them from other landowners. In some areas continuous cultivation has resulted in soil erosion and consequently a decline in productivity, while in others the lack of a farming system suited to erosion-prone uplands has been the major cause of soil erosion.

Despite the reality of the problem, however, communities do exist in hillylands. In certain areas, population has increased to such an extent that the only alternative is to use hillylands for food production. Government, for reasons of social and economic dislocation, is forced to allow the establishment of these growing agricultural communities (PCARRD 1977).

Farming systems acceptable in hillylands can be developed. The delicate balance which exists in the energy and hydrologic systems in a defined geographic area is directly and greatly influenced by people and their activities. Inhabitants cut down trees to build shelters, clear the land and kill animals and plants for food, dam rivers for electricity, do not dispose of wastes properly, and extravagantly waste energy.

Two case studies of farmers in two provinces—Batangas and Batanes—are presented in this paper. The case studies are essentially an account of the adaptation of farm production practices farmers evolved to operate a resource-poor landscape; and illustration of farmers' capacity to overcome, or at least deal with, physical and environmental constraints.

Study Areas

The case studies covered two provinces, Batanes and Batangas. Batanes is the northernmost province of the Philippines. It is isolated by sea from the rest of the country and within the province itself, the sea separates the three inhabited islands. Trade is limited as no commercial boats service the province.

The economic opportunities in the province are quite limited. Almost three-fourths of the economically active population are farmers, fishermen, and related workers.

Located about 100-125 km southwest of Manila the study areas in Batangas included three barangays in the municipalities of Calaca and Agoncillo. The three barangays are Tamayo, Bisay, and Subic.

With a person:land ratio of 3:26, Batangas is one of the most densely populated provinces in the country. Approximately 97% of the labour force is employed, about half of which is in agriculture. Regular transportation goes to the towns, however two of the three study villages have no regular transport facilities, although they are traversed by a newly constructed dirt road.

Extension services are quite limited in the study villages in both provinces. No irrigation system has been established and even for domestic purposes rainwater is used.

The farms in the study villages are all characterised by rugged terrain and hilly topography. In Batanes, farmers live in town and have to travel to their farms mostly on foot. In Batangas, however, the farmers live in the village which is next to their farms, except in the case of Subic where part of the farm operated is located in an island separated from the main community by Taal Lake.

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Farmers' Households

All farmer respondents in Batangas were male and the average age was 39 years (Table 1). Likewise there was not much disparity in their farming experience (21 years). In Batanes, farmers were much older and more experienced.

The education level of the farmers was very low (4.5 years), making these farmers ineligible for other occupations. Therefore only a few had non-farm jobs such as fishing in Taal Lake for Subic farmers, thus complementing their agricultural production and providing a major source of food.

Household income is low which may be attributed to the low farm productivity and lack of non-farm activities. Income is very important as it is the major factor farmers would consider in making decisions regarding soil conservation resources.

Attitude to Erosion

This section attempts to determine the Batangas farmers' awareness of the extent to which soil erosion occurs on their farms. It was of course difficult to standardise or provide a scale of seriousness; what may be very serious to one may be considered less serious by another. Nevertheless, two scales are considered, very serious and serious, as perceived by the farmers themselves. A third scale was no erosion.

When asked what causes soil erosion, the general answer of the farmers was floods and rains. In addition, however, farmers were asked about what they perceived as indicators of soil erosion and their reasons for classifying erosion in their respective farms as either very serious or less serious.

Thirteen of the 100 farmers considered erosion as very serious, as indicated primarily by the formation of gullies along the slopes, loss of topsoil, and plants getting uprooted (Table 2). Four out of 9 farmers reported that gullies were formed in more than half their farm area or that a large part of the topsoil had been eroded. Other reasons for very serious soil erosion as perceived by the farmers were: decline in fertility/productivity and crops having been washed out totally by water during heavy rains.

Although soils showed some erosion problems 75% of the farmers studied considered erosion less serious as indicated by the loss of part of the topsoil. The farmers appear to perceive the seriousness of soil erosion as shown by the reasons for classifying it as less serious. Most of them reported that the standing crops were not severely affected or that no erosion occurs with normal rainfall (Table 3).

The analysis that follows classified farms according to the degree of seriousness of soil erosion, that is, very serious, less serious, and no erosion. Because of the inherent subjectivity of this classification, however, location of the barangay was also used. From our observations of the farms and the distribution according to degree of erosion, it appeared that Tamayo was

Table 1. Characteristics of the sample farmers/farms by location in Batangas.

Item	Tamayo	Bisaya	Subic
Number of respondents	33	33	34
Age (years)	40	38	39
Farming experience (years)	22	20	21
Average years of schooling	4.2	4.0	5.3
Household size	6.3	5.9	6.0
Annual income (pesos/household)			
Farming	3 909	4 471	6 493
Off-farm	2 297	1 093	3 610
Farmer	73	210	1 589
Other family members	2 224	883	2 021
Total	6 206	5 564	10 103
Annual income/capita (pesos)	958	942	1 684
Average Farm Size (ha)	2.42	1.65	1.29
Less than 1 ha	4	8	14
1-1.9 ha	11	14	10
2-2.9 ha	6	7	7
3 and above	12	4	3
No. of parcels/farm	1.6	1.7	1.9
Land Tenure (number)			
Owned	20	27	7
Share tenant	7	4	20
Part owner	6	2	7

Table 2. Indicators of soil erosion by degree of seriousness by location (Batangas).

Item	Loss of topsoil	Formation of gullies along slopes	Plants are uprooted	Other indication[a]
	No. reporting			
For very serious erosion				
Tamayo	2	3	4	-
Bisaya	1	2	-	-
Subic	1	-	-	-
For less serious erosion				
Tamayo	14	7	1	2
Bisaya	13	6	5	2
Subic	16	6	1	1

[a] Includes decreasing soil fertility or decreasing production.

the most eroded, followed by Bisaya, and then Subic.

Using location as an average indicator of degree of soil erosion seriousness, farm size increased with erosion problems, thus: Tamayo had 2.45 ha/farm, Bisay 1.65, and Subic 1.29. Farmers try to compensate for soil problems by having larger farms. Because of less fertile soils and loss of topsoil, the resource base of the more seriously eroded farms is much smaller per unit. The very seriously eroded farms averaged 3.26 ha which was almost 2.5 times larger than the less serious. The no-erosion problem farms, however, were slightly larger than the latter.

Land Utilisation

Farms tended to be small and highly parcellised particularly in Batanes, where a farmer could have 20 or more parcels of land. Crop production, especially rice and corn and rootcrops (for Batanes), is principally for home consumption while other crops and livestock are sold. These affect the land use pattern.

Steep slopes build up the eroding capacity of runoff water. While it is not always economically feasible to alter the slope of the land and to control rainfall, farmers can minimise such eroding capacity by proper crop selection and by employing management practices that are suitable to particular rainfall patterns.

In Batanes, about 25% of the farm may be permanently covered by trees and cogon grass, 45% for cropland, and the rest for pasture. Farmers try to compensate for the low crop productivity by planting a variety of crops. On the average, seven crops were planted per farm in Batangas. Again, taking location as an indication of erosion problems, the number of crops planted varied directly with the seriousness of erosion (Table 4).

The production complex centres around the cultivation of upland rice which serves as a staple subsistence crop. It is interesting to note that regardless of any erosion problem, farmers will plant rice. Rice is the staple food and planting this crop provides food security for the family. In Batangas, rice is planted mainly for home consumption. In the cropping calendar, this is followed by cassava which provides cash income and livestock feed.

Multiple cropping is intensively practiced. Tree crops are grown together with the arable crops. In terms of number of farms planting the crops, corn and bananas are the second and third most important. Bananas are planted primarily as a source of cash income while corn is for home use either as food or livestock feed. Corn is usually intercropped with rice or in some cases, with legumes and vegetables. A few farmers reported that bananas were planted for soil conservation purposes. Some other fruit trees like avocado, jackfruit, mango, and others were

Table 3. Reasons for classifying soil erosion as less serious by location.

Reasons	Tamayo	Bisaya	Subic
	No. reporting		
Standing crops are not severely affected	14	15	6
Soil can still sustain crop growth	4	5	7
No erosion with normal rainfall	7	5	11

Table 4. Types of crop planted.

Item	Tamayo	Bisaya	Subic
Number of respondents	33	33	34
Cereals			
Rice	32	33	34
Corn	31	27	29
Root crops			
Cassava	6	11	21
Sweet potato	17	4	3
Taro	14	-	-
Yam	2	1	-
Fruit trees			
Banana	29	27	29
Avocado	18	8	2
Jackfruit	8	1	1
Mango	1	4	2
Santol	1	3	1
Guava	1	2	1
Papaya	1	2	1
Other fruit trees	-	1	1
Vegetables			
Tomato	5	12	9
Squash	3	1	12
Ginger	7	3	4
Upo (Bottlegourd)	-	2	7
Eggplant	2	-	5
Other vegetables	4	4	1
Legumes			
Stringbeans	7	4	13
Cowpea	9	4	3
Lima beans	1	5	1
"Kadyos"	2	2	2
Others	4	2	5
Coconut	19	21	6
Coffee	17	6	4
Tobacco	-	4	-
Ipil-ipil	21	18	17

planted to prevent soil erosion. Together with coconuts and coffee, they provide cash income for the farmers.

Legumes such as beans and cowpea are also planted. Increased use of legumes should be encouraged in these types of farming systems because of their nitrogen fixing capacity, which will help improve the soil.

Ipil-ipil is quite popular among the farms studied mainly because of the use of leaves as feed. A secondary purpose is for soil conservation.

Increased use of multiple cropping systems was observed. Such systems are desirable not only because they increase and stabilise income but also because they provide long-term or year-round productive cover for the soil, thus reducing soil erosion.

In order to determine if farmers' land utilisation practices relate to soil erosion, data were collected (Table 5, 6) on the various crops planted according to location and degree of soil erosion seriousness. Among all the farms, the most

Table 5. Reasons for the choice of crops to plant.

Crop	Source of food	Source of cash income	Livestock feed	Soil suitability	Soil conservation	Others[a]
			No. reporting			
Cereals						
Rice	83	–	–	5	–	11
Corn	67	1	15	1	–	6
Rootcrops						
Cassava	4	22	11	1	–	2
Sweet potato	16	7	–	1	–	–
Others	2	16	–	–	–	–
Fruit trees						
Banana	2	75	–	2	4	2
Avocado	2	22	–	1	1	2
Jackfruit	2	6	–	2	1	1
Others	8	13	–	1	3	3
Vegetables						
Tomato	19	7	–	–	–	–
Squash	16	–	–	–	–	–
Others	33	2	–	–	–	–
Legumes						
Stringbeans	24	–	–	–	–	–
Others	36	5	–	–	–	–
Coconuts	4	35	2	2	–	2
Coffee	5	14	–	3	1	4
Tobacco	4	–	–	–	–	–
Ipil-ipil	–	–	50	–	50	8

[a] Others include landlord's desire, following other farmers, for trial purposes, and land was already cultivated to the particular crop when acquired.
[b] Some respondents gave more than one answer.

Table 6. Cropping pattern per parcel by location and degree of soil erosion seriousness.

Crops	Tamayo	Bisaya	Subic	All parcels: Very serious	All parcels: Less serious	All parcels: No erosion
			percent			
Cereals only	9.7	10.5	12.3	40.0	11.5	11.5
Cereals and other crops	14.5	14.0	6.2	15.0	12.3	3.8
Cereals and trees	14.5	17.5	10.8	15.0	13.8	15.4
Cereals, other crops and trees	37.8	36.8	35.4	10.0	41.3	30.8
Other crops only	6.5	7.0	12.3	–	9.4	11.5
Trees only	9.7	14.0	20.0	20.0	11.6	26.9
Trees and other crops	8.1	–	3.1	–	5.1	–

common cropping pattern found is a combination of cereals, other crops and trees. This seems to indicate that in general, farmers are aware of soil erosion problems and they try to conserve the soil by planting trees. In fact, more than 65% of the farmers had planted mainly fruit trees. The proportion of parcels planted to trees was inversely related to the degree of soil erosion seriousness, that is, more of no-erosion-problem parcels were planted to trees than those with seriously eroded parcels. While farmers reasoned that fruit trees were planted primarily for cash, it seemed that a latent objective could have been soil conservation.

