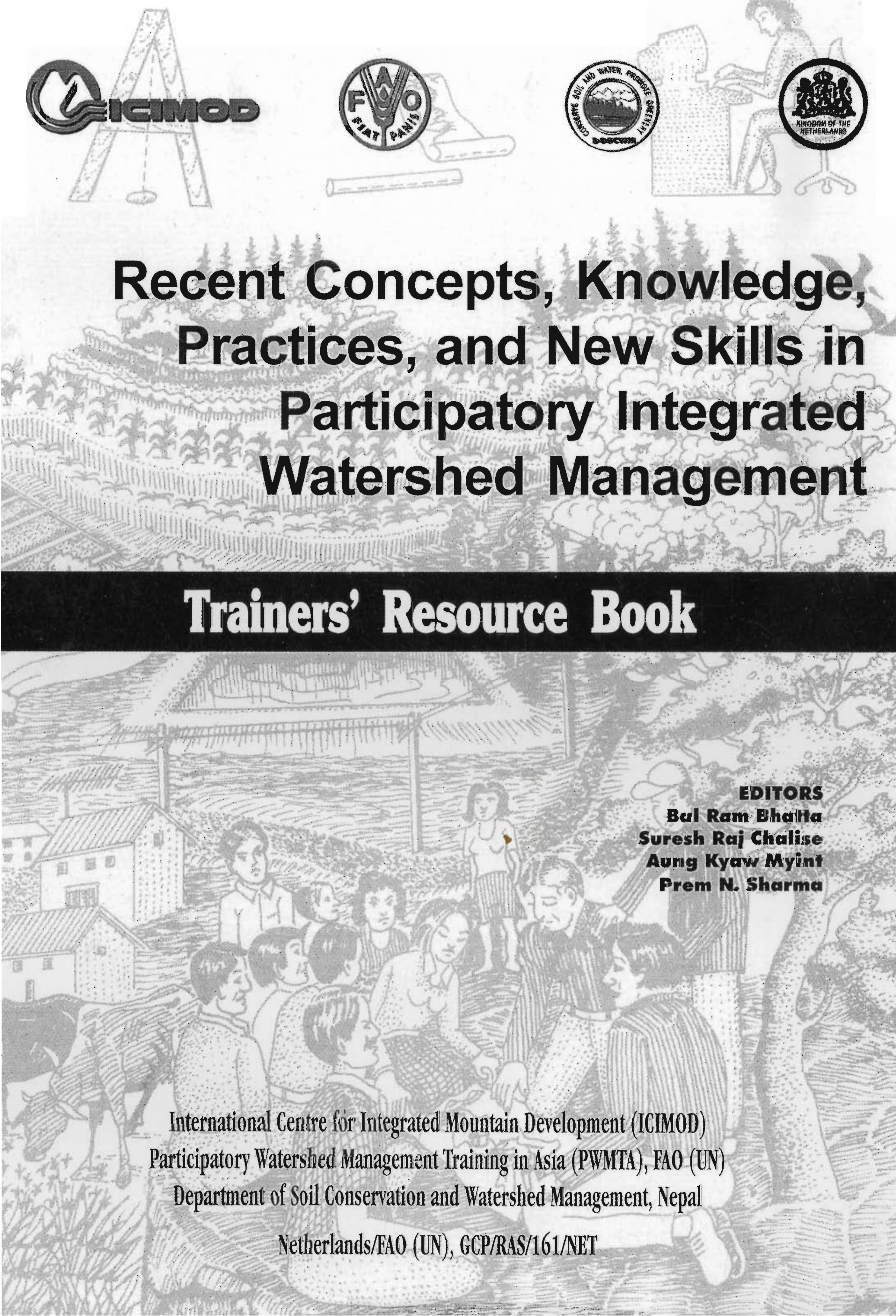

Recent Concepts, Knowledge, Practices, and New Skills in Participatory Integrated Watershed Management

Trainers' Resource Book

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Panel of Contributors

Panel of Experts and Contributors for the Training

The subject of the resource book—recent concepts, knowledge, practices, and new skills in participatory integrated watershed management—is so varied and of such importance and magnitude that it required inputs, knowledge, and experience from a multidisciplinary panel of specialists. Their contributions to designing and organizing the training, preparing the modules of this resource book, and carrying out the training are greatly appreciated.

Panel of Experts

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Panel of Contributors

Names of the contributors to this resource book have been mentioned in their respective papers. More papers than are actually included in this volume were prepared and presented during the training. In spite of their importance, some papers could not be included in this volume because they were also presented at two previous training sessions and have already been published in previous resource books. We acknowledge with sincere thanks the contributors of the following topics which, for reasons explained above, are not included in this volume.

Ms. Jeannette D. Gurung	Gender and Development Specialist, ICIMOD 'Gender Equity in Watershed Management Programmes'
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Illustrations for this resource book were prepared by Mr Badri Ram Shrestha, Artist.

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Foreword

With 20 per cent of the world's population living in upland and mountainous areas and many more in the plains below, sustainable management of watersheds is of global importance. In no region of the world is this more obvious than in Asia, where nearby every country has substantive mountains and upland areas. While natural phenomena such as heavy monsoon rains and fragile geological formations in themselves are major threats to the stability of watersheds, expansion of agriculture, forest exploitation, and population growth are causing increasing degradation on steep and sloping lands. Within upland watersheds and below, landslides and floods inflict much loss of life and damage to property and infrastructure annually.However, there is now a general awareness of the problem of watershed degradation in Asia.

Various efforts are undertaken by government institutions, NGOs, and international and bilateral donor organizations, to reverse the trend of degradation and promote successful approaches to sustainable management of watersheds.

However, the rate of degradation still by far exceeds the rate of restoration, and there is an urgent need to identify successes and failures in watershed management. In recent years, there has been a remarkable change and transformation in concepts and approaches in watershed management in the fields of both institutional development and technologies. Indigenous knowledge and technologies of natural resource management have been (re) discovered as often being more effective, affordable, and appropriate in the more remote areas. At the same time, new technologies and tools for planning and implementing watershed management programmes have been developed and applied also.

A serious constraint in the widespread adoption of successful concepts, technologies, and skills has been the lack of sufficiently trained human resources to apply them.

Sharing information on indigenous and modern technologies and concepts in watershed management among institutions in Asia was the main objective of a training course held in Kathmandu, Nepal, in April 1998. During this course a draft of the present Training Resource Book was used. The course was organized by the International Centre for Integrated Mountain Development at the request of and in close collaboration with the Participatory Watershed Management Training in Asia Programme of the Food and Agriculture Organization of the United Nations (FAO).

The Participatory Watershed Management Training in Asia (PWMTA) Programme (GCP/RAS/161/NET/ of the FAO(UN)/The Netherlands) is making efforts to train manpower and to help human resource development in participatory watershed management for sustainable use and management of primary natural resources; soil, water, and forests; and by enhancing national capabilities to plan, implement, evaluate, and monitor participatory watershed rehabilitation programmes. This is being achieved by regional training courses, workshops, seminars, preparation of resource books, and manuals for training and regional and national network of trainers and institutions.

The International Centre for Integrated Mountain Development (ICIMOD) attaches great importance to watershed management and is involved in many programmes. It has joined hands with the PWMTA programme of FAO(UN) to organize training and develop materials for human resource development. The objective of preparing this Trainer's Resource Book, which is the third and final in this series, is to help improve, upgrade, and update the skills and capabilities of the available manpower in recent concepts, knowledge, practices, technologies, and skills in participatory integrated watershed management as facilitators so that the practitioners can own and implement them successfully.

We hope that this resource book will be useful and helpful, not only to professionals and to institutions engaged in transferring and improving skills for sustainable management of watersheds, but also to the real stakeholders, the people living in those watersheds.

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Preface

Degradation of upland mountain watersheds, particularly acute in the Asian region, is increasingly becoming a problem of world-wide concern. It is seriously undermining the economic, social and environmental security and well-being of people living in these watersheds.

Though the importance of natural resource conservation is being realised increasingly in the region, full awareness and understanding of the multiple benefits that can be achieved from the management of watersheds on a sustainable basis, and the disastrous consequences of watershed degradation on socioeconomic and environmental conditions of the people living therein, have yet to be realised fully by policy-makers, practitioners, and the ultimate beneficiaries or the sufferers – the watershed farmers and downstream inhabitants.

Various efforts by the people, governments, NGOs, INGOs and donors to manage watersheds have produced mixed results. There are many success stories that are mostly based on the active participation of local people, the application of indigenous knowledge and technologies, and the application of new concepts, knowledge, and practices that have been discovered, rediscovered, and used successfully. At the same time, new developments in today's science and technology and the availability of advanced tools and skills, such as the three 'S' technologies, which are efficient, effective, cheap and quick, can help greatly in the successful planning, implementing, monitoring and evaluation, as well as managing of watershed rehabilitation programmes.

Efforts have been made in preparing this resource book to include recent concepts, knowledge, practices, and new skills in participatory integrated watershed management (PIWM) based on the experiences and lessons learned from within Asia and other parts of the world. This book is mainly for the use of trainers and practitioners of PIWM in mountainous watersheds so that they can increase their understanding, knowledge, and skills for sustainable management of natural resources.

This resource book is organized into three modules: (1) Recent Concepts and Approaches in PIWM; (2) Appropriate Technologies and Practices in PIWM; and (3) New Methods, Skills and Tools in PIWM. These modules contain sub-modules that deal with important elements of PIWM.

We hope that this book will help to improve the understanding, knowledge, and skills of the professionals, trainers, and people involved in managing mountain watersheds in Asia.

Bal Ram Bhatta   Suresh R. Chalise   Aung Kyaw Myint   Prem N. Sharma

Acronyms

ArcView	A GIS-based information computer software package
ATSCFS	Appropriate technologies for soil-conserving farming systems
CARL	Comprehensive Agrarian Reform Law
CBO	Community-based organization
CDO	Chief District Officer
CF	Community forestry
DD	Diagnosis and design
DENR	Department of Environment and Natural Resources
DFO	District Forest Officer
DOF	Department of Forestry
DOS	Department of Soil Conservation
EIA	Environmental impact assessment
EIS	Environmental impact statement
FAO	Food and Agricultural Organization of the UN
FD	Forest Department
FINNIDA	Finnish International Development Agency
FUG	Forest user group
GIS	Geographic information system
GL	Group leader
GO	Government organization
GPS	Global positioning system
HFC	Hamlet-level farmers' organization
HKH	Hindu Kush-Himalayas
HMG/N	His Majesty's Government of Nepal
HP	Himachal Pradesh
HVC	High-value crops
HYV	High-yielding variety
ICIMOD	International Centre for Integrated Mountain Development
IIDS	Institute for Integrated Development Studies
INGO	International non-governmental organization
INM	Integrated nutrient management
INSM	Integrated nutrient and soil management
IPM	Integrated pest management
ISFP	Integrated Social Forestry Programme
ITK	Indigenous technology knowledge
IUCN	International Union for Conservation of Nature and Natural Resources
IWM	Integrated watershed management
M & E	Monitoring and evaluation
MBRLC	Mindanao Baptist Rural Life Centre
MFSC	Ministry of Forests and Soil Conservation
NARC	Nepal Agricultural Research Council

NFT/S	Nitrogen-fixing trees/shrubs
NGO	Non-government organisation
NWDPRA	National Watershed Development Project for Rainfed Areas
OAT	Other appropriate technologies
OP	Operational plan
PARDYP	People and Resources' Dynamics Project
PFT	Plastic film technology
PIWM	Participatory integrated watershed management
PMA	Production marketing association
PRA	Participatory rural appraisal
PWMTA	Participatory Watershed Management Training in Asia
R & D	Research and development
RRA	Rapid rural appraisal
RS	Remote sensing
SALT	Sloping Agricultural Land Technology
SBT	Seabuckthorn
SEA	Strategic environment assessment
SEGA	Socioeconomic and gender analysis
SRSC	Sarad Rural Support Corporation
SWFO	Small watershed farmers' organization
UG	User group
UNDP	United Nations Development Programme
USA	United States of America
VDC	Village development committee
WM	Watershed management

Introduction

Land, water and vegetation, the basic resources of the life support system in the south east Asian region are under intense pressure due to natural factors and human induced accelerating factors. Rapidly increasing population density, excessive number of livestock, overexploitation of watershed resources, environmentally unsound infrastructural development, turning into development disasters and inadequate management practices, are disturbing, damaging and degrading the highly sensitive fragile and precariously balanced watershed ecosystems in Asia. Most of the people living in these fragile marginal areas are poorest of the poor and are totally dependant on the use of local natural resources for their sustenance and survival. Increasing poverty of the people forces them to encroach on to very vulnerable marginal lands for cultivation, deforestation, overgrazing and overexploitation of the resources further aggravating watershed degradation, soil erosion and deterioration of the wholesome natural environment. Mountain top soils erode, silting and polluting the streams and rivers and causing the river beds to rise. This increases the incidences of flash floods in the lower valleys and plains with consequent damage to fertile farms, irrigation systems, dams, hydro-electric power systems, roads and bridges, severe loss of socio-economic development and tragic loss of life and property with increasing intensities and frequencies year after year.

In recent times it is being realised increasingly that serious degradation of upland watersheds creates biophysical, socio-economic and environmental problems not only for those living within the watersheds but also for those living in the valleys and plains below.

Concern for these problems led to the establishment of Regional co-operative Participatory Watershed Management Training in Asia (PWMTA) Programme, (GCP/RAS/161/NET) for human resource development for ten countries of Asia: Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Pakistan, Srilanka and Thailand.

PWMTA is funded by the Government of Netherlands and executed by FAO (UN). The development objectives of the PWMTA programme is to contribute to human resources development (HRD) for people's participation in sustainable natural resources management in the Himalayan and other tropical watersheds in participating countries by enhancing skills, knowledge and awareness of the problems of watershed degradation as well as by enhancing national capabilities to plan, implement, evaluate and monitor watershed rehabilitation programs for the benefit of affected populations through their own participation in watershed management.

In line with the recommendation of the Regional Expert Consultation cum Advisory Committee Meeting (REC-ACM) of the PWMTA program and to achieve its objective, ICIMOD joined in partnership to implement the activities. Three following major activities were to be carried out.

Firstly, Training Manual Development on "Farmer-Led Integrated Watershed Management" and conducting of Regional Training, which has been already completed successfully (April 7-13, 1997).

Secondly, Training Manual Development on "Participatory Watershed Planning, Monitoring and Evaluation and conducting of Regional Training, which has also been already completed successfully (September 12-19, 1997).

Finally, Trainer's Resource Book development on "Modern Concepts, Knowledge, Practices and New Skills in PIWM" and the Regional Training was completed successfully in April 3-10, 1998. During the training the draft of the resource book was widely circulated among the participants, resource persons and interested people and was tested discussed and deliberated upon extensively. Eight working groups were also formed to study the modules thoroughly to provide comments and suggestions for further improvements. Very useful comments and suggestions were received. These valuable comments and suggestions have been incorporated in this final version of the resource book. We are extremely pleased to announce that this resource book is a product of participatory process of preachers and practitioners.

This resource book contains three modules namely: Recent Concepts and Approaches; Appropriate technologies and practices and New methods, skills and tools in PIWM and a total of twenty one sub modules covering a very wide range of important and useful subjects.

It is hoped and believed that after the successful completion of these major activities the following two main immediate objectives of PWMTA programme have been fulfiiled.

Firstly, the development of human resources (HRD) in order to improve national capabilities for participatory watershed management, and

Secondly, exchange of technology and sharing of national indigenous experiences in participatory watershed management have been achieved and these will further improve, strengthen and help attain the short term and long term objectives and goals of participatory integrated watershed management (PIWM) to deliver the socioeconomic and environmental benefits to the people of the region on a sustainable basis.

It has been now realised that although increasing efforts and resources in terms of money, manpower, policy, institutions awareness and priority are being invested in watershed management by regional governments, international funding agencies, NGO's, INGO's and the people, watershed management is at widely different stages of development throughout the participating countries of the region.

Watershed management principles, concepts, approaches, practices, skills and the knowledge required for watershed management have experienced a vast change during past few years. This has resulted in change of definitions and objectives, purposes of watershed management itself, due to lessons learnt from past successes and failures as well as due to widening of the knowledge base and integration of participatory natural resource management and socioeconomic and environmental parameters, with close involvement of people, professionals and related institutions.

Recent watershed programmes and projects have not been that successful and many have failed. Very little have been learned from past experiences of the successful ones. The success stories could not be replicated widely and failures have occurred again and again. A lot of ground has been covered recently in developing new ideas, practices and significant progress made in PIWM. Considerable efforts have been made in preparing this manual to incorporate these recent concepts, knowledge, practices and skills in participatory integrated watershed management (PIWM), and this manual has now been placed before the experienced professionals and practitioners of (PIWM) for testing, comments, suggestions and further improvements. These will help in updating and improving the manual and to make it more useful and practical for wider dissemination within the Asian Region and other parts of the world.

This resource book cannot include all the recent concepts, knowledge, practices and skills related to a very complex, varied and multi faceted subject as PIWM. The focus of the manual has been on most important components of PIWM, their practical application, and the experiences gained and lessons learnt under actual field conditions, as well as on implementation and operations under actual real world situations. Simple, affordable, socially acceptable and environmentally friendly methods and tools based on indigenous knowledge and technology which can meet the needs of the people and could be self sustaining have been given due consideration in this resource book.

MODULE 1

Recent Concepts in and Approaches to Participatory Integrated Watershed Management

Module 1.1

An Overview of Recent Concepts and Participatory Integrated Watershed Management (PIWM) Processes

Prem N. Sharma

Objective

- To provide an over view of recent concepts, including the role of indigenous technology knowledge (ITK), and to arrive at a better understanding of participatory integrated watershed management (PIWM) processes and related aspects.

Overview of Recent Concepts

While there are limited lessons to be learned from recent watershed management (WM) efforts that have been successful at upland watershed rehabilitation in certain places, much can be learned from the indigenous efforts made by people over the centuries in all aspects of participatory watershed management.

People's indigenous knowledge systems in watershed management

In a recent regional workshop on indigenous technology knowledge (ITK) for watershed management (WM) by PWMTA, Mr Anupam Mishra (1996 a,b; 1997) highlighted the importance of people's indigenous knowledge systems as follows.

- Conservation, utilisation, protection and development of forest, land, and water resources are as old as civilisation. In fact, civilisations have evolved around them.
- Society has traditionally moulded WM into socio-cultural mechanisms thus supporting people sustainably over the centuries by assimilating it into the life of each member of society without barriers of caste, class, or gender.
- Today, technology agents (who often consider themselves donors) label people beneficiaries, if not labourers ,making them feel alien in their own lands. Thus they break the spirit of independence and self-confidence in the society.

- Subsidies and many incentives used for WM also do the same, even though they are unaffordable over the long term. Then where will the initiative to undertake such work come from? It will only come about by restoring confidence in social institutions, by recognising the people's strengths and the depth of their experience and by not looking down upon large sections of our society as illiterate, poor, and weak.
- Thus the most important task in WM is to help reinstate the self respect and sense of identity that the people have lost due to recent interventions.
- Sustainable WM should be based on age-old indigenous knowledge within a society.

This new paradigm addresses the watershed degradation problem as perceived by farmers and gives economically viable, environmentally sustainable, production-oriented conservation alternatives that are built upon indigenous knowledge. In this respect, simple concepts of appropriate land use and conservation technology based on traditional farming systems, which can be directly understood and implemented by farmers without much external technical or financial assistance, play an important role. Modern tools, such as GIS and advanced models ,can be used to assist farmers by converting their outputs into simple rules of thumb as an aid to correcting land use and other related decision-making mechanisms.

What Are the Other New Concepts in PIWM?

In addition to basing WM programmes on ITK/WM, some new concepts that have come to be accepted in the past 10 years or so are as follow (Dent 1995; Gupta and Chokkakula 1998; Hamilton 1986; Moldenhauer,1989; Nair 1986; Sanders 1990).

- Building on indigenous knowledge and grafting suitable frontier technologies, e.g., biotechnologies, biofertilizers, bio-engineering, biodiversity, etc to upscale productivity and conservation
- Farmers' institution-building firmly rooted in local indigenous social institutions
- WM techniques to aim at production-oriented conservation
- Assurance of ground cover, tree litter/mulch and multi-storey forest plantations for soil conservation by forests
- Agroforestry contributions to soil and water conservation if planted as barriers and/or used as ground cover/mulch
- Encouragement of live barriers versus alone or with mechanical methods to be encouraged for production-based soil and water conservation
- Appropriate management of land use by agronomic and cultural practices, e.g., correct time of crop planting on contours to provide cover at peak-intensity rainy season, use of beds/ridges and furrows, use of crop residue as mulch and compost, traditional minimum tillage practices, live barriers and suitable agroforestry practices, etc.

- Provision of investments to farmers and other land users for self-help rather than doling out dependency-creating incentives
- Participatory process-based WM rather than target-based WM programmes that call for natural resource management in a small watershed for overall human development.

New Paradigms in Participatory WM

These new concepts are used to redefine sustainable PIWM as utilisation and conservation of land, water, and forest resources at farm household and community (or given watershed) levels for continuously improved livelihoods and overall human development (Table 1).

Thus, in the Asian context, participatory watershed management consists of natural resource management by farmers and communities for poverty alleviation and local overall development. This shifts the old paradigm of target-based WM to a new process-based PIWM paradigm.

Participatory Processes for Integrated Watershed Management

The following key elements are required to make integrated watershed management programmes into participatory processes. These elements can overlap, be continuous, or be in sequence depending on the need (Sharma 1997; Sharma et al. 1997).