However, among the very seriously eroded parcels, a large proportion (40%) is planted to rice and/or corn only, which exposes the soil more to rainfall intensity.

It is seen, therefore, that diversity is the rule of the game. Most of these farms are hillylands which comprise a wide array of ecological niches. Microclimate plays an important role in plant distribution and growth as well as in land use and management.

In order to examine the trend in land utilisation, farmers were asked their cropping patterns during the last 10 years (Table 7). It seems that most farmers (71%) never changed the crops planted in any given parcel. Trees, however, have been added to cereals and other crops.

The regularity of the rotation in Batanes has been established through the years. Yam and sweet potato are the principal crops. It takes 9 months for yam to mature and harvesting is done not once but usually several times. Late in the harvest season, sweet potato is planted. In 4–6 months, the two-crop system ends to start a new cycle—3.5 years on fallow and 1.5 years on crops. The sugar cane crop planted (alternately in parcels) is for the production of sugar and wine. Other minor crops include garlic and corn.

Farm Production Practices

The 'PCARRD Philippines Recommends for Soil Conservation' suggests various ways of conserving the soil. Among others, these include cover-cropping, crop rotation, buffer strip cropping, etc. Farmers were asked which practices they followed, what effects they had observed, and if not practiced, the reasons for non-adoption.

Farmers were asked the following questions: (1) who do you usually approach to obtain relevant information on farming operation and soil conservation? and (2) are you aware of any soil conservation program or any agricultural production program in your locality? The second question was answered negatively by all respondents. While Maisagana (corn) and Gulayan sa Kalusugan (vegetable) production programs were reported by the extension workers apparently the three villages have not participated in these programs.

Although a majority of the respondents answered 'None' to the first question, a few mentioned the technician of the Ministry of Agricul-

Table 7. Ten-year (1973–82) land utilisation by location[a]

Item	Tamayo		Bisaya		Subic	
	No. reporting	No. of parcels	No. reporting	No. of parcels	No. reporting	No. of parcels
No change during the last 10 years	32	37	30	35	9	11
Cropping pattern during the last 10 years						
All cereals	3	3	4	4	-	-
Cereals and other crops	3	3	4	6	-	-
Cereals and trees	4	5	5	7	1	1
All other crops	1	2	2	2	2	2
Other crops and trees	6	7	1	1	1	1
All trees	3	3	4	5	3	4
Cereals, other crops and trees	12	14	10	10	2	3
With change during the last 10 years	2	2	5	5	12	20
Cereals and trees added with other crops	1	1	1	1	10	18
Trees and other crops added with cereals, trees and other crops	1	1	1	1	-	-
Trees added with cereals	-	-	2	2	1	1
Cereals added with other crops	-	-	1	1	1	1

[a] Excluding the farms acquired after 1973.

ture. As mentioned earlier, the study areas are not easily accessible to public transportation hence with the limited mobility of the technicians, they could not visit the villages as regularly as they would want to.

Despite the absence of soil conservation programs, however, farmers had followed certain conservation measures which had been learned by experience and from other farmers, parents and elders.

FERTILISER APPLICATION

All respondents in Batangas used fertiliser especially for rice, corn, and cassava. Although a few farmers had used fertiliser prior to 1970 most of them started the practice only in the 1970s.

Fertiliser was usually applied by broadcasting twice, once at planting time and once at early vegetative growth of the plants. The rate of fertiliser application was compared from the time the farmer started using it and the last cropping season. Data showed a slight upward trend in the utilisation rate except for a few cases of declining rates especially in corn and other crops. Decreasing rate of application might be due to the increase in the price of fertiliser.

Table 8 presents the rate and types of fertiliser applied to the different crops. Two major types of fertiliser were used — nitrogen only or complete — on two primary crops, rice and corn. The rate varied according to crop and location. In Tamayo, nitrogen application ranged from 27 kg/ha for corn to 46 kg/ha for rice and corn intercrop. For the complete fertiliser, one bag was applied per hectare of rice and corn.

A slightly higher rate of fertiliser application was noted for rice and corn in Bisaya but lower for the other crops. Subic farmers applied a much higher rate for corn, 74 kg/ha.

The rate of fertiliser used varied inversely with the degree of seriousness of soil erosion, that is, as the soil becomes more eroded the amount of fertiliser applied decreased. While no-erosion-problem farms used 61 kg/ha, the moderately eroded rice and corn farms used 55 and the very seriously eroded farms applied 50 kg/ha.

For Batanes, no chemical fertiliser was

Table 8. Rate of application by type of fertiliser by crop fertilised, by degree of seriousness of soil erosion.

Item	Crop fertilised				
	Rice & corn	Sole rice	Sole corn	Rice & other	All other
Very serious erosion					
Used N fertiliser					
No. reporting	3	-	2	-	1
N Level (kg/ha)	50	-	60	-	11
Used NPK fertiliser					
No. reporting	5	-	-	-	-
NPK Level (kg/ha)	31	-	-	-	-
Less serious erosion					
Used N fertiliser					
No. reporting	32	5	6	9	17
N Level (kg/ha)	55	29	16	66	63
Used NPK fertiliser					
No. reporting	16	2	-	1	6
NPK Level (kg/ha)	48	42	-	35	73
No erosion problem					
Used N fertiliser					
No. reporting	5	2	-	-	1
N Level (kg/ha)	61	50	-	-	61
Used NPK fertiliser					
No. reporting	4	-	-	1	-
NPK Level (kg/ha)	41	-	-	42	-
Combination					
Used N fertiliser					
No. reporting	5	1	-	-	3
N Level (kg/ha)	37	84	-	-	51
Used NPK fertiliser					
No. reporting	2	-	-	1	1
NPK Level (kg/ha)	52	-	-	124	28

applied. The distance from the market and the high cost of transportation had virtually isolated the farms from fertiliser supply.

TREE PLANTING

Many farms have planted trees. When asked about practices to prevent soil erosion, not all of the farmers reported tree planting as a preventative measure. Apparently fruit and other trees were planted not for the purpose of preventing soil erosion per se but for cash income. Ipil-ipil and banana were the two most commonly reported trees for the purpose.

BUFFER STRIP CROPPING

This practice was done by planting trees like ipil-ipil or grasses every 2–3 m of the main crops like rice, corn and legumes. This strip area would serve as a buffer and a permanent dividing line to prevent soil erosion since they retard water runoff. Twenty-one respondents practiced buffer strip cropping.

OTHER PRACTICES

Only 3% practiced green manuring using legumes. Other practices were ploughing across the slope, with 20 respondents using the practice. Cultivation using human labour was very slight. Six practiced diking/ditching and a total of 22 respondents practiced fallowing. Fallowing was practiced for 4–5 years only in Subic with less seriously eroded soils. A few farmers practiced cover cropping using sweet potatoes on grasses as covercrop.

Crop rotation and terracing were also practiced. In a study of the Lake Buhi Watershed in Bicol (FORI Consultancy Team, Watershed Management and Socio-Economic Verification Report. FORI-BRBDP Rinconada Joint Project. Forest Research Institute), only 28% of upland farmer respondents believed that terracing would help them maintain their farm lands; 34% did not believe terracing would help; 38% did not know what terracing was all about. The second group (those who did not believe) said terracing was not feasible because they had no source of irrigation water, or that terracing was just a waste of time and money; and that too much expenditure was involved.

One of the recommended soil conservation measures is cover-cropping (e.g. coconut areas) with crops like *Centrosema*, Kudzu, and *Calopogonium*. It is further recommended, however, that the soil should be limed and fertilised. At current high prices of fertiliser when it is difficult for small farmers to purchase fertilisers for crops, it may be more difficult to apply these inputs to cover-crops.

FALLOWING

The size of cropland belies the actual area planted to crops. Prevailing practice required that a parcel be cropped for 1.5 years and fallowed for the next 3.5 years. Particularly for Batanes, the long period under fallow is necessary to replenish soil nutrients after each cropping, since no commercial fertiliser is now in use. Such practices of fallowing are done in two ways. One is to maintain the second growth of trees which must be uprooted each time the field is to be planted to crops. Seeds from the uprooted trees are permitted later to germinate even while the crops are still unharvested. This makes possible the continuing cycle of tree growth without any need for replanting or reseeding. Organic matter from decomposing leaves provides the replenishment of used-up soil nutrients.

The second fallowing procedure uses land as pasture to keep down growth of vegetation. The droppings of the cattle or carabao provide the principal replenishment of nutrients. In either case, the crop rotation period is the same.

Production Practices

Success of agricultural production programs has come from the use of improved production practices. Batanes farmers have only vague ideas of the merits this package could offer. They have never tried them although they are aware of them.

For livestock, cattle are kept on the permanent pasture most of the time. No concentrates, food suppplements, or medication are given. Hogs are simply tied and fed with kitchen slop, sweet potato tubers, and tops for roughage. No feed supplements or vaccination are given. This is also true for the few chickens which are left loose and fed occasionally with corn.

These have been the unchanging practices. No visible cash costs are involved. Time and effort are combined with farm-produced feed to generate production.

Effects of Farm Practices

The effects of the various farm practices are summarised in Table 9. Fertiliser application resulted in better yields while tree planting minimised soil erosion.

Yields were very low (Table 10). Rice yield of 694 kg/ha was only about one-third of the national average rice yield for the country. Rice

Table 9. Effects of farmers' practices to prevent erosion/maintain soil fertility (as perceived by farmers).

Practice	Effects: Better crop growth and yield	Minimise soil erosion	Maintain soil fertility	No perceived effects
	No. reporting			
Fertiliser application	94	-	7	-
Tree planting	-	61	-	-
Buffer cropping	-	12	-	9
Cover cropping	-	5	2	-
Green manuring	2	-	1	2
Plowing across slope	-	20	-	-
Diking/ditching	-	-	-	6
Fallowing	-	-	22	-

was commonly intercropped with corn, and since planting density was very low, the corn yield was only 233 kg/ha.

The effects of erosion on crop yield are shown in Table 11. Very seriously eroded rice farms produced only 484 kg/ha, 48% lower than moderately eroded areas.

Very seriously eroded corn farms also produced 45% less than moderately eroded areas. Noticeable, however, was the very low production of no-erosion farms, which may be explained by low planting density.

While banana output exceeded 1200 kg/ha in farms with less erosion, it barely reached 550 kg/ha in places with very serious erosion. Bananas produced in no-erosion farms were about 200 kg/ha more than in very seriously eroded lands but 32% less than moderately eroded farms.

Cassava seemed more responsive to soil condition than rice, corn and bananas. No-erosion farms produced 73% more per hectare than moderately eroded areas. No definite relationship existed between coffee yield and soil status. Coffee is recommended for hilly areas.

Table 10. Annual yield per farm and per hectare by crop and location.

Item		Tamayo	Bisaya	Subic
Rough rice				
No. reporting		31	33	34
Average area harvested (ha)		1.17	1.12	0.69
Annual yield:	kg/farm	644	850	549
	kg/ha	552	769	798
Shelled corn				
No. reporting		31	27	29
Average area harvested (ha)		1.09	1.25	0.67
Annual yield:	kg/farm	176	417	122
	kg/ha	162	334	183
Bananas				
No. reporting		29	27	29
Average area harvested (ha)		1.29	1.02	0.78
Annual yield:	kg/farm	1 059	1 058	1 346
	kg/ha	823	1 040	1 719
Cassava				
No. reporting		6	11	21
Average area harvested (ha)		0.18	0.21	0.34
Annual yield:	kg/farm	474	529	1 555
	kg/ha	2 709	2 542	4 542
Coconut				
No. reporting		13	18	6
Average area harvested (ha)		1.18	0.96	0.61
Annual yield:	nuts/farm	2 334	4 017	5 258
	nuts/ha	1 970	4 172	8 527
Coffee				
No. reporting		15	6	4
Average area harvested (ha)		1.14	0.79	0.75
Annual yield:	kg/farm	108	57	49
	kg/ha	94	72	65

Income and Use of Capital

Farm production in Batanes involves no cash expenditures. Seeds are either obtained from previous year's crop or given by other farmers. Fertiliser and chemicals are neither bought nor used. Occasional help on some farm operations is obtained through exchange labour. All these inputs including hired labour constitute cash outlays for Batangas farmers.

Annual revenue of a Batangas farm averaged P7464 (Table 12 and 13); 45% came from crops and 55% from livestock.

For Batanes, farming is oriented principally to the provision of family consumption needs. Practically all rootcrops are consumed. Indeed, home consumption may be the only alternative in the absence of a well-developed market. Livestock/poultry account for about 84% of total farm sales. Weather conditions have favoured livestock over crop enterprises, short-season over long-maturing crops, and rootcrops over other kinds of crops.

Adaptation to Micro-Climate

The micro-climate of the area has two significant components; the seasonal typhoons and the relatively well-distributed rainfall during the year. These phenomena have developed a set of local production practices over the years. Hence, the response to the seasonal typhoons which come usually between July to early November has been a set of practices involving principally the following: (1) subdivision of the farms into small

Table 11: Annual yield by type of crops by degree of seriousness of erosion.

Item		Very serious	Less serious	No erosion	Combination
Rough rice					
No. reporting		8	66	13	12
Average area		1.29	.95	.89	.92
Average yield	kg/farm	625	679	586	774.25
	kg/ha	484	715	659	845
Shelled corn					
No. reporting		8	60	10	9
Average area		1.29	.88	.98	.96
Average yield	kg/farm	253	251	101	278
	kg/ha	196	284	103	289
Bananas					
No. reporting		6	59	9	11
Average area		1.24	1.02	1.03	1.04
Average yield	kg/farm	674	1 229	937	1 020
	kg/ha	544	1 204	912	984
Cassava					
No. reporting		1	28	4	6
Average area		.1	.44	.26	.29
Average yield	kg/farm	44	1 054	1 097	1 205
	kg/ha	176	2 387	4 140	4 133
Coconut					
No. reporting		4	25	3	5
Average area		1.42	.92	1.00	1.35
Average yield	nut/farm	382	3 580	4 567	7 560
	nut/ha	270	3 858	4 567	5 600
Coffee					
No. reporting		3	16	1	5
Average area		2.00	.72	1.00	.75
Average yield	kg/farm	161	59	51	146
	kg/ha	81	82	51	195

Table 12. Cost and returns of production per farm by location, all farms.

Item	Tamayo	Bisaya	Subic
No. of respondents	33	33	34
Average farm size (ha)	2.42	1.65	1.29
		pesos per farm	
Total revenue	6 244	6 572	9 514
Landlord and harvesters share	378	646	1 293
Gross benefits to farmer	5 866	5 926	8 221
Paid out cash costs			
Livestock purchased	936	397	701
Fertiliser	390	503	362
Marketing/transportation cost	179	301	91
Food for hired/exchange labourers	82	67	239
Hired labour	170	25	149
Interest on borrowed capital	159	150	131
Others[a]	41	62	55
Total cash costs	1 957	1 455	1 728
Gross income	3 909	4 471	6 493

[a] Include purchased chemicals, seeds, fuel, repairs, etc.

parcels bounded by a row of sturdy trees serving as wind breaks; (2) practice of crop rotation whereby soil-hugging root crops are the principal crops during the typhoon season; and (3) providing for anchorage of the twining vines of the rootcrops either from the uprooted trees, staked-out reeds, or the stumps of the preceding crop.

The relatively well-distributed rainfall has partly compensated for the lack of irrigation systems in the province. It is relatively dry during March to May. Hence, the response of the farmers has been to conserve and effectively utilise the available soil moisture. This has evolved the following set of practices: (1) fallowing the area regularly to maintain or build up the organic matter in the soil thus improving its water-holding capacity. This practice also increases the water-absorbing capacity of the soil and minimises excessive runoff and soil erosion; (2) cover-cropping to minimise the direct exposure of the soil to sun and wind. This is achieved by relay cropping and the planting of root crops particularly at the later part of the rotation cycle; and (3) efficient weed control which minimises competition with the standing crop in the use of the available soil moisture.

Variations of temperature during the year are not critical and no apparent organised response to this micro-climate element is reported.

Adaptations to Terrain

Farmers cultivating the hillylands have evolved common practices which may have come

Table 13. Costs and returns per farm by location (full owners only).

Item	Tamayo	Bisaya	Subic	All farms
No. of owners	20	27	7	54
Average farm size (ha)	2.50	1.58	1.64	1.93
		pesos per farm		
Total revenue	6631	6572	8526	6847
Value of shares	338	517	469	444
Cash variable costs	6293	6055	8057	6403
Livestock purchased	1048	461	621	699
Fertiliser	380	474	444	435
Market expenses/transportation	181	340	201	263
Hired labour	107	14	238	77
Food for hired/exchange labourers	51	50	207	71
Others[a]	38	61	70	53
Sub-total	1805	1400	1781	1598
Cash fixed cost				
Interest on borrowed capital	142	84	-	94
Non-cash variable costs				
Family and exchange labour	1163	953	1288	1074
Animal feeds	101	132	144	122
Seeds	147	127	78	128
Food for hired/exchange labourers	5	11	-	7
Sub-total	1416	1223	1510	1331
Non-cash fixed costs				
Depreciation	85	75	133	86
Opportunity cost of capital	2753	1574	1666	2023
Sub-total	2838	1649	1799	2109
Total cash costs	1947	1484	1781	1692
Total variable costs	3221	2623	3291	2929
Total costs	6201	4356	5090	5132
Gross income	4346	4571	6276	4711
Net income	4261	4496	6143	4663
Gross economic profit	3072	3432	4766	3474
Net economic profit	92	1699	2967	1271
Opportunity cost of operator's labour and management	2328	2091	2462	2227
Pure profit	(2236)	392	505	(956)

[a] Include purchased chemicals, seeds, fuel, repairs, etc.

about as responses to a variety of factors rather than discretê single factor-specific practices. Hence, some of the practices given as responses to the micro-climate of the area have also been adapted to the requirements of the hilly terrain of the farms. The major adaptations to the hilly terrain include the following: (1) parcellisation into small fields bounded by rows of trees serving as wind breaks and also to prevent soil erosion; (2) fallowing at regular intervals provides the interlacing roots which improves the water-absorbing capacity of the soil while also helping hold the soil firmly; (3) cover-cropping and relay cropping would have the same role as fallowing by preventing soil erosion and improving water-absorbing capacity of the soil; and (4) minimum cultivation largely with human labour provided mainly by members of the family. Ploughing if practiced is done using animal power working across the slopes of the farms.

Adaptations to Cover

The lifeblood of the agricultural production system seems to revolve around the good management of the vegetative cover. This has enabled the farmers to produce crops at reasonable yield levels even without the input of extraneous manufactured materials, such as fertilisers and herbicides, which have become indispensible in other agricultural production areas. The vegetative cover management practices developed over the years consist principally of the following: (1) fallowing to maintain or build up the fertility and physical condition of the soil; fallowing is coupled with a limited cropping cycle; (2) land preparation and cultivation practices to minimise the destruction of the soil structure and prevent soil erosion; and (3) natural seeding of trees for the fallow which maintain the natural replacement from the seeds of the trees during the previous fallow. Hence, the germinating seeds are usually left to develop to have a good number of trees established at the end of the cropping cycle. In addition, the cultivated area is usually situated beside some fallowed areas where natural seeding might also have occurred.

Adaptations to Inputs

Farmers in Batanes have not been using manufactured inputs like fertilisers and herbicides. They have relied mainly on the natural replenishment of soil nutrients by maintaining almost a continuous vegetation on the farm. The droppings of the work animals would have been very limited. Pests and diseases have been minimal possibly because of the practices of crop rotation and local seed selection of resistant varieties. Other relevant practices related to these minimum resource inputs and limited market potentials included the following: (1) painstaking selection of seeds and planting materials from the previous crops or other locally proven varieties; (2) intensive use of human labour provided mainly by family members for effective weed control and care of crops; (3) cultivation of a limited area at a time to produce basically the food requirements of the family rather than from sale because of limited product market; and (4) harvesting of the sweet potato on an 'as-you-need-it' basis. The crop was allowed to cover the entire field rather than being ploughed over. Meanwhile, the tree seedlings which had already germinated continued to develop unhampered, but mulched by the sweet potato vines. In a more limited way, other crops such as yams and rice were not harvested all at once. Only the well-matured rice panicles were individually harvested.

Research Problems

Relating the actual production practices of the case-study farmers to the operation of the ecological support systems discussed earlier gives rise to the seeming logical responses of such farmers. Their present practices have been the product of their long years of experience. There must be more adaptive land use management practices developed by other farmers in other parts of the country. However, there has not been much research done to document such practices particularly on the hillyland areas.

There would be opportunities also to use the results of such research in order to evolve policy packages on hillyland use management at the national, regional, and sub-regional levels.

Conclusions

The hillyland farmers live and operate their farms under trying conditions—physically, economically and socially. The typhoons (particularly in Batanes) limit the opportunities for increasing farm production; the physical isolation of the community limits the market. Insufficient institutional services and support are apparent. Off-farm and non-farm employment opportunities have also been very limited.

Presently, there seem to be a number of possible and profitable areas of adjustment. The apparent over-production in root crops relative to the present uses requires more consideration of various alternatives.

One may ask the following questions: Are present crops, both in kind and magnitude produced, the best alternative for utilising existing resources and in coping with existing natural conditions? Are there other feasible alternative uses of the present products? What adjustments in resources, uses, operations, and services are necessary? How best can they be carried out?

What the alternatives are and how they can be achieved are challenges to the farmer, the extension agent, the researcher, the policy-makers, and all development workers.

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Soil Management Policy in Australia: Institutions, Criteria and Socioeconomic Research

Warren Musgrave and Robert A. Pearse*

WHILE there appears to be some disagreement among historians as to why Australia was originally selected by the British as a penal colony (Blainey 1982), there would be general agreement that it was not because of its potential for agricultural production. Indeed, it was not for some years that the infant colony attained food security, and several decades before an agricultural commodity suitable for export was identified in the form of wool (Davidson 1981).

After an initial period of concentration of ownership in a few hands, the 100-year period from approximately 1860 to 1960 was one where the appropriate objectives of public policy toward land and water resources were perceived to be the promotion of development and the pursuit of social justice. These objectives were pursued by a variety of policies including the clearing of land, the provision of infrastructure, the construction of irrigation schemes, and the settlement of smallholders on crown land or on large private holdings acquired by the state (Campbell 1982).

As indicated, this perception of the most appropriate objectives of public policy persisted until the mid-1960s when it started to dissipate. Among the reasons for this were the decline in the agricultural dominance of foreign exchange earnings and the later abandonment of fixed exchange rate regimes leading to the relative decline in the importance of agriculture in development. Also important was the recognition that social justice could now be pursued more efficiently and equitably through other means such as progressive taxation, and the provision of health, education and welfare services (Campbell 1982).

From the commencement of settlement, individuals and organisations, both public and private, were adapting the farming methods they had imported from the higher rainfall, stable, land-short but fertile environment of Europe to the lower-rainfall, highly unstable, land-abundant but comparatively infertile environment of Australia (Davidson 1981). The achievements have been substantial, but so too were some of the mistakes that resulted in severe degradation of land and waterways. However, some of the errors have been reversed.

In brief, Australia could be described as entering the second half of the 20th century with land and water resources and associated institutions reflecting about 150 years of development, experimentation and exploitation. The rewards from this period have been immense as Australia's overall development attests, but some of the degradation costs have also been high. However, it is not clear that the inherited institutional arrangements are appropriate to the challenges of the 1980s.

The decline in the significance of agriculture in national growth and prosperity, which is illustrated in Table 1, has recently been associated with a shift in policy emphasis towards the protection and restoration of Australia's resource base. As far as agriculture is concerned, this shift has been particularly concerned with problems of land degradation. This has not meant abandonment of the pursuit of increased labour productivity. Agriculture is still an important export sector; and productivity growth is essential if competitiveness is to be maintained. Moreover, stable long-term sustainable growth in labour productivity is what ultimately underpins the economic and social well-being of farmers, and the rural sector generally.