- The basing of integrated WM programmes on the cosmic vision of the people, i.e., their relationship to nature and the universe, which often is through spiritual and/or religious thought in Asia.
- Farmers' empowerment and ownership of WM processes, i.e., by building farmers' organizations
- Land-use titling/tenure should be given to the land users.
- Mainstreaming gender concerns, ensuring women's and other disadvantaged group's participation.
- Assured and quick-benefit generation by WM programmes using indigenous technologies and the in-

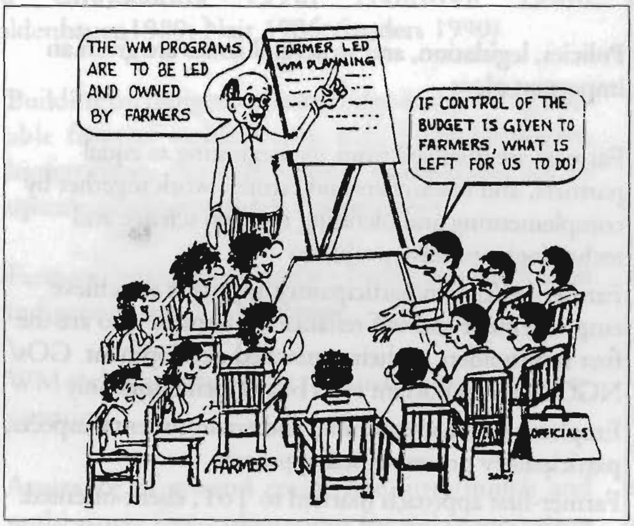
Table 1: Old Versus New Paradigm for PIWM

Old/Outdated	New/Recent
WM was synonymous with soil conservation	Synonymous to NRM for poverty alleviation and overall human development in a watershed
WM was addressed in separate components and sectors	WM seen in its entire complexity but made into simple rules of thumb for farmers
Land-use decisions based on land capacity	Land-use decisions based on land suitability and people's interests, needs, and preferences.
Farmers viewed as backward, illiterate and unwilling to change, as culprits in damaging the watersheds and part of the problem, and unable to manage their natural resources	WM programmes to be grounded in indigenous technical and institutional knowledge of farmers who have rich traditions of sustainable WM.
Policies, legislation ,and structural issues such as land laws, forest policies, ownership, management, etc not considered	Policies, legislation, and structural issues are given an important place
WM programmes were designed, researchers tested various options, extensionists conveyed the new technology to farmers, and farmers passively waited for science to provide solutions	Farmers are involved from the beginning as equal partners, and researchers and farmers work together by complementing and blending modern science and technologies to solve problems
GO/NGO/executing agency-led/driven and target-based approach	Farmer-led/driven participatory approach to achieve empowerment and self-reliance for farmers who are the first stakeholders in their watershed development. GOs/ NGOs have important roles but as facilitators only
Emphasis on technical activities and targets	Emphasis on socioeconomic and environmental aspects, participatory process-based approach
Transfer of technology (ToT) extension method, message-oriented (one-way communication)	Farmer-first approach married to ToT, client-oriented.
Extensionist and scientist-led, based on imported ideas and technology, ITK ignored	Farmer-led based on indigenous knowledge technology (ITK) and the culture of the people.
Supply-oriented research: supplying technical innovations based on assumptions	Demand-driven research responding to the problems faced by farmers.
Top-down planning, monitoring and evaluation – Top-down thinking and approach	Participatory planning, monitoring, and evaluation Grass-root's based thinking and approach
Controlled by single sectors, departments, disciplines, and strong sectoral compartmentalisation; little cross-sector linkages, interactions	Multisectoral and multidisciplinary, close inter-sectoral linkages, interactions
Empowered officials and extension agents	Empowers farmers, other land users, stakeholders
Selected generally better-off farmers, and little concern for women and disadvantaged people.	Aims at poor, marginal, small farmers with special emphasis on gender equity and disadvantaged classes
Aimed at long-term benefits	Aims at quick net benefits first to attain long-term socio-economic and ecological benefits
Incentives and monetary aid used for co-opting people's participation.	Investment at the disposal of farmers
Did not encourage people's initiatives.	Based on people's initiatives
Disjointed and arbitrary approach	Uses farming systems and common property resources' management approach
Preference for engineering structure, methods	Preference for biological methods
Large watershed based	Small watershed based
Sustainable development not an important consideration	Sustainable development gaining greater importance and prime consideration

tegration of recent frontier technologies into indigenous technology systems.

Other Important Aspects of Participatory WM

To facilitate implementation of the above participatory processes, the following aspects (Sharma and Krosschell 1997) should be planned, implemented, monitored ,and evaluated in order to facilitate farmers'/land owner's empowerment and their true ownership of WM/NRM programmes.



- Farmer-led facilitation
- Farmers' capacity-building
- Farmer-led planning
- Farmer-managed funding
- Farmer-led implementation
- Farmer-led monitoring and evaluation

The final result of such an approach will be that the confidence of farmers (women/men) has been boosted and innovative ideas have spread from farmer to farmer. By this, it is hoped that prevalent practices in local indigenous WM will also be realised by professionals (Mishra 1997), i.e., 'Instead of looking down upon large sections of society as illiterate, poor, and weak, we need to reinstate the self-respect and sense of identity that they have lost. It is by building on the age-old knowledge (or indigenous knowledge) in our society that foundations for sustainable watershed management can be laid'.

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New Developments in Social and Economic Concepts and Participatory Integrated Watershed Management

Mahesh Banskota

Objectives

- To review new developments in social and economic dimensions in the context of participatory integrated watershed managemenr
- To understand and address critical components of the current economy and environment

What are the changing perspectives on development ?

Economic consideration has received systematic priority in development for the past four decades and, although its role is still critical, it is today being better balanced by incorporating other concerns related to basic needs, the environment, human development, and ,more recently, democracy, human rights and liberalisation.

What is an acceptable framework for development?

There is widespread debate on what is actually an acceptable framework for development. Depending on the specific problems encountered in a particular area, it is possible to come up with many different options— some of which may be mutually conflicting. The recognition that development must deal with these conflicting realities is a crucial step forward and clearly underscores the role of participatory approaches in any development effort, including in watershed management where there are many open conflicts regarding use and access of resources: e.g., between conservation and development, between uplanders and lowlanders, and so on.

What do the developing countries want from development? And what do developed countries emphasise?

Developing countries want higher economic growth, improved standards of living for their people, and greater access to developed country markets. They argue that environmental controls should be relaxed until a certain level of development has been reached. Developed countries, on the other hand, emphasise the need for greater liberalisation and openness in the domestic economies of developing countries, greater environmental control, more human rights and democracy.

Which problems are receiving attention in all countries?

In both the developing and developed countries increasing attention is being given to the problems of women, children, minorities, and disadvantaged groups.

What is sustainable development (SD)?

There is widespread divergence in what is meant by SD. Ecologists talk about SD in terms of resources and waste management. Economists talk about basic needs, income and well-being. Demographers and biologists talk about carrying capacity. The most popular definition of sustainable development was given by the Brundtland Report which said it is 'meeting present needs without reducing the options for further generations' (World Bank 1994). Others have defined it as increases in income options without degradation of the resource base (WCED 1987). This definition is appropriate for participatory watershed management as it identifies the conditions under which incomes can continue to increase. There is some debate about the number and type of resources one should consider, but this is difficult to discuss in the abstract. Different areas have different endowments and there are always some resources more important than others. Watershed management is now 'people-based' and the local people have a major say in planning and implementation of most activities. Local people have a better understanding of the complexities in the watershed and are better prepared to deal with them than outsiders. From the point of view of watershed management, many perspectives are essential because it is, in essence, developing a harmonious relationship between the people and the watershed.

What are the guiding principles of sustainable development?

Efforts have been made to integrate all the major components. Some principles of sustainable development (World Bank 1994) have also been proposed. These are guiding principles and cannot be taken in isolation. They are all interrelated.

- **Principle of the cultural and social integrity of development.** This emphasises the notion that development cannot be imposed or imported from outside. It must grow and come from within. Every society must make its own decisions regarding priorities and how to deal with them. As a nation is a non-homogenous entity, it should develop mechanisms for similar decisions at regional and local levels. This has implications for different watersheds and the communities that live in these watersheds.

- **Ecological principle.** Development can no longer be at the cost of degradation and rapid loss of natural resources. Loss in biodiversity is reaching alarming proportions in many areas. Urgent efforts are needed to restore diversity and introduce sustainable forms of resource use. Ultimately these will also help to improve the quality of human life as their loss has some adverse effects. There are many examples in which people's participation has successfully rehabilitated degraded watersheds and local residents are receiving better economic returns than previously. Through proper management it is possible to introduce sustainable harvesting that will not deplete the environmental capital.

- **Solidarity principle.** Everyone is different culturally, socially, economically, politically and historically. These differences should be respected and at the same time should be made to work together to provide basic necessities of life and secure living, working and participating conditions for all. As far as possible, everyone should benefit from watershed management activities. Even if everybody does not gain there should be no losers. This is obviously a difficult principle to implement but needs to be given full consideration.

- **Emancipation principle.** Development must foster self-reliance, local resource control, empowerment and participation of the weaker sections of society—women, the disadvantaged, and deprived—as much or as extensively as the more fortunate members of society. In the long run most sustainable practices have incorporated this aspect. To a great extent this is influenced by the political process and framework. Most rural development and poverty eradication programmes have incorporated this emphasis through focus on participatory processes.

- **Non-violence principle.** Development must be peaceful for, without peace, there is no development for anyone. This is equally true for nations, between sexes, and for communities and ethnic groups. With ethnicity becoming a major basis for violence, this principle must be better understood and practised. Being non-violent does not mean being submissive to injustice.

- **Principle of error friendliness.** There are no ultimate technical blueprints for development and the more we can accept this the better the chances are that we will look around and become more open to other ideas.Development is a dynamic process: it is not just economic dynamism but learning to develop in different ways. It is not a static process. This dynamic process must allow for mistakes—for learning, improving and obviously building a stronger basis for future development.

Will there be other principles of sustainable development? What were the problems encountered in the past in watershed management?

Yes, there will be other principles besides the ones identified above. However, what should always be emphasised is the 'opening-up' of the development debate. All ideas are relevant for participatory and integrated watershed management. In the past, implementation of watershed management activities has encountered various problems—little or no local participation, inadequate extension and technical assistance, inadequate testing and development of resource management options, a fragmented government structure, conflicting interests among various actors that are not easily resolved and various territorial questions and issues. Use of these principles will assist in resolving many of these problems. They force the 'framework' or 'approach' to open up and once this is achieved a healthy beginning for generating sound local solutions to problems is made.

What is growth?

Redefining growth

Conventionally, growth has come to be seen primarily as economic growth. Growth meant increasing the size of the economy over time, measured in terms of income of the people. So long as incomes were growing rapidly, it was believed that other problems could be eventually tackled. This position neglected many things—environment, equity, non-material quality of life, participation, etc.

What are the main contributing factors to growth? What is the meaning of the politics of international development?

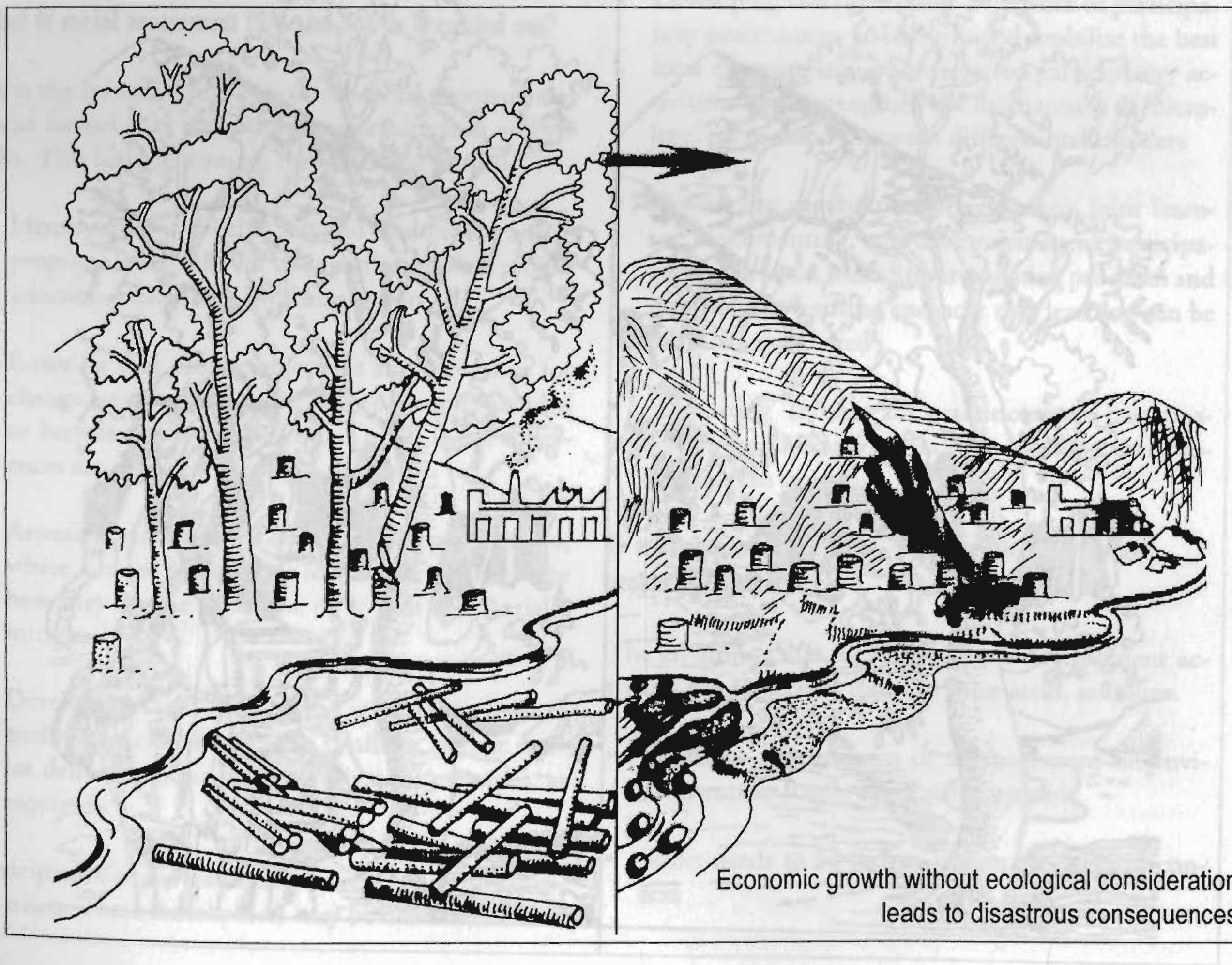
The main contributing factor to growth was believed to be improvements in technology. The challenge now—particularly from an environmental point-of-view—is to achieve a continuing process of technology development but with less and less use of natural resources, especially of those facing serious environmental problems. In other words, the emphasis in redefined growth is to substitute human-made capital for natural capital (Goodland et al. 1992). This is a slow process and cannot happen overnight. The implications of this process are far reaching because, if physical inputs are limited then, by the law of conservation of matter-energy, physical outputs will also be limited. So someone has to begin giving up and making sacrifices. This is where the politics of international development come in—who should give up? how much? how to enforce it? etc. All these questions are being asked quite clearly in the continuing debate on the ozone layer and global warming—between rich and poor countries, among rich countries, and between small and bigger nations both rich and poor.

Do the conflicts of redefining growth matter in watershed management?

Yes, some conflicts related to redefining growth are also encountered in watershed management. There is always the pressure to add one more development project either to use available resources or to support development objectives. This tendency does not consider the overall status of the watershed—not just in terms of pollution and resource depletion, but also in terms of 'wilderness', 'openness' and other 'pristine' characteristics that are lost to the onslaught of development.

What is meant by ecological economics?

Ecological economic principles have developed in response to the prevailing limitations of conventional economics to deal adequately with the problems of the environment, particularly those related to increasing scar-



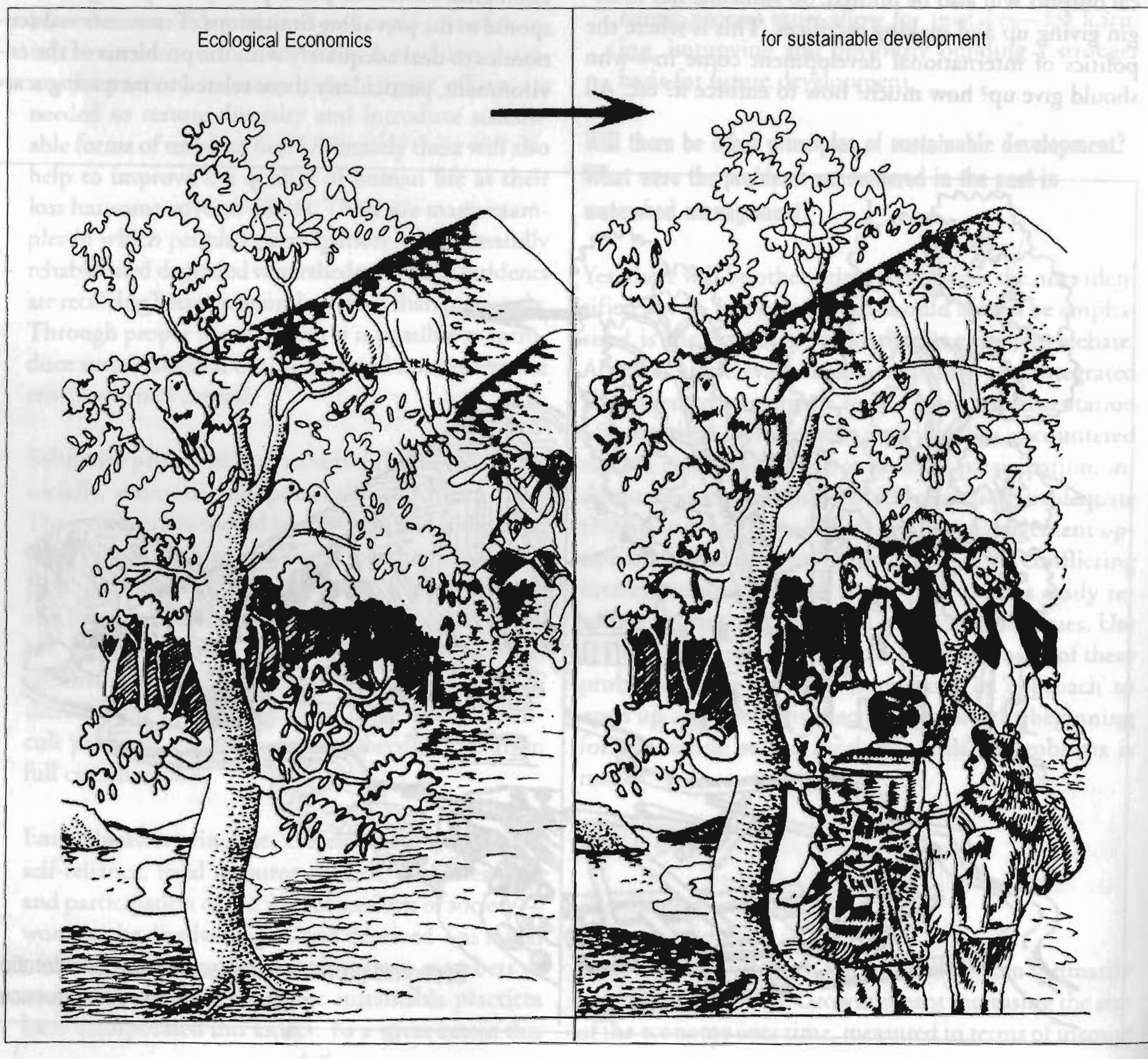
Economic growth without ecological consideration leads to disastrous consequences city of resources and resulting from our production and consumption systems or 'externalities'. Two important reasons for the lack of adequate attention were that, until recently, most environmental goods were relatively abundant and that these have been non-tradable or non-marketable goods. Ecological economics attempt to deal with some of these problems in a systematic manner although in some aspects there are still wide differences within the discipline on how to handle these problems and issues. Some of the new thrusts (Goodland et al. 1992) are as follow.

- Reflection of the full, social marginal opportunity costs in prices. This means that we should know or at least try to find out what the society wishes to pay for a particular activity and measure this in terms of opportunity costs. There are difficulties in arriving at this measure by depending on market prices and other economic information.

- Repeal of environmentally perverse incentives such as subsidies for resettlement in forest areas, use of fertilizer and pesticides, vehicles for agricultural use, and so on.

- Use of a 'cradle-to-grave' approach in valuation by looking at the entire cycle of an activity even if this is somewhat distant.
- Use of the 'polluter pays principle'. Whoever pollutes should pay. The owners of vehicles should pay for air pollution problems in urban areas and not the rest of the nation.

- Inclusion of non-monetary values in project justification. Rigorous efforts should be made to capture all values in quantitative terms, but if this cannot be achieved, qualitative assessments should be used by assigning weightage.



- Use of environmental accounting to separate what is a liquidation of natural capital from what is income. Decapitalisation should not be confused with income. Environmental accounting helps to monitor the drawing down of natural capital. For example, harvesting plants provides incomes but there may also be a loss of biodiversity. Bringing marginal land under cultivation gives food but the loss of forests, topsoil, and flora and fauna is a depletion of natural assets. Using iron ore to make a plough depletes the stock of minerals. Thus while the plough is a useful piece of capital, its valuation should incorporate the loss of natural resources.

- Use of the transparency principle to emphasise the critical importance of not hiding information. Without appropriate information, awareness and action will not be forthcoming. All sectors and sides should make their decisions transparent and encourage wider sharing and participation.

Most of these concepts are being applied to some extent already in watershed management decisions. The place to apply them is in the preparation of watershed management plans and the implementation of project activities.

What is social assessment (SA) and how is it carried out?

SA is the systematic analysis of the social processes and social factors that affect development impacts and results. This is done through the following process.

- Identifying key stakeholders and establishing an appropriate framework for their participation in project selection, design and implementation

- Ensuring that project objectives and incentives for change are acceptable to the range of people intended to benefit and that gender and other social differences are reflected in project design

- Assessing social impact of investment projects and, where adverse impacts are identified, to determine how they can be overcome or at least substantially mitigated

- Developing capabilities at the appropriate level to enable participation, resolve conflicts, permit service delivery, and carry out mitigation measures, as required.

Participation of the stakeholders helps to identify critical issues. These stakeholders may be officials, NGOs, beneficiaries and affected groups. Depending on the objectives and complexity of the area, SAs can be carried out by either a team or an individual. SAs are not only useful for planning but also for monitoring and evaluation of programmes and objectives.