Perceptions of the Soil Problem

The flag-bearer of the policy shift referred to above is the National Conservation Strategy which was published in 1983 (Department of Home Affairs and Environment 1983). The document, which was prompted by the World

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Table 1. Contribution of Major Sectors to Australian GDP.

Year	Gross Domestic Product	Contribution to GDP by: Agriculture Fishing Forestry	Mining	Manufacturing	Tertiary
	$M	%	%	%	%
1948–9	4 031	21	3	26	50
1949–50	4 837	25	2	25	48
1950–1	6 585	29	2	24	45
1951–2	6 853	19	2	27	52
1952–3	7 543	21	2	26	51
1953–4	8 109	19	2	27	52
1954–5	8 743	16	2	28	54
1955–6	9 483	16	2	28	54
1956–7	10 236	17	2	28	53
1957–8	10 267	13	2	29	56
1958–9	11 137	14	2	29	55
1959–60	12 211	14	2	29	55
1960–1	12 982	13	2	29	56
1961–2	13 335	12	2	28	58
1962–3	14 446	13	2	27	58
1963–4	16 074	14	2	26	58
1964–5	17 640	12	2	27	59
1965–6	18 403	10	2	27	61
1966–7	20 416	12	2	26	60
1967–8	21 736	8	2	27	63
1968–9	24 668	10	2	26	62
1969–70	27 369	8	3	26	63
1970–1	30 313	7	3	25	65
1971–2	33 835	7	4	24	65
1972–3	38 486	8	4	23	65
1973–4	45 967	9	4	23	64
1974–5	55 088	7	4	22	67
1975–6	64 127	6	4	21	69
1976–7	73 300	6	4	21	69
1977–8	79 911	5	4	21	70
1978–9	90 072	7	4	20	69
1979–80	100 685	7	5	20	68
1980–1	114 674	6	5	20	69
1981–2	129 481	6	na	na	na

na = not available

Sources: Australian Bureau of Statistics; Bureau of Agricultural Economics, and Trade and Resources.

Conservation Strategy, while perhaps more remarkable for its 'motherhood' sentiments than its hard and practical policy suggestions, offers to provide a widely acceptable framework within which debate over conservation issues can take place. An important reason for this is that the strategy is not just the product of the bureaucracy but reflects a strong community input from two national conferences.*

The status of soil erosion in Australia has been the subject of a major collaborative Federal-State review. The conduct of such a review in a country as large as Australia is not easy. The review data are based on the reports of a large number of State soil conservation officials. Consequently they are subject to problems of comparability and uniformity of criteria and procedure, particularly between States. Despite this, the study has provided the basis for two major reports (Department of Environment, Housing and Community Development, 1978; Woods 1983) which provide the best description available, on a national basis, of the status of soil erosion in Australia.

The results of these collaborative studies suggest that, of Australia's arable land, '... approximately 3 million km^2 (61%) of land

* Both conferences were organised by the Department of Home Affairs and the Environment and were held in Canberra, the first on 30 November to 3 December 1981 and the second on 10–13 June 1983.

used for agriculture are in a degraded condition and require treatment, either with changed management practices (42%) or through the construction of structural works (20%) ... the estimated capital cost of repair would be approximately $A1000m' (Blythe and Kirby 1984, p. 1).

It is not surprising that soil conservation and its management have become important issues in Australia. For example, a recent major inquiry into the nation's agriculture and agricultural policies described land degradation as being among the most serious environmental problems facing agriculture (Balderstone et al. 1982).

Australian economists, with a number of notable exceptions (Campbell 1982; Dumsday 1972), have, until recently, paid little attention to soil conservation problems. The recent rise in community concern has aroused increased attention by economists to conservation problems resulting in a literature buildup. Economic notions of investment appraisal (Dumsday and Edwards 1984), market failure (Samuel and Jenkins 1983) and property rights (Wills 1984) have been applied to the problem. Assessments have been made of the impact of policy on erosion status (Blythe and Kirby 1984) while models of farming systems have been constructed to assess the impact of on-farm and off-farm policy options (Dumsday et al. 1983). The present paper concludes with a brief discussion of an on-going farming systems study.

Other social scientists are displaying heightened interest in soil and water conservation with studies underway or foreshadowed into farmer attitudes, perceptions and motivations and, very importantly, into the role and operation of community groups in the pursuit of soil conservation objectives.

The discipline of economics, because of both its explicit treatment of social objectives and values and its provision of a rigorous theory of choice (Mueller 1979), has much to offer in the pursuit of socially optimal soil conservation policies. A brief outline of the economist's perception of the soil conservation problem follows.

Economics of Soil Conservation

Regardless of the viewpoint adopted, landowner, tenant or society, soil conservation should be viewed as an investment. Degradation should not be viewed as something to be corrected for its own sake, but as something to be corrected if its removal contributes to the attainment of the objectives of the landholder, tenant, or society. These various sets of objectives are complex and may even be contradictory and mutually exclusive. Some ranking of objectives is inevitable and the outcome may be levels of conservation greater than those warranted by farm income considerations alone. This outcome does not deny the appropriateness of the investment model in the sense that future costs and returns are what is important. The degradation we have inherited from the past is a sunk cost and whether it should be repaired is a question of the time flow and magnitude of future benefits and costs from so doing.

The farmer in a developed economy can be assumed to be seeking to maximise the present value (PV) of the stream of expected net income from the farm (and any other sources) over his working life plus the PV of change of the terminal value of the farm (from the present). That is he wishes to maximise the present value of his assets. Discounting requires the choice of an interest rate which is usually taken as the rate at which the farmer can borrow or lend, depending on his status on the capital market. The selected interest or discount rate enables a set of weights to be attributed to income received at different points of time. The quantities obtained by multiplying the expected flow of future income by the appropriate weight can be summed to obtain the present value of the future income stream. This sum also represents the market value of the farmer's assests. Net worth is the value of the assets minus the value of liabilities. A farmer, because of the multiple objectives, may be prepared to sacrifice some net worth in order to achieve non-income objectives. For example, subsistence farmers may choose reduced exposure to risk while wealthy farmers may seek increased amenity value from their farms. Despite these comments, in general it is safe to assume farmers attempt to avoid actions which would reduce their net worth.*

* The model requires extension if it is to deal with the situation of the subsistence farmer facing ruin, particularly starvation.

Following this reasoning, if land degradation reduces productivity, there will be a decline in asset values. The farmer should perceive the process of degradation as a cost to be minimised. Similarly if an action to slow the rate of degradation were to increase net land productivity, asset values should increase. The increased value following the action should incline the farmer to take that action. The implication is that farmers will undertake soil conserving strategies that are profitable to them. Well-informed farmers, getting accurate price signals from the market place, will invest in a level of conservation and consequent rate of degradation that is optimal for them as individuals.

However, farmers are not always well informed; nor do they always get accurate signals from the market place. As has already been mentioned, this point is illustrated in the Australian context by the degradation caused by past ignorance and by the distortion of market prices by government policy. Farmers, too, can make errors in their expectations about future output and prices. Finally, price signals may be distorted by market imperfections such as monopoly or other anti-competitive market structures. Further problems can arise due to insecurity of tenure and inadequate farm size. In general these do not cause problems of soil degradation in Australia, though they may be important in the Arid Zone and in the Murray Valley, both as a consequence of past and present government policies. In other countries, similar problems may exist as a result of the basic distribution of rights and wealth. The issues of redistribution and social justice which are raised by such situations are beyond the scope of this paper.

Economists have identified a number of reasons, in addition to those already discussed, why landholders may perceive inadequate incentives to engage in soil conservation. Most important among these reasons are externalities, irreversibilities and preservation value. Hence, even if the basic distribution of rights and wealth is judged to be acceptable and the farmer's conservation efforts are close to private optima, the possibility exists that, from the viewpoint of society as a whole, these efforts may be inadequate. That is, even if private rates were optimised everywhere, community advocacy of still higher rates of land conservation should not be viewed as surprising.

Externalities are costs and benefits not debited or credited to the parties that caused them. Noise, smell, or smoke caused by factories and chemical pollution from fertiliser are externalities. The pleasant scenery provided to travellers by the rural landscape is an externality of the farming sector located at that landscape.

Because of the intimate association between land and water, the fact that soil conservation is replete with externalities should not be surprising. Nutrients and soil particles mobilised in the process of runoff or percolation are not constrained by man-made farm boundaries. As a result there is a divorce between the farm decision-maker and responsibility for the external effects of his decisions. There is no incentive either to expand production of the externality if it is a net benefit, or limit its production if it is a net cost.

Soil-related externalities include siltation, turbidity, salinity, flood losses, disturbance of the water table and loss of habitat. If such externalities are significant, the optimal rate of conservation cannot be determined without taking them into account. For example, if externality is a cost which is ignored by the relevant decision-makers, then the resulting level of conservation would be less than is socially desirable.

IRREVERSIBILITY AND OPTION VALUE

Irreversibility of resource use occurs when valuable optional uses of the resource are lost and can only be restored at prohibitively high cost. The destruction of long-lived systems that are slow to regenerate constitutes an irreversibility. The loss of landscapes, ecosystems and biological species fall into this category. So too does the loss of soil.

Some irreversibilities can be measured satisfactorily. These tend to be events occurring in the present or the near future that can be readily valued. An example of this would be the inundation of productive land by the construction of a dam. In such a case, the irreversible loss of land has known values of future streams of income, the present value of which can be calculated. But what if the lost option was something that may have significance in the distant future; so distant that we are very uncertain about it happening let alone its nature?

What if the irreversibility is on such a scale that, though calculable and presently tolerable, should there be some unforeseeable upsurge in demand for the goods or service in question in the distant future, supplies would then be grossly inadequate? If the stock of land appears to be adequate for the present and foreseeable future then the appropriate rate of soil loss, everything else being equal, would be greater than the rate that would be appropriate should there be the feeling that the stock of land may eventually prove to be inadequate.

On the other hand, worries for the future could lead to concern that the rate of irreversible soil loss is too great and will argue for a reduction in the rate of degradation. The transfer of soil services to the future such a slowing down would represent, reflects the value placed on preserving the option for use of certain soil stocks in that distant future. Understandably, this value is called option value, i.e. the preservation of future options for use.

EXISTENCE VALUE

Existence value is a concept that acknowledges that people can value a thing, even if they do not consume it in any direct or definable way. For example, people may obtain satisfaction, and hence value, from knowing that a landscape exists, even if they never visit it. Most Western people would place positive existence values on such sites as the Grand Canyon, even though they are remote from it and never expect to visit it.

INTERGENERATIONAL EQUITY AND BEQUEST VALUE

Turning now to the question of intergenerational equity, we find ourselves confronted by a number of difficult issues. The calculus of the perfect investment market is seen to be capable of ensuring the satisfactory well-being and survival of families and firms over a time-period of two to three generations into the future which would be sufficient for most decision-makers. There is, however, widespread acceptance that society as a whole places a higher value on the well-being of distant generations than do individuals alone. This concern extends well beyond the 'myopia' of the market place and is often linked to the value placed on the perpetuation of society and its culture.

This is territory for moralists and philosophers, one of whom, in acknowledging the difficulty of coming to grips with this issue, described the force underlying it as love (Passmore 1980). Because of our concern for future generations we are prepared to make sacrifices for them, even though we do not know whether society will value what we save. Though history teaches us that technological change has consistently enabled man to cope with scarcity, we prefer to be safe and run the risk of unnecessary sacrifice in order to ensure consumption in the distant future. The cost of these present sacrifices for the distant future has been called bequest value. Existence value, option value and bequest value could be dubbed together as 'preservation value.' Presumably this value, along with a number of externalities, is important in the management of the Philippine uplands.

In summary there can be no debate with the contention that soil conservation is an investment. The intention is to maximise some objective by allocating the use of soil and land resources through time. The difficulty is that, even if individual landholders make optimal, well-informed private decisions about soil degradation, the aggregate of their decisions may not maximise the position of society as a whole. One reason for this could be distortions introduced by government itself. Another is the failure of the market, particularly in the form of externalities. Even if these deficiences were corrected, on-farm conservation rates might diverge from socially optimal rates because preservation values are non-zero.