What is participatory action learning (PAL) and how can it be promoted?

PAL seeks to promote participatory development and is defined as a process through which stakeholders influence and share control over development initiatives and the decisions and resources that affect them (Ladekodi 1992). This shift towards participation emphasises the increasing role in development of ownership, commitment, and sustainability. There is a critical gender dimension to participatory development. Based on experience the following activities are carried out to promote PAL.

- Establishing a database of existing participation capacity and experience

- Developing strategies and action plans to strengthen capacity

- Developing and promoting a network of participatory practitioners to identify and mobilise the best local expertise to support selected participatory activities and to strengthen the mechanisms of micro-level partnerships between different stakeholders

- Developing capabilities for systematic joint learning, documenting, and disseminating of participatory experience, including articulating processes and products for learning and how that learning can be captured and shared

- Supporting training for practitioners of participatory approaches and in the design of supportive communication strategies

Is environmental screening of development activities/ projects important?

The environmental impacts of most development activities can be seen in terms of three areas, as follow.

- Location: proximity to or encroachment on environmentally fragile or sensitive uplands

- Scale: needs to be judged within the country context

- Sensitivity: refers to issues such as impacts that are irreversible, affect vulnerable ethnic minorities, or involve involuntary resettlements, etc

Projects can be then be grouped into three categories

Category A. A complete environmental assessment (EA) is required. These would be carried out for dams and reservoirs, forestry production projects, industrial plants and estates, irrigation, drainage and flood control, land clearance and levelling (excluding terracing), mineral development(including oil and gas), port development, reclamation of new land development, resettlement, river basin development, thermal and hydropower development, manufacturing, transport, and use of pesticides or other toxins and/or hazardous materials.

Category B. Although complete EA is not required, environmental analysis is needed. The projects may have adverse environmental impacts that are less significant than the category A impacts. Few, if any, under B are irreversible. The impacts are not as sensitive or numerous. Preparation of mitigation plans could be sufficient.

A mitigation or management plan should include

- identification and summary of all anticipated significant, adverse environmental impacts,
- description and technical details for each mitigation measure,
- implementing schedules,
- monitoring and reporting,
- cost estimates and sources of funds,and
- measures to strengthen environmental management capability: staff development, technical assistance, procurement of equipment and supplies, and organizational charges.

Projects in this category would be agro-industries, electrical transmission, aquaculture and mariculture, irrigation and drainage (small scale), renewable energy, rural electrification, tourism, rural water supply and sanitation, watershed projects (management and rehabilitation), rehabilitation, maintenance, and upgrading projects.

Category C. Environmental analysis is normally not required because the project is unlikely to have adverse impacts. Judgement indicates that either these are marginal or not evident. Most projects here deal in education, family planning, health, nutrition, institutional development, and most human resource development activities.

How have the main concerns and gaps in watershed management been corrected and the focus shifted recently?

Watershed management has come a long way since the days when a few technical solutions for runoff control and afforestation were its main concerns. A major gap was the watershed community and this neglect was corrected only after a string of failures in watershed management. In spite of the shift in focus from biophysical problems to people, the approach was still top-down, expert-oriented, and technology-driven and the role of external inputs was high. Over time even these ran into problems, but not without displaying other problems and conflicts within the watershed community, economy, and biophysical space. Loss in biodiversity was not compensated for by increases in monospecies' afforestation. Increase in the number of development projects hastened resource extraction and degradation, highlighting the urgent need for balancing development with conservation. Whose development it was became a difficult question as it was realised that women were in many ways worse off than before and poorer groups were losing access to resources that were critical for their survival. Development was creating a few prosperous groups, but many others were being degraded, marginalised, displaced, and sadly, in some instances, even forced to fight for their space in the watershed. Inappropriate concepts and methods have contributed to some of these problems. The present situation in which substantial efforts are being made to deal with these problems conceptually and empirically will hopefully contribute towards participatory, integrated watershed development in the future.

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Module 1.3

Factors Supporting Small over Big Watershed Development*

N. S. Jodha

Objectives

- To examine social dynamics that affect participation and to gain a better understanding of the dynamics of group action so that factors that induce and encourage group action for the natural resource management system can be identified
- To understand better the factors and processes associated with community approaches and usage of natural resources in mountain areas under traditional and present-day systems
- To identify factors that could promote participation and collective action in watershed management and the choice of watershed size and approaches to upscaling participation

Definitions

Devoid of finer, technical definitions, integrated watershed management implies usage or harnessing of an organically (naturally) unified land-resource unit which permits continuous regeneration and prevents degradation of the natural resource base in the interests of overall human development.

What is participatory integrated watershed management (PIWM) and what are the watershed management approaches and shifts in primacy?

This module views PIWM as the latest stage in the evolutionary process of thinking and action on watershed management. Accordingly, users' participation is being increasingly emphasised as the kingpin of strategies for WM. Participation is a social phenomenon rather than a physical one. However, the former is not a context-neutral phenomenon. The watershed provides the context. The module pleads for a better understanding of the dynamics of group action to help promote participatory approaches. Furthermore, an understanding of these dynamics also supports the small rather than the large watershed as a unit of PIWM. To elaborate, the factors and processes associated with the biological and physical diversity of watersheds, the weakening of the traditional community stake in the local natural resource base, the lack of scale neutrality in participatory practices, and physical and socioeconomic constraints to upscaling participation tend to favour small watersheds for effective PIWM.

Approaches to watershed management: the shifting primacy

The extent of resource degradation (as against regeneration) is closely linked to the degree of indiscriminate intensification of resource use. Increased instensification of resource use, unaccompanied by appropriate measures for conservation of the resource base through terracing, hedgerows, etc) invariably leads to resource degradation. Realisation of this fact has been the primary motive behind advocacy and action for integrated watershed management. Despite over three decades of concentrated work in this field in Asian countries, approaches and mechanisms are still evolving. Every new step reveals new gaps and the need for adding new components to prevailing approaches. For instance, work on watershed management/development largely focussed on aspects such as land shaping, promotion/protection of the tree component as under alley cropping, and other agroforestry initiatives. Specific sectoral focus, particularly the forest component or soil conservation, received higher priority in watershed development.

Learning from the above led to greater attention being given to an integrated approach through which different land uses within the watershed were emphasised. For a long time such integrated approaches did not go beyond the pilot-project stage. Lack of sufficient funds was identified as a key constraint. This led to substantial fiscal resource support from donors to promote a watershed approach to land use in different countries. However, the injection of additional resources through government agencies (e.g., forest departments, soil con-

* *In this paper, use of ther term 'upscaling' refers to improvement in contexts related to training, skills, increasing participation and also physical improvements. It is not to be taken in a social sense and does not imply inferiority in the social sense.*

servation departments, etc) led to a reinforcement of the sectoral approach rather than a genuinely integrated approach. Moreover, this meant the imposition of the old public works' department (PWD)) culture of project planning and implementation, in which watershed development was treated as civil works involving top-down decisions, engagement of contractors, little concern for local knowledge and community participation (except as wage labourers or recipients of grants or subsidies). Following the realisation of the inappropriateness of this approach and the increasing advocacy of participatory approaches supported by NGOs, donors, etc, a new element, namely, user participation, was added. This led to what is described as participatory integrated watershed management (PIWM).

What does the PIWM approach share with previous approaches ?

As of today PIWM represents the latest stage of thinking and action on the subject. This is promoted by fiscal support, technical training, capacity building, and to some extent, government commitment. However, this approach also shares some attributes of past approaches, which need to be minimised in order to avoid consequences detrimental to the promotion of PIWM. They are discussed below.

Uncontested acceptance of the approach

If one looks at the history of watershed management/development programmes in Asian countries, each stage or phase was dominated by a specific focus. Perceived primacy and domination of conservation techniques; overemphasis on specific sectors (e.g., forestry); overreliance on public sector wisdom; and a PWD approach in execution of watershed projects— equating increase in resource allocation and spending with watershed development— treatment of NGO involvement as the final indicator of community participation, etc. As in the past, present efforts are now treating participation of resource users (e.g., farmers) as the kingpin for watershed development. This paper pleads for closer examination of the social dynamics that affect participation.

Emphasis on a generalised, standard approach to community participation

Community participation is a social phenomenon. Rural communities are highly diverse, and because of these diversities participation can not be a scale-neutral phenomenon. Participation is emphasised as a major component of PIWM for diverse biological,physical,and socioeconomic environments. This paper pleads for greater attention to the diversity of stakeholders and their natural resource base because the nature and degree of participation, as watershed management cannot be detached from these diversities.

Persistence of the primacy of the biological and physical dimensions of watershed management but how to incorporate linkages with economic activities extending beyond the physical boundaries?

All approaches to watershed management look at the watershed resource users/managers through the window of a watershed as a spatially fixed biological-physical unit. Accordingly, by implication, the watershed users' 'demands and supplies' are seen to be confined to the watershed. Economic activity by watershed users is assumed to coincide with the physical boundaries of the watershed. In traditional, subsistence-oriented, isolated and small communities this was largely true. However, in today's context, the users' economic links go far beyond the physical boundaries of their watershed. Consequently, users' sustenance-driven stakes in the watershed are diluted; and efficient watershed management ceases to be their exclusive concern. Unless the concept of the watershed is extended to incorporate the catchment of economic activities extending beyond its physical boundaries, the users' stake cannot be fully understood and used for its protection and conservation. This is a major challenge.

Common goals with conflicting perceptions

The focus of WM strategies in the past had the general support of most agencies. However most of them also had their own perceptions about the realities necessitating such focus. This is more so in the case of PIWM: focus on participation is a product of perceptions and the consequent decisions/actions of different stakeholders. Apart from rural communities who have primacy as stakeholders because they are direct users, there are other secondary (but more powerful) stakeholders, such as the state, NGOs, donors, etc. Their perceptions about issues involved in participation differ. The state acting through its technical bureaucracy equates its authority with the knowledge to manage the watershed; it wants the permanent involvement of its agencies in the task even while promoting community participation. NGOs, while helping social mobilisation and community participation, also tend to promote their own agenda as indispensable to donors and governments that use them as mediating agencies between communities and the state. Donors have their own perceptions of watershed development problems and solutions, which may not match with the community's. Rural communities, due to increased economic differentiation and factionalism, also do not have a uniform view of watershed management issues.

However, the most important feature of secondary stakeholders' perceptions is their understanding of the rural community and the watershed as a unit of resource management. Accordingly, heterogeneities or diversities characterising rural communities and watersheds are ignored in the promotion of a generalised approach to PIWM. Any PIWM approach built upon the recognition and understanding of these diversities will have a greater chance of success. By implication this will call for the designing and evolution of location- and community-specific micro-solutions within the overall framework of macro-level strategies. This line of thinking again supports small rather than large watersheds as a unit of planning and management.

All of these issues are interlinked and suggest greater priority be given to small rather than large watersheds as a unit of management.

Has group action for natural resource management (NRM) changed? How? And why?