Economic theory provides a helpful conceptual framework for the analysis of the conservation problem. Important in this respect are notions relating to market failure and preservation value which suggest that on-farm decision-making will often not be sufficient to determine socially optimal rates of conservation. This implies a need for government involvement in conservation, not just to undertake research and extension but to work with land-users to determine appropriate rates of conservation.

Economic research can assist by (a) developing field procedures for the definition of optimal on-farm and catchment conservation plans, (b) developing procedures for obtaining estimates of preservation value, (c) providing an indication of likely preservation value in a range of situations, and (d) the design of policies and implementation procedures that take due account of the factors that determine preservation values, the distribution of benefits and costs, and of less tangible externalities.

Further, economists can contribute usefully to the debate as to whether society should induce or coerce farmers into accepting levels of conservation greater than they would wish to undertake. Important in this respect, as well as others, is the appropriateness of the conservation technologies available to farmers and the nature of the institutions developed by government to cope with the soil conservation problem. The next section of this paper is a brief discussion of public institutional arrangements for soil conservation, while the last section is a discussion of a particular piece of research into the development of on-farm conservation plans in Australia.

Conservation Agencies in Australia

Land and water policies are constitutionally the responsibility of the states in Australia. The Commonwealth, however, has substantial capacity to influence state policy through its constitutional responsibilities for defence, trade and international relations and through its control over public finance. This latter set of powers is a result of the surrender, by the states, of their income taxing powers to the Commonwealth during World War II. This surrender conferred on the federal government greatly increased authority in the processes of taxation and fiscal policies generally.

In Australia the Commonwealth government has tended to be deferential to the powers and responsibilities of the states with respect to land and water. To some it may have been too deferential, particularly with respect to resource management problems falling within the jurisdiction of several states, such as in the Murray-Darling Basin (affecting the three states of New South Wales, Victoria and South Australia) in the south-east of the country. This basin contains serious problems of land and water degradation which would probably be best handled by means of an integrated basin-wide approach. Such an approach has, to date, been precluded by the failure of the state governments involved to achieve the necessary level of cooperation.

An interesting recent development, however, has been the willingness of the Commonwealth to assert itself on a small number of major (non-soil) conservation issues. Intervention in these issues has been justified in terms of Australia's international trade and relations obligations. Particularly significant among these was the intervention by the federal government to override the Government of the State of Tasmania with respect to the latter's intention to tap the Franklin River for power development. This river is in the southwestern wilderness area of the state which is on the World Heritage List. This fact enabled the Commonwealth, as a signatory of the World Heritage Agreement to override the State Government. Perhaps just as important as the Commonwealth initiatives has been the willingness of the High Court to find in favour of the Commonwealth when an appeal was made over the matter.

With regard to soil conservation, the most important recent initiative by the Commonwealth has been the establishment of a National Soil Conservation Program. This is an interesting exercise in 'cooperative federalism' with the Commonwealth providing funds to the states to supplement their soil conservation work. Under the Program the Commonwealth retains a portion (about 17.5% of $A4 million in 1984) of the budget for its own purposes. One of these Commonwealth purposes is the development of Commonwealth incentives to individual landholders to adopt effective soil conservation practices. No funds have been allocated to this activity to date though some thought has been given to the ways in which Commonwealth fiscal powers might be used to influence soil management by farmers.

To date the program budget has been quite small with a budget of only $1 million in 1983–84 and $4 million in 1984–85. This compares with total annual state soil conservation authorities' expenditure of $40 million. The states determine their own project priorities but details are not available. In 1984–85 the National Component fund ($700 000) was allocated to 25 projects, 19 of which were for research, four for public education and two for documentation.

A range of Commonwealth departments provide advice to the government on land and water matters, and administer the various relevant policies. They also provide executive support for the various intergovernmental committees, such as the Agricultural Council. They also provide representation on the standing committees of these bodies.

Sound management of the national economy is a necessary condition for sound management of the national land base. Particularly important, with regard to soil conservation, is an efficient credit industry. In Australia, as in most countries, these are matters of national responsibility and, at the risk of stating the obvious, if the management of the national economy is unsound, the task of the state agencies dealing directly with soil conservation is very difficult indeed.

At the state level, responsibility for land and water is split between a number of different ministers and agencies, operating under a wide range of not wholly consistent legislation. In consequence, resource administration is divided rather than unified. All states have separate water agencies while two, New South Wales and Victoria, also have separate soil conservation authorities. In the other states, soil conservation is a responsibility of the state departments of agriculture.

The administration of land and resource conservation policies in Australia is made even more complex by the existence of state departments of lands. These departments are responsible for the administration of the nation's vast areas of arid land and much of its forested areas, most of which are held under lease from the state. The leasehold arrangements they administer take a variety of forms which emphasise development, closer settlement and conservation to varying degrees (Young 1979). The potential influence of these arrangements on the status of the land-base is substantial. The land in the higher rainfall zones, while much smaller in area than the arid zone is, commercially, much more significant because most agricultural production comes from it. The bulk of this non-arid land is held with fee simple or freehold title. Not all of these titles are totally unencumbered with some having restrictions on subdivision and amalgamation of holdings.

State soil conservation agencies promote the protection of the land base through the provision of information and the administration of a program of incentives and regulation aimed at reducing soil erosion. The former consists of the provision of advice, technical assistance, concessional credit, and other subsidised inputs, while the latter includes the potential for substantial intervention in, and direction of, land management.

The intuition of most observers and the logic of economics suggest the inevitability of substantial government involvement if socially optimal programs of soil conservation are to be developed. Unfortunately, the desirable nature and extent of this involvement is not obvious or easy to determine. As already indicated, valuable work is being undertaken at the farm level but much more research needs to be done into the issues relating to externalities and preservation value before this problem can be resolved. The conceptual base may be adequate but the informational base adequate for a coherent and broadly accepted soil conservation policy does not yet exist. While little is known about the present extent of land degradation, even less is known about its causes, particularly from a socio-economic point of view. Similarly, too little is known about the technical, economic and social consequences of alternative policy scenarios. Further, the important moral and political question of the appropriate mix of carrot and stick needed to bridge the gap between private and social conservation optima is not answered. To what extent should soil conservation officials be distributors of largesse intended to encourage private decision-makers to act in the overall public interest, or be 'technical policemen' (Schapper 1983) dragooning private decision-makers into compliance? In this last respect Downes (1970) in his review of soil conservation legislation in Australia nominated some essential provisions of a statute for soil conservation, while Bradsen (1984) has presented a strongly critical review of the existing legislation from the point of view of a lawyer. In Australia these two discussions of the relevant institutional arrangements are oases in what is otherwise a desert.

While important work needs to be done on biophysical problems relating to soil conservation in Australia, our feeling (which is no doubt influenced by our disciplinary standpoint) is that research in the socioeconomics of soil erosion and conservation policies (including economics, law, sociology, administration and politics) is urgent. Without it, no radical advance on the present level of achievement will be possible. We suspect that Australia is not alone in this need.

Farm-Level Problems

In moving from the national to the farm level we refer back to our assumption that a farmer's goal is to maximise net worth. This had two components—the flow of cash income over time and the change in property value. Neglect of the latter could result in increasing annual cash flow by consuming capital.

If the farmer had no interest in intergeneration transfer, he might be prepared to allow the value of the farmland to erode considerably as he approaches death. As the time of death is uncertain, we may wish to consider the farmer's planning horizon from now until retirement, at which stage the value of his farm provides his retirement pension — either by sale or by passing on to a relative who in return will meet the farmer's needs for food, shelter, etc. for the rest of his life. These ideas may be summarised as follows:

Total net present value = (sum of present value of annual expected net income for each year of the planning horizon) + (present value of the farm in year T),

or

$$NPV = \sum_{n=1}^{T} \left(\frac{1}{(1+i)^n} NI_n\right) + \frac{1}{(1+i)^T} FV_T \quad \text{Eqn 1}$$

where T is the length of the planning horizon
i is the interest rate
NI is the net farm income in year n
and FV is the Farm Value

The calculation of Net Present Values (NPV) requires two sets of assumptions; one relating to prices, yields, and costs over time in determining the net income; and the second relating to the interest rate used in weighting future income to determine the present value. The interest rate component is that which allows the farmer to weigh between the value of present and future consumption, for example:

at an interest of 1% the present value of $1 is 90 cents,
at an interest of 5% the present value of $1 is 61 cents,
at an interest of 10% the present value of $1 is 39 cents
at an interest of 20% the present value of $1 is 16 cents
at an interest of 40% the present value of $1 is 3.4 cents

in 10 years' time. Thus, low interest rate indicates a relatively low preference for present versus distant consumption; while high rates indicate a preference for immediate consumption. The value of a dollar in 10 years' time is clear evidence that subsistence farmers place a strong preference for present consumption (survival) rather than distant consumption. High interest rates would place little or no value on the terminal value of an asset in 20 years' time. For example, at an interest rate of 40% it is likely that conservation practices would hold little or no value for a 40-year-old farmer acquiring a farm and hoping to retire in 20 years' time.

We would expect, if the model above is correct, that a farmer would adopt these soil conservation measures (if any) which would raise the NPV of his life earnings (including changes in asset values). Introducing a conservation measure may cause both positve and negative changes in the right-hand side of Eqn 1 — it is the net weighted effect which is important. A likely result of soil conservation measures, especially mechanical ones, such as contour banks, is that:

(a) current net income is lowered (due to repaying capital cost and soil disturbance reducing crop yields);
(b) future net income is increased (due to the benefits of the measures taking effect): and
(c) the future value of the farm will be raised (if there are ongoing benefits of crop yields, higher value crops being grown, etc.).

The general case above is exemplified in Fig. 1. The figure represents a decline in income (due to lowered fertility, need to grow hardier, less profitable crops, lengthening rotation, and so on) if conservation measures are not undertaken and a steady rise in income, after an initial reduction, if the erosion control measure is implemented. Note that for t years the farmer will be worse off and that for $(T-t)$ years he will be better off. (N.B. The initial decline is not due solely to the expense of the measure. It is due to the consequence of change such as taking land out of crop and into pasture, growing a fertility-building rather than depleting crop or waiting for disturbed soil to regain its former fertility. The capital cost, if any, could be amortised over the life of the investment).

From Fig. 1 we can see that over the whole period benefits (area marked 'future gains from conservation measures') exceed losses (area marked 'current loss from conservation measures'). However that may be of little relevance when we take our set of discount (interest) weights into account. If t were 5 and T 10 years it would not require a very large discount factor $(1/(1+i)^n)$ weight to make the present value of the benefit less than the present value of the losses. If the time 0 value of the dashed line represented an income close to subsistence, then it is evident that the farmer could not undertake the project without funding to meet the difference between current and the reduced income. Note that such

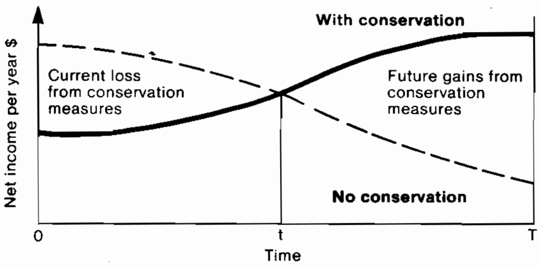

Fig. 1. Hypothetical income flows for 1 ha.

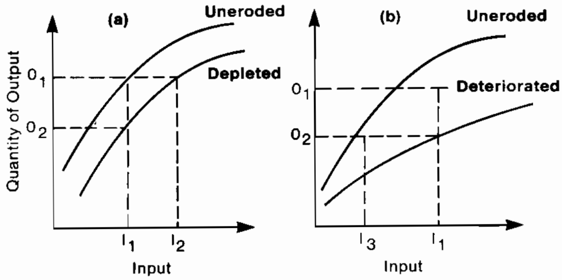

Fig. 2. Output relationships for two soils.

assistance would be beyond any assistance required to meet the cost of implementing the conservation measure.

It might be noted that Fig. 1 could be drawn in one or other of two ways, first to represent the costs and returns per conserved hectare; second to represent the return per farm, with the possibility that only small proportions of the farm might receive conservation treatment in any one year. In the latter case the decline in income would not be as substantial as that shown in Fig. 1, which is based on the first alternative. It is also evident that the situation may be very different for a large-scale landholder and a subsistence farmer. Nevertheless, the shortfall in income associated with conservation measures is likely to require efficient credit systems and relatively low rates of interest before conservation measures will be attractive to subsistence farmers.

Soil erosion may affect farm productivity and income in two contrasting ways (MacCallum 1967). The first is that erosion simply reduces the replaceable stock of nutrients or a replaceable characteristic of the soil. In this case the soil can be restored to its original fertility by the application of nutrients or by whatever means are necessary to restore the diminished characteristic. A crop rotation where the grain crop reduces fertility and a leguminous crop restores it is an example. The second way is where there is permanent loss of output due to irreversible damage to the soil matrix. Here, it is not possible to restore the fertility of the soil, or at least not in an economically rational way. Perhaps these should be contrasted with a third situation where soil fertility as such is not affected but yield can be influenced by varying the level of some input, such as labour. These situations are illustrated in Fig. 2.

O_1 may represent output from a soil before heavy cropping. O_2 shows that the fertility has declined but could be taken back to O_1 by using more inputs. Permanently damaged soil can not produce an output of O_1. In terms of a rotation, one would ideally hope to retain the uneroded relationship shown in Fig. 2, but depending on the stage of cycle within the rotation, more or less, resources may be required to achieve a given output.

Implications for Soil Management

How will a farmer with an objective function as described by Eqn 1 manage his soil resources? The results obtained by McConnell (1983), who applied economic theory to analyse the decision of a farmer with such an objective function, provide some insight on the question. McConnell specified the following four rules:

(1) A farmer will continue to use an input until its returns in use equal its costs in use. A farmer who allows soil loss to occur can be regarded as using soil as a variable input. Thus an efficiency-maximising farmer will continue to allow soil loss until the value of returns obtained from additional soil loss equals the implicit cost of using the soil;

(2) Any one asset must earn a rate of return equal to the returns on all other assests. For an individual investor, such as a farmer, this rate is approximated by the general opportunity cost of capital. Soil is a capital asset to the farmer, just as his machinery is a capital asset. So, the soil resource should earn a return equivalent to this general opportunity cost;

(3) If additional soil depth has no impact on production (and hence no impact on net income), the value of extra depth of soil can only be reflected in the capital gain of increased land value. This gain will occur as the increased value of the farm at the end of

the planning horizon; and

(4) Soil conservation may either reduce the rate of loss of depth of soil or increase the depth. For the depth to increase (i.e., natural development of the soil profile is faster than the rate of loss of soil), the rate of increase in soil value has to be greater than the farmers own time rate of discount.

These 'rules' require that the farmer is aware of the soil's contribution to net income and land values. The implicit cost of soil loss (in Fig. 1) is the sum of the change in net income plus the change in sale value of the farm.

When Will a Farmer Conserve

An individual with a strong sense of resource conservation or moral obligation to future generations will tend to conserve his soil, other things being equal. Apart from this personal motivation, what economic factors induce the farmer to conserve his soil resource and undertake conservation measures?

(1) The basic objective function of Eqn 1 includes the sale value of the farm. The rational profit-maximising farmer will only exhaust his soil, and reduce the resale value of the farm through lower land values, if the present value of the gains in annual net income is greater than the present value of the decline in land value at time T.

The farmer will be encouraged to recognise the land value component if there is a competitive market for his land. He will, therefore, tend to conserve when there is such a land market and when conservation measures increase land value.

(2) As Fig. 1 indicates, any factor that raises future gains relative to present gains may favour the adoption of conservation measures. Such factors include higher future output prices, lower future input prices and lower discount rates. They also include anything that lowers current losses, such as low-interest loans to undertake the necessary measures.

Methodological Approaches

Many different approaches have been used to examine the economic costs and returns of soil conservation. The methods used generally reflect the nature of the particular problem being examined and the context in which it is being examined, that is, either from the point of view of society or that of the individual. The most common methods used to examine the economics of soil conservation can be broadly classified into the following categories: linear programming, benefit-cost analysis, gross margins-budgeting, simulation, and regression analysis. The distinction between these methods is not always clear, and most methods can also be used in conjunction with one or more of the other methods.

Linear programming (LP) is a method of optimising a system that is specified by a series of linear equations. It is concerned with the efficient allocation of limited resources to known activities with the objective of maximising or minimising a desired goal. The solution of an LP model will result in the optimisation of an objective function under the constraints specified in the formulation of the model. Extensions of LP include integer programming and non-linear constraints and/or objective equations.

Examples of the linear programming approach are those of Hickman and Jackson (1979), based on Universal Soil Loss Equation; Berglund and Michalson (1981) who evaluated a 'five point soil conservation program'; Walker and Timmons (1980) who examined 12 policies over 109 crop production combinations; Boggess et al. (1979) and Alt and Heady (1977) who assessed alternate conservation policies; and Frohberg and Swanson (1979) who used non-linear programming to determine economically efficient rates of soil erosion. Examples of the benefit-cost approach (or a variant) are Kim and Dixon (1983), MacCallum (1967), McConnell (1983), and Troch et al. (1980). A regression analysis application is that of Ervin and Ervin (1982). Dumsday and Flinn (1977) used a simulation model to evaluate alternate soil conservation systems at the farm level.

An Australian Linear Programming Example

In 1983 the Soil Conservation Service of New South Wales funded Drs Pearse, Perrens and Sinden of the University of New England to produce a model which would allow conservation officers to evaluate the economics of alternative methods of soil conservation in relation to a specific farm. They wanted to be able to demonstrate to the operator whether or not it was economic for him to introduce conservation measures and to describe the extent and timing of any profitable measures. After reviewing alternate approaches it was decided that the most appropriate form of analysis would be that of a polyperiod linear programming model.

Linear programming was selected because it is a well-developed mathematical technique capable of incorporating such variables as alternative crops, methods of finance, criteria for farmer goals, methods of conservation, and a range of livestock activities. In terms of resources and constraints, it is simple to specify soils of different slope, structure and fertility, labour resources, financial resources, machinery resources, limits on specific crop or livestock activities (imposed by quotas or risk constraints), and 'counter' rows for grain and livestock production, as well as expected soil loss.

The first step was to find a base farm against which the proposed model could be tested. Records were made available of a farm which had been evaluated at 1-2-year intervals for 15 years. After extensive discussions and research into the records of soil conservation research stations we defined estimates of the probable rate of soil loss for each type of summer and winter crop and for pastures or soils of varying slope and fertility (as defined by previous cropping history). With this information we were able to calculate the amount of soil loss associated with the profit-maximising plan. We then constrained the permissible soil loss and calculated the decline in profitability which resulted at each level of permitted soil loss.

The second stage was to extend the model from 1 year to 5 years, including a loss function which incorporated the effect on yield of soil loss, e.g. the effect of yields (in later years) of losing say 1 cm of soil from a soil of 5 cm depth was estimated from experimental and other evidence. (To the best of our knowledge the effect of soil loss in one year on the returns in later years is not incorporated in other models.)

The third stage was to extend the model to a 10-year period and to incorporate activities allowing the construction of contour banks (the stage one and two models only contained strip cropping or the use of low soil loss crops as means of reducing soil loss). Also included were minimum till methods of sowing crop, suitable for a farm growing winter cereals, sorghum and sunflowers. Minimum till techniques, by retaining straw cover at periods of high erosion probability, greatly reduce soil loss by wind and water erosion.

With the model we can do the following:

(1) Constrain soil loss to a desired level and calculate the most profitable combination of crop and livestock activities;

(2) Simulate the effect on yields of continued erosion over time:

(3) Simulate the effect of a one-off disastrous erosion event, and calculate the degree of yield reduction that would occur before contour banks were economically justifiable to prevent such occurrences; and

(4) Gain an insight into how crop/livestock combinations would change with different methods of conservation available to reduce soil loss to a specified maximum under different crop and livestock price regimes, different forms of government support for erosion control measures, etc.

So far we cannot properly account for the uncertainty of when erosion damage will occur. Our assumptions are based on an average soil loss per year but frequently there is little soil loss for 5-8 years and then one or two major losses in 1 year.

The polyperiod LP matrix for 10 years has 1140 activities and 500 rows, requiring about 90 min to solve on a DEC2060 mainframe computer. To meet the need for on-farm solution we propose to use either smaller matrices by eliminating activities not selected (in the regional mainframe analysis) or by solving on a mainframe and using advanced basis restart on-farm with the micro (or both methods). The National Soil Conservation Project has provided funds to extend and refine the model for different regions and to evaluate the practicality of on-farm analysis with data specific to that farm. A likely development scenario at this stage is to solve for the specific farm on the mainframe and to use a microcomputer on-farm to test alternative or 'what if' scenarios, each of which might take 15-20 min to solve.

The major challenges facing the project are the following: (1) allow for time-denominated uncertainty of soil erosion loss; (2) obtain better estimates of the effect of physical soil losses on crop fertility; (3) prove the fruitfulness of the on-farm evaluation with a microcomputer; and (4) means of keeping the matrix in manageable proportions by identifying redundant activities and constraints for individual farms and regions.

Conclusion and Summary

In the paper, the background to social attitudes towards land degradation and soil conservation in Australia was reviewed, the basic economic framework required for the analysis of land degradation problems was outlined, the main organisations providing an input into soil conservation policy in Australia were described, and possible approaches to the analysis of soil conservation problems at the farm level were outlined.

The major problems in developing a coherent and acceptable set of conservation policies are those of resource allocation and the distribution of cost and benefits at the farm level. The latter problem is exacerbated by the long time periods involved, and the consequent problems of selecting appropriate interest (discount) rates and forecasting price relativities of inputs and outputs, as well as by the consideration of such externalities as flood damage to private and public facilities off-farm, to the siltation of dams, and so on.

Conservation policy impinges on a wide range of organisations in Australia at federal, state and local government level, and may well be inimical to some of the objectives of these organisations. Work on resolving conflicting policy objectives and goals, as well as specifying the interconnection of economic and physical relationships is vital.

Soil conservationists, of both the economic and biophysical camps, will fall far short of providing the contribution which society can rightfully expect from them if they fail to appreciate each others strengths and weaknesses and fail to work jointly toward a goal of common understanding of the physical, economic and political framework within which the country functions.

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Soil Erosion Management in the Philippines: Observations on Visits to Leyte, Cebu, Mindanao and Luzon

J.V. Remenyi*

PRECEDING the ACIAR/PCARRD Workshop at Los Baños, a field trip was organised to expose Australian scientists to the soil erosion management problems being encountered by researchers in the Philippines. The group visited hill country in remote parts of the Philippines, a community works project, research centres, and discussed soil erosion management with community development workers in erosion-prone areas.

The group first met with the Farming Systems Group and the members of the Centre for Social Research in Small-Farmer Development, at the Visayas State College of Agriculture (VISCA) on the island of Leyte at Baybay. It was in Leyte that we encountered the poorest groups of hill-farmers we were to meet throughout the trip. The research program at VISCA is spread over several regions in Leyte, where researchers are integrating the spread of new technologies together with documentation of the current status and problems of hill farmers. Many of these farmers are squatters farming less than one acre per household. Little effort seemed to be devoted to evaluating the technologies being extended, but adoption rates of new varieties of food and cash crops seemed to be quite high. Some hill farmers complained that their yields suffered because of competition for their own labour from cash-generating off-farm employment opportunities at crucial times in the season.

In Cebu there is a major initiative in community development for upland farmers being implemented. The program incorporates alley-cropping-based technologies, which are being promoted as appropriate to erosion-prone uplands. Some of the areas into which this upland technology is being applied are exceedingly steep—too steep for farmers to stand upright, so they secure themselves with a rope. Meanwhile, down in the flat lands and open areas under and around coconut groves, land begs for intensive cultivation. We heard many reasons why farmers choose not to crop the coconut groves, but these must remain hypotheses. Probably something more than simple land tenure considerations is involved. Nonetheless, in Cebu we did also see very successful upland farmers, some of whom had managed to turn their upland plots into highly productive horticulture enterprises serving the nearby urban centres. As was the case in Leyte, the predominant set of technologies employed by farmers in their hilly and precarious holdings involved a variant of alley cropping, designed to achieve a gradual terracing between hedgerows of leucaena, gliricidia, napier grass, etc.