Group action for NRM - past and present

This digression into traditional or indigenous systems of natural resource management (NRM) is essential because most agencies (donors, NGOs, and governments) have a 'romantic' view of rural communities and their traditional group actions. They often look at rural communities as homogeneous entities ready for group action, provided that some incentives, technical assistance ,and local capacity building are ensured. This view is complemented by the 'romantic' view of traditional forms of group action, which in fact were products of circumstance and are non-existent today. As Table 1 indicates, with changed institutional, economic, and technological circumstances, the community's stake in natural resources, and hence the group action for their management, quickly disintegrated and disappeared. For instance, (i) market penetration and changes in the attitudes of village communities have promoted values and approaches that put a low premium on collective strategies; (ii) population growth, the rise in factionalisms, and increased economic differentiation have made it difficult to evolve and maintain a community stake; (iii) depletion of the natural resource base (NRB) and depletion of the culture of group action (representing what is called 'social capital') tend to reinforce each other in accentuating the community's indifference towards rehabilitation of the NRB for collective gains; (iv) the legal, administrative and fiscal mechanisms (despite lip service to the opposite) have a strong tendency towards centralisation and application of uniform, generalised top-down solutions, ignoring diversities at the grass roots.

However, while it is neither feasible nor desirable to revive traditional circumstances and practice, the latters' rationale could help to evolve approaches to PIWM. To understand this it is essential to look at the factors that induced and encouraged group action for NRM.

What are the major factors that induce and encourage group action for natural resource management (NRM) systems?

Three pillars of traditional NRM systems

Three elements of traditional resource management/ usage systems, which in the past played a crucial role in preventing human-induced degradation and facilitated regeneration of natural resources, can be identified. These elements, along with the objective circumstances that promoted and strengthened them, were

- a strong community stake in their NRB facilitated by almost total or crucial dependence on it,
- local control over local resources, resulting from isolation and inaccessibility that induced a degree of autonomy,and
- resource users' and decision-makers' functional knowledge of limitations and usability of their diverse NRB resulting from the people's close physical proximity and access to resources.

The incorporation of the three elements into the present resource-use systems may help in rehabilitation and conservation and should be promoted. However revival of historically associated objective circumstances (e.g., exclusive and almost total dependence on local resources, semi-closed communities, physical proximity) is neither possible nor desirable. Hence, the challenge lies in creating present-day functional substitutes that can promote the three elements and induce communities to protect and regenerate their watershed resources. In fact remedial approaches indicated in Table 2 sum up the prerequisites for successful PIWM.

When reinterpreted in the context of PIWM, the understanding of traditional arrangement could be put in terms of factors favouring and those obstructing participation in watershed (or natural resource) management. Table 3 summarises them. Though most factors

Table 1: Factors and processes associated with the community approaches and usage of natural resources in fragile mountain areas under the traditional and the present systems

Situation under traditional systems	Situation under present-day systems
A. <u>Basic objective circumstances</u>	
• Poor accessibility, isolation, semi-closeness, low extent of and undependable external linkages and support; subsistence-oriented small populations • Almost total or critical dependence on local, fragile, diverse NRB	• Enhanced physical, administrative and market integration of traditionally isolated, marginal areas/communities with dominant mainstream systems on the latter's terms; increased population • Reduced critical dependence on local NRB; diversification of sources of sustenance
Bottom line: High collective concern for health and productivity of NRB as a source of sustenance	Bottom line: Reduced collective concern for local NRB; rise of individual (extractive) strategies
B. <u>Key driving forces/factors generated by A</u>	
• Sustenance strategies totally focussed on local resources • Sustenance-driven collective stake in protection and regeneration of NRB • Close proximity and access-based functional knowledge/understanding of limitation and usability of NRB • Local control of local resources/decisions; little gap between decision-makers and resource users	• External linkage-based diversification of sources of sustenance (welfare, relief, trade) • Disintegration of collective stake in NRB • Marginalisation of traditional knowledge and imposition of generalised solutions from above • Legal, administrative, fiscal measures displacing local controls/decisions; wider gap between decision-makers and resource users
Bottom line: Collective stake in NRB supported by local control and functional knowledge of NRB	Bottom line: Loss of collective stake and local control over NRB; resource users respond in a 'reactive' mode
C. <u>Social responses to B</u>	
• Evolution, adoption of resource-use systems and folk technologies promoting diversification, resource protection, regeneration, recycling, etc • Resource use/demand rationing measures • Formal/informal institutional mechanisms/ group action to enforce the above	• Extension of externally evolved, generalised technological/institutional interventions that disregard local concerns/experiences and traditional arrangements • Emphasis on supply-side issues ignoring management of demand-pressure • Formal, rarely enforced measures
Bottom line: Effective social adaptation to NRB.	Bottom line: NRB over-extracted as open access resources
D. <u>Consequences</u>	
• Nature-friendly management systems evolved and enforced by local communities; facilitated by close functional knowledge and community control over local resources and local affairs	• Over-extractive resource-use systems, driven by uncontrolled demands • Externally conceived, ineffective and unenforceable interventions for protection of NRB • Little investment and technology input into NRB
Bottom line: Resource-protective/regenerative social system-ecosystem links	Bottom line: Rapid degradation of fragile NRB; 'nature pleads not guilty'.

Source: Table adapted from Jodha (1997)

favouring participation or collective action are interlinked they can be broadly grouped as economic, social (cultural), historical, and (for want of any other appropriate term) operational factors (Table 3). Most of these factors favour small watersheds. According to Table 3, the factors that promote participation include commonality of perceived interests or a collective stake in the watershed, possibilities of integrating diverse interests and developing functional interdependencies, and upscaling of participation in

Table 2: Approaches and constraints to revival of key elements of traditional natural resource use systems in the present context and remedial approaches

Community stake in local natural resources	Local control over local natural resources	Recognition and use of resource users' perspectives and traditional knowledge systems
	Constraints	
• Formal legal, administrative fiscal controls/restrictions creating a range of perverse incentives; reactive mode of community behaviour as individuals	• State's in-built resistance to self-disempowerment through passing decision-making power to local communities; focus on 'proxy arrangements' e.g., village *panchayats*	• Top-down interventions with a mix of 'arrogance, ignorance and insensitivity' towards local perspectives and traditional knowledge systems
• Highly depleted status of NRB creating no hope and no incentive to have a stake in it	• Faction-ridden rural communities driven by diverse signals and concerns	• Focus on old context-specific forms of traditional practices rather than their rationale for use in the current context
• More diverse and differentiated communities with different individual rather than group-based views on community resources	• NGOs as key change-facilitating agents, often governed by own perspectives and concerns	• Rapid disappearance and invisibility of indigenous knowledge
	Possible remedial approaches	
• Genuine local autonomy for local resource management; legal framework and support system for NR users' groups	• Genuine decentralisation, decision-making powers and resources to communities; raising latters' capacities to respond to the above (with the help of NGOs)	• Promotion of bottom-up approaches to resource management strategies using participatory methods and NGO help
• Resource protection, investment and use of new technologies for regeneration/high productivity of NRB	• Rebuilding 'social capital', mobilisation and participatory methods using NGO input; focus on diversified, high-value products from rehabilitated NRB	• Focussed efforts to identify present-day functional substitutes of traditional measures for resource management
• Collective stake through planned 'diversification' and 'shareholding' system in natural resource development and gains	• Required changes in NGO approaches/perspectives by introspection; involving small local groups and unlabelled agencies	• R&D to incorporate rationale of traditional knowledge system using experiences of successful initiatives

Source: Table adapted from Jodha (1997)
Note: Most remedial measures require new/changed institutional arrangements at micro- and macro-levels as indicated by Jodha (1997)

natural resource management. Furthermore, most of the above possibilities are directly linked to participants' close and functional knowledge of the watershed resources and a history of collective action in the past. Most factors mentioned above are social phenomena, and they need to be understood fully before action is taken. How to set the boundaries of PIWM? How to choose the size of PIWM: big versus small?

Participation is a social phenomenon and neither a biological nor a physical entity. Hence the choice of a big or small watershed as a unit of management is likely to be dictated by socioeconomic circumstances characterising the watershed or its users. Furthermore, participation (and size of participating groups) is context specific. The context is provided by the watershed. The biological and physical features of a watershed (and the functional knowledge of the users) and the degree to

Table 3: Dynamics of Participation in Natural Resource Management and Choice of Large Versus Small Watershed

Factors favouring participation	Factors obstructing participation
Economic: Commonality of interest (collective stake) based on sharing of common (or similar) products, meeting common demands, following common/similar resource-use practices/systems, diversification of resource-use involving inter-linked activities; physical proximity and knowledge of resource potential/limitation help in evolving collective or integrated measures.	• Diversity/heterogeneity of products/supplies, resource-use practices and requirements • Diversities of demands or expected gains from natural resource base - The larger the size of the watershed (WS) or users group, the greater are obstructions to group action
Social: Possibility of integration of diverse interests in common stake through 'social capital', i.e., perceptions of collective inter-dependence despite diverse uses and products using shared values, trust, mutuality, perceived inter-dependencies, etc, promoting group action; community's closer knowledge; and control of natural resource base helps in promoting collective perceptions for common stake	• Lack of physical proximity and practical knowledge of resource base, awareness of nature–society interactions in the past, oral history of traditional sharing system, etc - The larger the WS, the greater are the above gaps, which obstruct the building of collective stakes, 'social capital'
Historical: Learning and dependence on traditional systems of group action and resource management systems **Operational:** Possibility of upscaling participation through diversification and federating small units or integrating production-processing-marketing activities rooted in WS potential (see Table 4)	- Traditional arrangements and their oral history being more location specific, they lose their immediate relevance/ effectiveness with increased size of watershed and number of users. • Participation in natural resource management is not scale neutral. For reasons of biological-physical and socioeconomic diversities, operational logistics, etc, participation cannot grow in a linear fashion as required in a large watershed.

which the resource base, its products, gains, etc is shared provide the context in which social and economic interactions take place. The area of social-economic interactions thus sets the boundaries of a watershed as a functional spatial unit. In other words the boundaries of social group action when superimposed on the biological-physical boundaries create spatial units in which social system and eco-system links reinforce each other. Thus watershed size for PIWM is decided more by non-physical features and less by physical ones. In view of this, the size of a watershed cannot be fixed. Yet if one thinks in terms of boundaries of effective social interactions,a small watershed has a better chance of facilitating PIWM.

While talking of big versus small, we talk of the functional unit rather than the specific area of a watershed. The preference for small is guided by factors facilitating participation. The issues involved are summarised in Table 3. To reiterate, commonality of interests or common/ collective stake; possibilities of integrating diverse interests into a common stake through 'social capital' ; possibility of learning from and dependence on traditional/ indigenous knowledge and practices; and scope for upscaling participation may help to promote PIWM. An intimate understanding and knowledge of the resource base (both potential and usability) may help in the above processes. It may also be added that all of the above factors and their imperatives tend to weaken with an increase in the size of the watershed and its users' group.

Other problems associated with past efforts to promote PIWM will decrease with small watersheds. For instance, the extent of irrelevant standardisation imposed through top-down approaches; problem of 'leakages' of resources for unintended purposes; gap between decision-makers and resource users can be reduced with the greater focus afforded by small watershed units. Due to greater transparency and visibility of association between efforts and gains, local resource mobilisation for PIWM will have greater chances of success when focussed on small watersheds.

How should diverse concerns be reconciled? How should participation (horizontal and vertical) be augmented ?