The Philippine-Australia Development Assistance Program (PADAP) in Mindanao was also visited. Alley cropping, combined with a variety of rotations plus fish and animal components, is at the heart of this largely extension-oriented area development program. The group was impressed by the success with which farmers were being reached with, and were adopting, the technology

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being demonstrated. Again the land being tilled was hilly and erosion-prone. Terracing with shrub legumes seemed to offer a productive erosion management system of cultivation, which also gave farmers a source of feed for animals, through regular pruning of the hedgerows, and fuelwood.

More than anywhere else, the PADAP program in Zamboanga betrayed what we gradually recognised as a common set of observations that had begun to crystalise in the consciousness of the group by the end of the field trip. These observations can be summarised as follows:

1. In the erosion-prone uplands of the Philippines, development workers are acting on the assumption that the alley cropping or SALT (sloping agricultural land technologies) methods of farming are *better* technologies. There has been insufficient research to evaluate alley cropping under a range of different slopes, soil types and climates.

2. Despite a long history of concern for soil erosion in the Philippines, there is a paucity of data available on: (a) trends in soil erosion by regions; (b) the extent of adoption by farmers of alley cropping and SALT farming methods by regions; (c) the documentation and quantification of problems encountered with the use of alley cropping by regions; and (d) the macroeconomic cost to the Philippines of soil erosion.

3. Alley cropping approaches soil erosion management by attempting to harness soil movement to alter the slope of cultivable land between hedgerows, into sets of contoured terraces. However, it is not clear, under all or even most upland farming environments, that these new terraced alley systems form a stable base for long-term agriculture. It could be that the alley formed between the hedgerows is storing up a potentially dangerous earth slide/slip for the future. Is it possible to test under what physical and environmental conditions risks of this sort are real and not imagined? Is there a need for a new form of land classification system that ranks different slope and soil type environments according to their suitability to alley cropping as a long term farming system option?

4. Despite some familiarity with the alley cropping style of farming system for erosion-prone areas in the Philippines, some recommendations affecting even crucial elements of the technology do not appear to be soundly based. For example, we observed no research to evaluate optimal hedgerow spacings depending upon slope, soil type or principal crop sown.

5. In all upland areas visited there is a significant dry season that causes farmers problems, plus a wet season when erosion is an everyday problem. Under these conditions it seemed to the group that there may be significant gains from exploring the possibility of attempting to incorporate water harvesting, chanelling or storage techniques into the upland farming system.

6. Almost without exception, the focus of what we saw throughout the field visits was on soil conservation to stop or mitigate soil erosion. This contrasts with a focus that sees the purpose of soil erosion management as a set of practices that manages soil erosion in order to achieve increased farm productivity. The latter recognises that often one farmer's soil erosion is another farmer's soil gain. This emphasises the 'externalities' associated with shifting an asset from one place to another. It also ranks soil conservation as a by-product of farming methods and public policies that give pride of place to agricultural productivity improvement. It seemed to the group that in the Philippines the stress on soil conservation as the primary goal of erosion management may have led to an inadequate concern for the productivity *losses* attributable to soil erosion. This may also explain why there seems to have been little effort to quantify such losses to the Filipino farmer and the macro economy.

7. Finally, we were struck by the parallel between soil erosion management techniques in the Philippines and the nature of public goods. Consequently, there is an important role for government to ensure that the returns to farmers for adopting productivity-augmenting, soil-erosion management farming methods are adequate. Policy design needs to give due appreciation to this responsible call on public funds.

The group consisted of J.V. Remenyi and A.R. Maglinao, ACIAR and PCARRD team leaders, A. Celestino, P. Dart, R. Loch, W. Musgrave, L.G. Nallana, E. Paninbatan Jr., R. Pearse, C.Rose, K. Turner and R. Viner.

Plenary Session I

Soil Erosion Management in the Philippines

Moderator: Dr Manuel Bonifacio
College of Arts and Sciences
UP Dilliman

Rapporteurs: Prof Warren Musgrave
Department of Agricultural Economics
University of New England

Dr Modesto Recel
Soil Research Division
Bureau of Soils, Philippines

DISCUSSION in the open forum component concentrated on the assessment of technology and the possibility that some existing policies negate conservation.

There was general agreement that technology assessment is important. The point was made, however, that there is no single agency responsible for the assessment of soil erosion management technology in the Philippines. Discussion tended to concentrate on the need to consider social and economic issues and assessment of soil erosion management technology. The importance of involving farmers in assessment through participatory research was emphasised. Likewise, future research on the perceptions and attitudes of farmers may be considered in this workshop. A final point was raised that upland farmers could no longer be ignored in this research.

Discussion of the possibility that some policies may actually negate conservation was initiated by reference to land tenure policy. Research on the problem in Central Luzon was mentioned.

In his response, *Cabrido* suggested the problem was not so much on policies negating conservation but rather on policies in conflict with one another and the fact that sometimes directives are not followed. Another example was raised by a subsequent discussant who referred to areas of land being rendered useless in Central Luzon and speculated that perhaps multinationals are exempted from rules and regulations intended to promote conservation. This prompted the observation that the problem is lack of, or laxity in, enforcement rather than lack of policy. *Velasco* made the point that the Philippines has enough laws to enact policies and guidelines. He did not think that new laws were needed, even if the problem of soil erosion management were a new area affecting a different class of farmer or tenant.

In concluding the session, the *Chairman* suggested that the thrust of discussion was toward the need for research into the phenomenology of land use in recognition of the principle that land-use policy must be a policy for the use of land by the people and for the people.

Time for discussion was limited, which was unfortunate in view of the strong interest in social and economic issues. Had there been more time, discussion may have focused on specific policy issues. As it was, the discussion prompted by *Cabrido*'s paper suggested that a comparison of Australian and Filipino institutions and organisations may yield some useful conclusions. Both countries have a complex array of laws and organisations relating to soil conservation. Law enforcement problems also exist in both countries.

Both papers showed evidence of the need for a definition of soil conservation and objectives of conservation policy. A conceptual framework of soil conservation which considers the economic and social dimensions is in order. Indeed, an initial paper providing such a framework would have greatly helped subsequent discussions in this workshop.

Plenary Session II

Advances in Knowledge on Soil Erosion Management

Forum I

Moderator: Dr Diosdado A. Carandang
Department of Soil Science
UP Los Baños

Rapporteur: Dr Rob Pearse
Department of Agricultural Engineering
University of New England

THE ensuing discussion was mainly centered on the *Rose* paper. The specific points raised concerned its validity on steep slopes, whether the key parameters required to be estimated were associated (for rough prediction) with soil taxonomy and methods of estimating the key parameters. Rose concentrated on a simple version of his complex model. Surprisingly, no discussion on the comparative costs and benefits of the two versions was raised. It seemed clear that the model should be sensitive up to the point where mud or landslide is likely to occur. The model is not useful for predicting such soil movement nor is it of value in the case of soil loss due to gully erosion. Questions were also raised about the effect of typhoon strength and winds on soil loss from water erosion. It is evident that immediate attention should be given to estimating key parameters and evaluating the model under Philippine conditions. Validation of the model would greatly reduce the need for data gathering.

This aspect should also be tested for McMahon's complex computer-based rainfall model for estimating rainfall intensities. There were some questions also about the relation of *Turner*'s results to Rose's model but it appeared likely that these difficulties were due to the use of different terminology. The absence of rainfall intensity measurements as input to the Rose model caused some concern. Rose emphasised the value of a physical process model for predicting erosion compared with statistical models which require vast amounts of data to be calibrated under new sites and conditions.

The question of appropriate plot size for soil loss evaluation trials raised considerable discussion but no clear answer was given. Rose indicated how his model could be used to extrapolate data from 1 m^2 plots and described methods for measuring vegetative cover.

From the discussion, some issues that could serve as bases for future research still need to be resolved:

(1) Precise nature and effect of the vegetative cover (leaves, sticks, straw, etc.);
(2) Acceptable amount of soil loss;
(3) Specific work to be done and where it should be undertaken;
(4) Problem of lake and downstream pollution; and
(5) Benefit/cost analysis of soil conservation measures.

Forum II

Moderator: Dr Diosdado A. Carandang
Department of Soil Science
UP Los Baños

Rapporteurs: Dr Calvin W. Rose
School of Australian Environmental Studies
Griffith University
Queensland
Dr Eduardo Paningbatan, Jr
Department of Soil Science
UP Los Baños

THE discussion in Session III was focused mainly on the use of ipil-ipil in contour strip-cropping in hilly areas. Questions were asked regarding the stability, origin, successes and failures in the use of ipil-ipil as hedgerow.

There was concern as to whether contour strips of ipil-ipil as used in highly sloping lands is stable enough to last in the long-term. Experiences in the Philippines, as mentioned by one of the resource speakers, was that the use of ipil-ipil as hedgerow was introduced and practiced only recently, in the 1970s, which is not long enough to answer the question of long-term stability of the system. In Indonesia, however, ipil-ipil has been used for more than 20 years in an alley-cropping system.

As to the origin of its use in hillylands farming, ipil-ipil was identified in an earlier PCARRD workshop as a crop that can be utilised as hedgerow as well as source of organic fertiliser. This was then tried in the hillylands of Cebu province with immediate success. In Batangas, the plant is being used extensively as forage.

Some of the disadvantages related to ipil-ipil use were pointed out: the plant does not grow well in highly acidic and phosphorus-deficient soils; farmers with small land-holding are concerned about the significant fraction of the land taken up by the hedgerows; and ipil-ipil was observed to have inhibitory effects on the germination of rice and on the growth of sweet potato.

Discussion ensued on the role of ipil-ipil when applied between rows in association with crop residues and as protection against soil erosion. Whether ipil-ipil or other legume tree crops should be planted exactly on the contour or on a slight grade was also discussed. In either case, safe disposal of excess water at the end of the hedgerow required consideration. In soils with high infiltration rate planting on the contour may not lead to erosion, but in soils with lower infiltration rates the use of graded hedgerows could be worth considering.

Research areas identified:

(1) Management problems with ipil-ipil, including regular cutting, the advantages and disadvantages of other legumes in different environment and as companion to various crops;
(2) Nutrient cycling in systems wherein different legumes and other crops are used as soil conservation measures. This will also include identification of various legumes and crops;
(3) Stability problems of various erosion control structures (or measures) adopted in hillylands;
(4) Cropping systems management research to develop local or specific farming systems to protect soil from erosion;
(5) Evaluation of tillage techniques as a sub-system of a given farming system;
(6) Development of an agroforestry farming system; and
(7) Legume-based pasture/livestock farming systems research.

Plenary Session III

Socioeconomic Dimensions of Soil Erosion Management

Moderator: Mr Benjamin Abellera
Cordillera Studies Center
University of the Philippines, Baguio

Rapporteurs: Dr Joe Remenyi
Australian Centre for International Agricultural Research, Canberra

Dr Obdulia F. Sison
University of the Philippines at Los Baños

THE paper presenters were one in their view of land degradation/soil erosion as among the most serious environmental problems in both the Philippines and Australia. In both countries, policies exist to confront the problems. However, for political and other reasons, these have not been seriously enforced.

Speaking of the Philippine experience, *Librero* raised questions which were not addressed during the open forum. These questions related to the search for profitable areas of farm adjustment. He stressed the need to recognise the importance of research in uplands on the following questions:

(1) Whether present crops, both in kind and magnitude produced, offer the best alternative for utilising existing resources and in coping with existing natural conditions?
(2) What are feasible alternatives available to farming? Are there input and marketing constraints?
(3) What adjustments in resource uses, operations, and services are necessary?

The identification of alternatives and how they can be achieved are challenges to the farmer, the extension agent, the researcher, the policymaker, and development workers generally.

Musgrave and *Pearse* presented a comprehensive view of soil conservation, the farm problems of soil conservation, policies addressing such problems, and the methodological approaches which have been used to examine the economic costs and returns to soil conservation. They pointed out that while important work needs to be done on biophysical problems relating to soil conservation in Australia, their feeling is that research in the social sciences (including economics, law, sociology, administration, and politics) is urgent if the present level of achievement is to significantly advance.