To reconcile participation supporting small watersheds with the benefits of macro-level approaches/logistics favouring larger units, participation must be upscaled. Firstly, measures supporting participatory efforts (planning, funding, R&D, etc), where group action by primary stakeholders is not involved, can focus on the larger scale within the watershed. Secondly, in order that small units benefit from macro-level arrangements the upscaling of participation can be addressed in two ways: horizontal and vertical (Table 4).

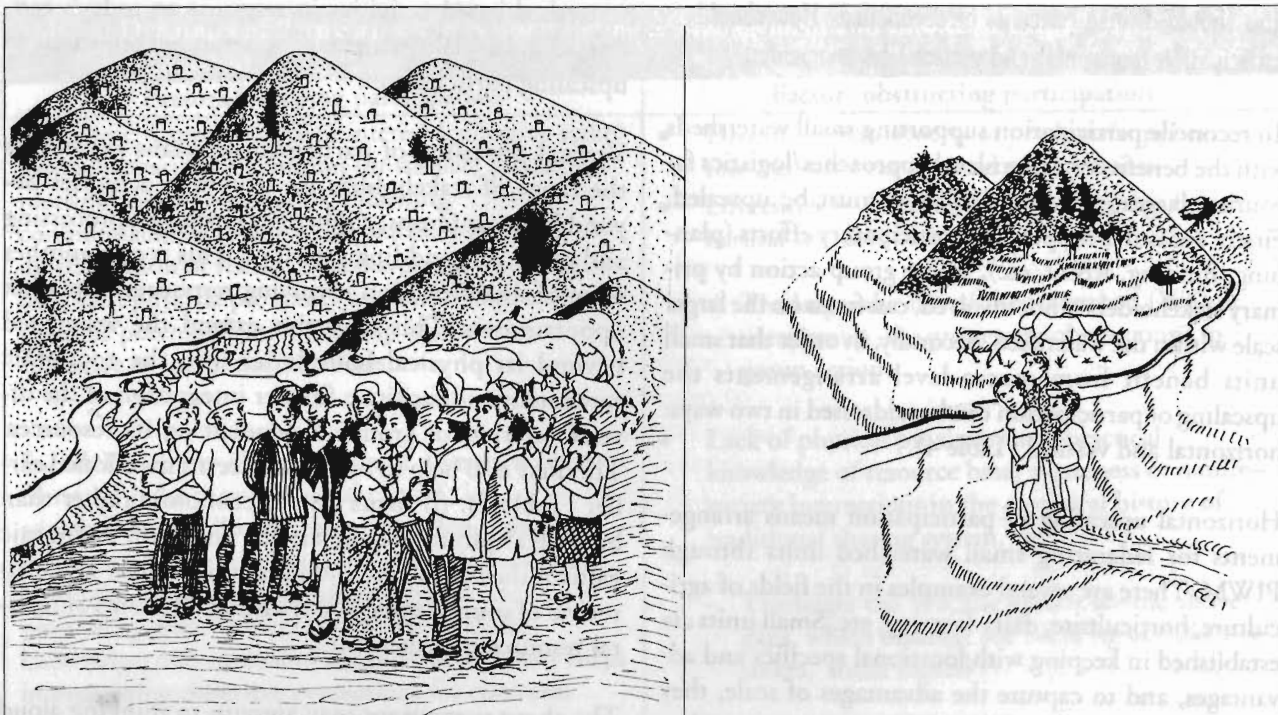
Horizontal upscaling of participation means arrangements for federating small watershed units through PIWM. There are several examples in the fields of agriculture, horticulture, dairy farming, etc. Small units are established in keeping with locational specifics and advantages, and to capture the advantages of scale, they have purpose-specific federating arrangements. They retain flexibility and autonomy of decisions suited to local requirements while securing the benefits of macro-level arrangements. The promotion of this approach will help address concerns associated with participatory natural resource management (Table 2). Diversification of watershed-based activities in response to today's economic and social circumstances is another approach to upscaling participation.

Vertical upscaling of participation means expanding the range of stakeholders by extending activities beyond biomass (crops, timber, etc) into agroprocessing and other value-adding activities. This is also another form of diversification involving responses to market opportunities. This may also extend the watershed beyond its physical boundaries into the economic catchment and facilitate further integration of the diverse interests of groups dependent on its resources. This may also help to address concerns mentioned earlier (Table 2): (i) focus on the economic rather than biological-physical context; (ii) focus on economic gains rather than just biomass production; and (iii) revival of some elements of traditional systems of natural resource management.

The above suggestions may amount to thinking aloud but they are supported by scattered field experiences. Explaining their potential through pilot-scale initiatives may have a high pay-off compared to mainstream participatory approaches to integrated watershed management.

Table 4: Approaches to Upscaling Participation (moving from smaller to larger watersheds)

Form of upscaling	Potential gains
HORIZONTAL UPSCALING	
• Focus on small watershed units • Product/purpose-specific federating of smaller units • Diversification based on spatially differentiated but economically interlinked activities rooted in the watershed resource base • Facility of access to macro-level services, inputs without discarding flexibility and priorities of local watershed units	• Recognition and use of factors favouring participation in PIWM (see Table 3) and also benefits of scale **Constraints:** Logistics of covering large-scale watersheds by PIWM through federating arrangements are more difficult than large-scale investment; needs innovative institutional arrangements
VERTICAL UPSCALING	
• Qualitative shift in diversification by focus on high-value/value-adding options (products/services) • Going beyond biomass production, incorporating processing/marketing, etc, of watershed products • Lessons from arrangements covering vegetable/spices, horticulture, food grain/seed production, processing/marketing in different areas	• Potential extension of watershed boundaries and watershed management activities to wider economic catchment of watershed communities and their partners in other watershed **Constraints:** Resistance to acceptance of innovative approaches by government agencies; lack of appropriate institutional arrangements



Big Watershed Small Watershed

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Module 1.4
Service Delivery versus Popular Participation and Extension

Deepak Tamang

Objectives

- To highlight the framework and concepts of participatory people-first development rather than the top-down service-delivery approach

- To advocate a participatory approach to designing, implementing, monitoring, and evaluating development so that by capturing the commitment, ownership, and popular participation of the community it becomes more effective and sustainable

How does the service-delivery approach compare to the people-centered participation approach?

Development efforts in the 1950s, 1960s, and 1970s were based on a top-down service-delivery approach. Fuelled by the success of the American-aided Marshall Plan in Europe, and the Soviet system of Five Year Plans, this service-delivery approach was used in many developing nations. Emphasis was placed on a centralised delivery system based on the efficacy of civil servants as agents of development. Scientific and rational planning was its hallmark. The 'answer' to many of the world's ills, it was believed, lay with bureaucrats, technocrats, administrators, and extension agents. This approach is now largely discredited since the trickle-down effect expected never took place.

Important factors for failure at the 'systemic level' were the lack of reward and punishment for development agents, lack of adequate resources, and lack of transparency and accountability. Also there was a lack of political will on the part of leaders and governments. At the community level, the people did not feel involved and, therefore, never took up the development projects as their own. Responsiveness, responsibility, and ownership were lacking. Sustainability factors, such as process, institutions, and finances, were not strengthened at the community level since this model believed largely in delivery from the top. It often did not consider a community's perspectives , their aspirations, needs, problems, and solutions. As a result of such failures, many thinkers and practitioners began to question the appropriateness of this growth-centred model.

Can GDP be considered a measure of welfare?

Some people feel that the purely economic-based gross domestic product (GDP) can be used as a measure of human welfare. However, many seriously question whether this is an appropriate measure of development and human well-being Many argue that GDP figures do not encompass the total well-being of a people—including human happiness or the quality of life. Lack of equity, equality, distributive justice, human rights, women's rights, child rights, ethnic and minority rights, and the gap between rich and poor are seen as serious flaws in the measurement of development and economic progress under the growth model of development based on patronage and service delivery. Hence, some development researchers are experimenting with the concept of human indices such as happiness and honesty. Development thinkers such as Kamala Bhasin have come to advocate a measure of gross domestic happiness (GDH) and gross domestic integrity (GDI) as more accurate and revealing than the mere use of GDP as a measure of a society's well-being and welfare.

Popular participation or bottom-up approach

The concept of popular participation in development (Figure 1) has gained credence and currency in the last decade or so largely due to the failure of the 'trickle-down' growth model of development. This approach, also called bottom-up planning, people-first, or popular participation, is based on a myriad of philosophical concepts. They are sociocultural, religious, and economic. It believes that economic theories alone cannot explain fully the concept of popular participation, since these theories, whether they are 'market' or 'Marxist', limit themselves to the phenomenon of wealth and poverty in the material sense.

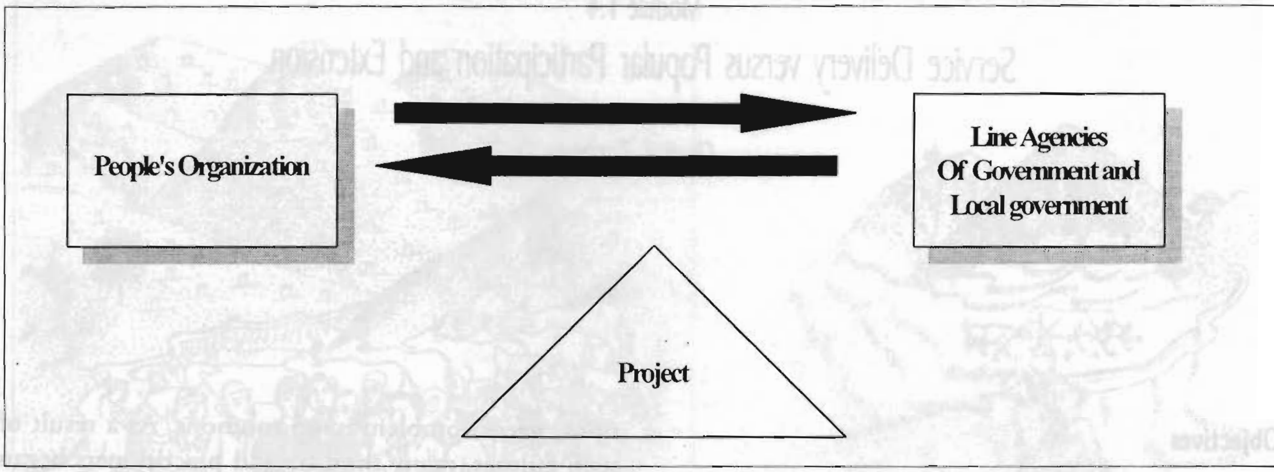

Figure 1: *Conceptual Framework of the Development Project*

The popular participation approach believes in empowering the community and individuals. Confucius the Chinese philosopher is believed to have taught his followers an early principle of popular participation and empowerment. He said, 'I hear and I am informed; I see and I understand; I do and I finally know what it is all about.' This laconic truth is still relevant today especially when we discuss issues such as participation and sustainable development. The teachings of Lord Buddha also have many principles of popular participation. Above all he taught compassion and empathy towards the people and that we should learn from one another the goodness of human beings. He taught us to live, learn , and unlearn from one another and to carry on meaningful dialogue in order to help one another.

What is the context of development and popular participation?