Musgrave noted that economic theory provides a framework within which objective and rational criteria can be applied to the difficult problem of public goods and externalities in the soil conservation area. Pearse noted that economics also offers powerful linear programming tools for the analysis of optimal cropping strategies under erodible soil conditions. These techniques give due weight to the importance of discount rates and optimal levels of soil erosion. This latter point was reinforced during the discussions by characterising soil conservation as a by-product in farming of productivity-augmenting technologies.

The question-and-answer sessions also reflected the need to:

(a) Clarify and refine the quantitative measures for determining soil erosion and the methodological approaches used to examine the economics of soil conservation;

(b) Take a look at soil conservation not only as an economic investment but a social investment as well. Soil conservation is part of a social system where an interaction of technology and organisational resources (human and material) is intimate. In this situation, management becomes an important interacting subsystem and an important area for research;

(c) Communicate research results and their implications to policymakers to serve as bases for judicious decision-making and policy formulation on land use and other aspects of ecological management; and

(d) Find explanations for farmer's observations/beliefs and claims at the micro-level to forestall broad claims and sweeping generalities and conclusions about the relationship between man-made environmental changes and observable natural phenomena.

We also want to note the following:

(1) The importance of population control as a soil erosion control measure, particularly as rapid increase in population relates to land availability and land use;

(2) The involvement of women in the programs on soil erosion management in recognition of women's significant role and contribution to agriculture in the Philippines;

(3) The inclusion of landless farmers in the non-formal education activities for soil erosion management;

(4) Need for research for social action, bringing into focus the search for basic knowledge with regard to organising and mobilising beneficiaries of soil erosion technologies for group and/or community action; and

(5) The need to control excessive logging.

The questions that have been raised also point to the need for a state-of-the-art report, synthesising what is presently known regarding soil erosion management technologies and policies. Lessons of experience could be drawn from these in order to determine gaps in knowledge which can provide direction to potential areas for study.

Joint Planning Session

Moderator: Dr Eric Craswell
Australian Centre for International Agricultural Research, Canberra

Rapporteurs: Dr Keith Turner
Agricultural Engineering Section
University of Melbourne

Dr Beatriz del Rosario
Farm Resources and Systems Research Department
PCARRD

A FRAMEWORK for soil erosion management research was suggested by the Chairman (Fig. 1). The whole process of research development involves: (a) diagnosis of the socioeconomic and biophysical environment; (b) providing solution/design in terms of technology such as alley cropping; (c) testing that technology; and (d) extension or policy formulation.

Comments/suggestions were raised on the following:

1. *Objectives* — need to be clearly stated or defined. Are the objectives directed for certain policy changes or are the objectives directed toward efforts that affect the farmers themselves?

For example, the feasibility of a catchment program will depend on what exactly is needed to be involved in this type of work, will take seriously the entire geometry of the catchment area involved, and will predict where deposition will take place. The group was informed about the plan to implement watershed environmental monitoring in terms of quantifying soil erosion sediments and assessing water quality by agencies in the Philippines, like the Bicol River Development Project (BRDP). This may be feasible, but is this what we are really concerned with at the moment? Should we be doing measurements of deposition in lakes or basins?

There was a general agreement as to the identification of the real problems, clear statement of the objectives, and identification of priorities. These things should be considered in the discussion by the individual session groups.

2. *Diagnosis of the biophysical environment:* (a) It was suggested that in order to understand quantitative data, i.e. area and severity of erosion, there is a need to understand the criteria by various collecting agencies. Commonality may not be desirable as there are differences in the perception about the area and severity of the problem itself.

(b) The assumption that alley cropping is the solution may be a hasty generalisation that this is the only technology being advocated. It must be noted that there are technologies which are either existing or an improvement of the existing ones which need to be tested/evaluated.

3. It was suggested that the socioeconomics group should identify "social" technologies that would give major elements in soil erosion for upland farmers. The social science group could contribute by employing modelling techniques.

4. A point was raised about the general impression that the results generated do not fit the farmers' circumstances. Hence, biophysical research needs to distinguish activity sets which can be done with the farmers and those which can be

	Socioeconomics	Biophysical
Diagnosis	farm size/income — document environment — costs—micro —macro	area severity land classification methodology
Solution	DEVELOP TECHNOLOGIES e.g. ALLEY CROPPING	
		study and refine — spacing — soil surface mgt. — N cycle
Testing	EVALUATE TECHNOLOGIES e.g. ALLEY CROPPPING	
	— profit — management — linear programming	— soil loss — yield — fodder fertiliser mgt. — implements
Policy/Extension	consequences benefits — macro — micro institutions Policy review — role of women — landless farmers — basic knowledge on group organisation	problems — acid soils — establishment — long-term consequences to soil loss

Fig. 1. Soil erosion management research framework

done at the research station.

5. Future plans should consider the effects of population pressure on rural land for much smaller farms in 20 years time.

The list of possibilities which PCARRD-ACIAR could consider include the following four major areas:

(1) define socioeconomic, physical scope and consequences of soil erosion in the Philippines and use data for (a) policymaking to advise on action program, and (b) determine areas of greatest need;

(2) develop farming systems which increase agricultural activity while conserving the soil resource. Alley cropping could be one focus;

(3) test and define conservation farming technologies and analyse present practices; and

(4) study constraints to adoption and consequences of conservation practices.

Remarks

The proposed framework suggests an integrated approach for doing research, which is popularly known now as a farming systems approach. This approach starts with the diagnosis of the problem (which includes gathering baseline data on the general environment or circumstances of the farmer, i.e. physical, social, etc. and formulating hypotheses), determining areas of intervention (or solutions, e.g., alley cropping), generating other/alternative technologies, testing technologies in farmers' fields, and dissemination of research results back to the farmer.

Conclusions

Priorities for Research on Soil Erosion Management in the Philippines

UPLAND farmers have been the neglected clients of research for agricultural development in Southeast Asia. In the Philippines population pressure and scarcity of arable land is forcing subsistence farmers to sow crops in hilly areas with vulnerable upland environments. Renewed effort by researchers and policy-makers to redress this neglect is critically needed.

Research Goals

The ultimate objective of research must be to improve the well-being of peoples dependent on upland agriculture in a way that fits the national social welfare goals of environmental conservation and long-term resource utilisation. In the main this objective can best be achieved by seeking to increase or at least maintain the productivity of upland farmers through the design and evaluation of productive but land-conserving methods of farming, appropriate to hillylands in the Philippines.

Principal Areas of Research Need

(a) Assess the economic cost of soil erosion in the Philippines in order to gauge a measure of potential returns to research and investment in soil erosion management;

(b) Assess the erosion potential in various environments using computer modelling to analyse and interpret data for use by development planners in determining priorities in research and project programming;

(c) Development and testing of soil erosion management technologies that are technically viable, socially acceptable and environmentally sound. An example where urgent research is needed is the package of alley-cropping technologies using contouring with shrub legumes;

(d) Establishment of an on-going capacity to monitor
- (i) trends in soil erosion;
- (ii) the extent of adoption of recommended soil erosion management technologies;
- (iii) changing socioeconomic situation of upland farmers;

(e) Research to improve our understanding of the sociological, institutional, technical, and economic factors that fuel the agricultural push into erosion-prone areas.

Specific Research Topics Identified

1. Measurement of the productivity losses associated with soil erosion in the Philippines:
   - (a) at the macro level;
   - (b) at the micro level; and
   - (c) in terms of returns to research on soil erosion management.
2. Estimation of the private and social opportunity costs of investing in upland agriculture development programs versus the returns to investment in intensification of lowland agriculture systems.
3. Assessment of the long-term stability and sustainability of specific alley-

cropping systems in different topographic, meteorological and geological environments.
4. The effect of alley-crop width and alternative alley surface management regimes on erosion and soil movement.
5. The establishment problems of shrub legumes in relation to site characteristics.
6. Testing the adequacy of existing models for the analysis of the effect of high slopes on soil erosion rates.
7. Analysis of constraints facing upland farmers that influence their ability to adopt soil erosion management farming systems.
8. Economic evaluation of alternative upland farming methods and systems.
9. Design of strategies/methods for the reclaiming and rehabilitation of badly eroded hillylands.
10. The role of mulching and other surface modifications on
    (a) water supply to crops;
    (b) soil transportation rates;
    (c) nitrogen cycling in the adopted farming system.
11. The use of soil taxonomy to transfer technology on soil erosion management within the Philippines.
12. Identification of more effective, resource inexpensive and rapid methods of assessing the felt priorities and needs of upland farmers so as to improve the involvement of farmers in the design and implementation of upland community development programs.
13. Documentation and analysis of the laws, regulations, decrees and institutions that impinge on soil erosion policies in the Philippines.
14. Description and analysis of land tenure systems in upland areas, and assessment of government programs to regularise tenure and occupant security.
15. Assessment of the effect of geothermal power plant and other emissions on surrounding vegetation and subsequent erosion implications.
16. Evaluation of the costs and benefits of continuing logging in erosion prone areas.

Closing Remarks

Alfonso N. Eusebio

THIS workshop has unearthed and witnessed the menacing problems caused by soil erosion as a result of improper land use and poor soil management practices.

It is obvious from the papers presented that there is a major policy issue related to soil conservation. Although there are three government agencies mandated to undertake programs and action on soil conservation, each of these agencies carries out different programs, as follows:

Agency	*Major Programs*
Bureau of Soils (BS)	(1) Small Water Impounding Projects (SWIP) (2) Soil and Land Resource Survey (SLRS) (3) Soil Conservation Guided Farms (SCGF) (4) Program on Soil Erosion Research (PSER)
Bureau of Forest Development	(1) National Integrated Social Forestry (NISF) (2) Watershed Development Program (WDP) (3) Non-Classification (NC)
National Environmental Protection Council (NEPC)	(1) Soil Erosion Susceptibility Studies (SESS) (2) Manpower Development for Soil Conservation (MSDC) (3) Rehabilitation & Monitoring Program (RMP) (4) Information Dissemination Program (IDP)

The focus in the past has been mainly on the technical aspects, to the apparent neglect of the administrative/management aspects. Both should be developed simultaneously.

These ongoing programs notwithstanding, the rate at which the destruction of our land resources is still taking place has far exceeded the tolerable limit and is indeed reaching an alarming stage with far-reaching implications.

The need to rehabilitate and conserve our soils can no longer be ignored, if we are to support our ever-increasing population, the majority of whom are mainly dependent on agriculture for their livelihood. Since soil is a finite resource, there is an imperative need to efficiently manage and conserve our soil resources in a manner that will allow maximum productivity on a sustainable basis. It seems unfortunate that despite advances in modern agriculture, improper soil management and lack of conservation practices have degraded our soil resources, negating directly or indirectly our efforts to sustain a desirable level of agricultural productivity in our country.

The mechanical structures for controlling and minimising soil erosion could be very expensive. Unfortunately, the value of vegetative control, such as the use of appropriate cover crops, cropping patterns and cultivation/tillage practices, have not been particularly appreciated especially by the farmers. While it is not very well understood why the adoption of appropriate soil technology for rehabilitation is slow, the truth of the matter is that the agriculture information network of both public and private sectors is extensive enough to promptly bring this technology to the end-users — the farmers.

Although crop production technology is continuously being developed to meet the food requirements of the growing population, soil conservation to sustain crop productivity has not been given the attention that it deserves. More recently, the research community, the policymakers, and private individuals have indicated their concern about an alarming situation — soil degradation has seriously affected the quality of agricultural production.

In general, however, there is still a lack of sufficient awareness that such a problem exists. Creating mass awareness could be a slow process, although most of the government agencies charged with the administration of the land are now engaged in several ways to support programs on soil conservation. Most of these programs stress soil erosion control through proper land use and management of crops and livestock, such as proper planting schemes, cropping patterns, grazing systems, agroforestry and reforestation strategies.

Benchmark information on the problems of soil erosion in the Philippines has been presented. We are happy that major research gaps and researchable areas have been properly identified, which should hopefully provide more meaningful approaches and strategies for the solutions of important national economic problems. In this context, we are certainly looking forward to strong collaborative activities on soil erosion research between Australia and the Philippines.

Finally, on behalf of PCARRD, we would like to express our sincere gratitude to all the participants for their hard work and valuable contributions.

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