Many people nowadays are talking about sustainable development and alternative development models using traditional wisdom and respect for indigenous knowledge and technology and the sanctity of nature. In the past fifty years or more, development has been equated with economic growth. The growth-centred model pursues centrally planned and controlled regimes and structures. Resources are concentrated in infrastructural development, industrialisation, and establishment of formal government institutions. One principle assumed by this model is that the fruits of development will trickle down to the poor ,thus lifting them from poverty and inequality. However, this phenomenon has not taken place. The trickle-down model has had the opposite result. The rich have grown richer and the poor poorer. This has prompted universal outcry and re-examination of this model. The need for an alternative based on addressing the well-being of the people first is needed.

Genesis of the popular participation approach

The genesis of the popular participation approach came from civil society and civil movements in Asia and elsewhere . The Gandhian *Sarvodya Shramdana* movement in Sri Lanka is one example of a successful people-first movement in Asia. Through this movement, leadership in civil society was able to reach millions of Sri Lankans, motivating, organizing, mobilising, and promoting sustainable local development. Many NGOs followed *Sarvodya*'s example and even the state now works closely with the movement. The core philosophy of *Sarvodya* and many other successful social movements is to appeal to the innate good sense of the people. Thus voluntary participation charity, solidarity, patriotism, empowerment ,and cultural 'mores' play important roles in such popular participation. Charismatic leadership and the ensuring of honesty and integrity as well as discipline are important core values. Systemic elements are devolution of roles and responsibilities, accountability, and transparency and decision-making at the local level by both men and women. Following these quintessential principles, many in the state and civil society have been able to replicate successful popular participation elsewhere in Asia.

Are there successful examples of the people-first approach? How was it done?

In Taiwan, popular participation has been most successful in the agricultural sector. It started as a state-sponsored initiative where the government provided impetus to academic and farmers' associations to work together. Land reform, secure tenancy, redistribution of productive assets, and making farmers' groups autonomous were the hallmarks. The government line agency functions as a facilitator and resource centre by promoting and preserving indigenous knowledge and technology. Millions of farmers are organized into cooperatives. The farmers' production and marketing group functions as the dynamic nucleus of the farmers'association. It interacts with the market, government ,and local farmers. It provides technology and know-how, and it also ensures that goods are produced, packaged, and marketed efficiently securing a fair farm-gate price for farmers. The farmers' groups actually employ the agronomist and extension officers. This model mobilises the target group and empowers them to solve their own problems. Hundreds of thousands of farmers' associations have been able to ensure accountability and transparency and create financial, operational, and institutional sustainability.

Bangladesh is a pioneer in the people-based development model. NGOs are in the forefront of development. Notable NGOs with almost country-wide or regional outreach are BRAC and Gramin Bank. There are also many NGOs in India and a few in Pakistan , and these include parastatals such as the Aga Khan Rural Support Programme initiatives that have had an effective impact on the lives of the rural poor by applying the bottom-up approach to development.

In South East Asia, what began as a small nucleus of academics, agricultural extensionists, and development workers in 1974 in Chiang Mai, Thailand, is now a major people-first movement spanning Indo-China, Indonesia, Malaysia, The Philippines, Korea, Japan, and Taiwan. The movement is called the Development of Human Resources in Rural Areas (DHRRAS). Its aim is to improve the quality of life of Aian rural farmers and their families. Its philosophy is the primacy of the farmers and their dignity, knowledge, and wisdom. Its core values are respect for nature, natural farming, and sustainable development, and its approach is called the 'rootedness' of the development programme in the community based on agrarian reform and rural development through human development. It is based on bottom-up planning and programming. The efficacy of this approach is now manifested through a dozen rural development movements and north-south cooperation within Asia through a process called the 'Dialogue of Life' and farmer-to-farmer exposure dialogue and action programmes (EDAP). The work of this movement is being carried out by the Thai DHRRA in Thailand, MasDHRRA in Malaysia, InDHRRA in Indonesia, PhilDHRRA and CenDHRRA in the Philippines, KoDHRRA in South Korea, ChinDHRRA in Taiwan, and JaDHRRA in Japan;. CamDHRRA in Cambodia, VietDHRRA in Vietnam, and NeDHRRA in Nepal are the new siblings of this movement.

What are the roles and responsibilities of the state, market and civil society?

Human society has developed various social structures so that its members can live secure and dignified lives. These structures are the state sector, civil society ,and the market sector. In the developed north, the state, civil society, and the market sector are fairly evenly balanced. They countervail one another to a greater or lesser degree to provide society with security and well-being socioeconomically and psychologically. In the developing south, the picture is not so well balanced: either the state or the market sector plays a dominant role. The state sector is dominant in centrally planned economies and in countries such as Nepal. The market is dominant in the so-called tiger economies of South East Asia. Civil society, with desired features such as autonomy, accountability, self-governance, and devolution of decision-making ,is just emerging in countries such as Nepal. It is important, however, that the civil society is promoted. It is imperative for development practitioners to be mindful of the roles and responsibilities of the state, the market ,and civil society. Each has its own comparative advantages (Figure 2)

The comparative advantages of the state are that it is inherently big and powerful and has wide coverage. It is a leader in science and technology and has adequate human resources. It has administrators, managers, and civil servants. It has huge financial and natural resources. It makes and shapes policies and legislation. It is also the essence of governance at the local level where development takes place. The market sector creates jobs, incomes, goods, and services. It has financial and human resources. It is also a leader in science and technology and can invest in research and development. It can provide government and civil society with financial, technical, and scientific resources. Civil society is equally indispensable as it represents the common person. It is an association of guilds, professions, trade unions, doctors, lawyers, students, men and women, and media. It also has institutions and organizations such as NGOs and CBOs. Ideally, civil society, especially through NGOs and CBOs, is the voice of the people. NGOs and CBOs are close to the people, flexible, innovative, efficient, and cost effective at their best.

What are the future directions?

Advocacy for popular participation through civil society is etched firmly in the minds of development practitioners. This has been possible because thinkers, both Asian and western, have articulated well the roles and responsibilities of the state, the market, and the NGO sector and articu-

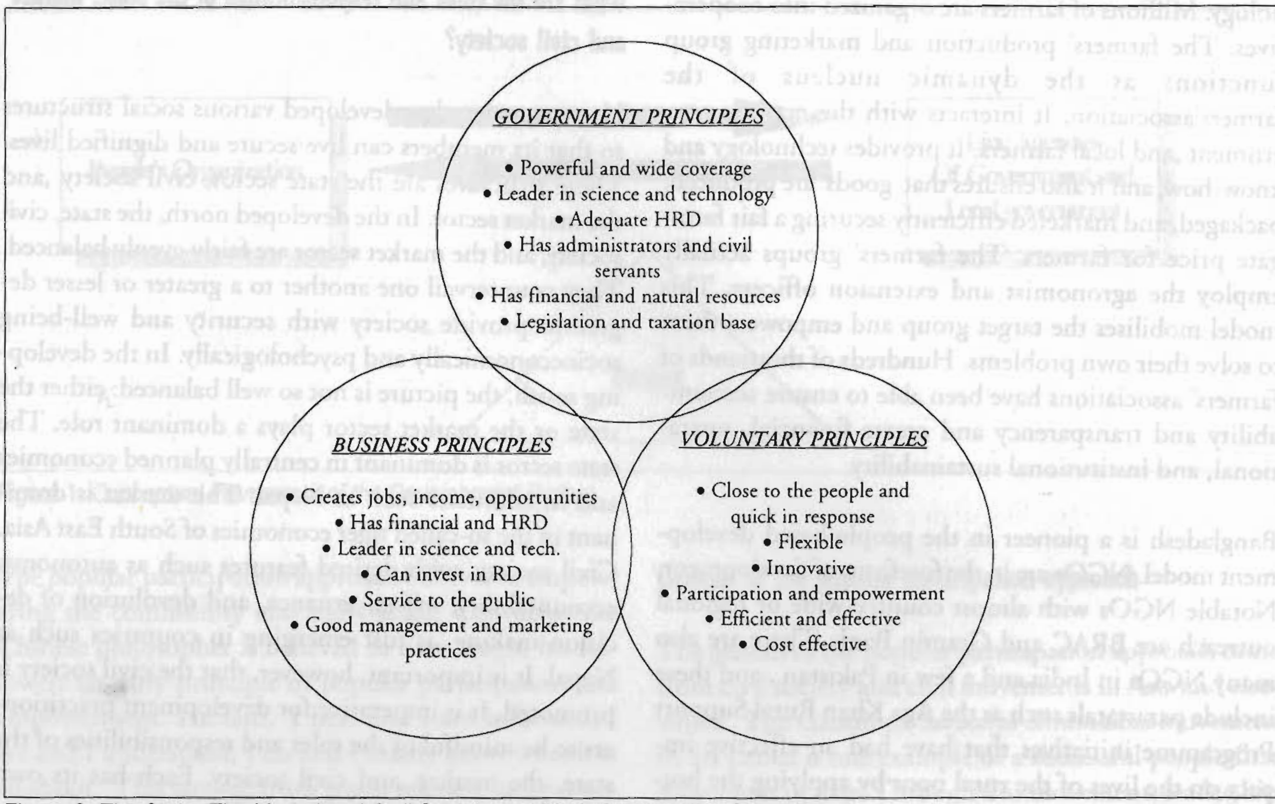

Figure 2: *The State, The Market and Civil Society and Their Comparative Strengths*

lated them persuasively. Thus, according to Alan Fowler, the development strategy to be aimed at is sustainable development based on accountable self-governance.

Development and extension strategy

Alan Fowler (1997) suggests a useful framework (Figure 3). It is a schematic presentation in which NGOs operate at both micro- and macro-levels. At the micro-level, NGO activities are material services, social services, financial services, capacity building, process facilitation, mediation and reconciliation. This is synthesised as empowerment of communities and individuals, strengthening of local institutions, and sustained improvements in the physical and environmental well-being of communities. The role of NGOs is primarily related to mobilising and strengthening civil society.

What are the essential steps in popular participation?

Participatory approaches fall within two broad frameworks. The first one is the project management design. The second one is the community mobilisation and community development framework. In both these approaches the conviction that local people can help themselves together with outsiders is the guiding principle. The Rural Reconstruction Movement in The Philippines articulates its principles and processes through a series of diagrams and schematic flow charts (Figures 4, 5 and 6).

Participation broadly means the ability of people at the grass roots to take decisions, implement projects and processes, derive benefits from them and evaluate the process of participation and implementation itself. This involves setting and prioritising activities, contributing and enhancing inputs, and shaping outputs, outcomes/effects, and future impacts. In doing this there is a dynamic action and reflection process that takes place between the grass roots' community and outsiders such as project personnel. Ideally such a process takes place at three levels: the programme or sectoral level in the headquarters of a project; the project and team level; and the community and people's level.

The IIRI/RRP framework leads us through five steps of community participation. They are preparation, mobilisation, initial people's project, integration and expansion, and separation. The first two steps can be termed community mobilisation. This takes time, skills, trust, creativity, persistence and energy to accomplish well. It requires plenty of human input but often involves no physical, monetary, or material inputs. The next three steps can be termed community development. This phase requires human, physical, material, mental, and monetary inputs.

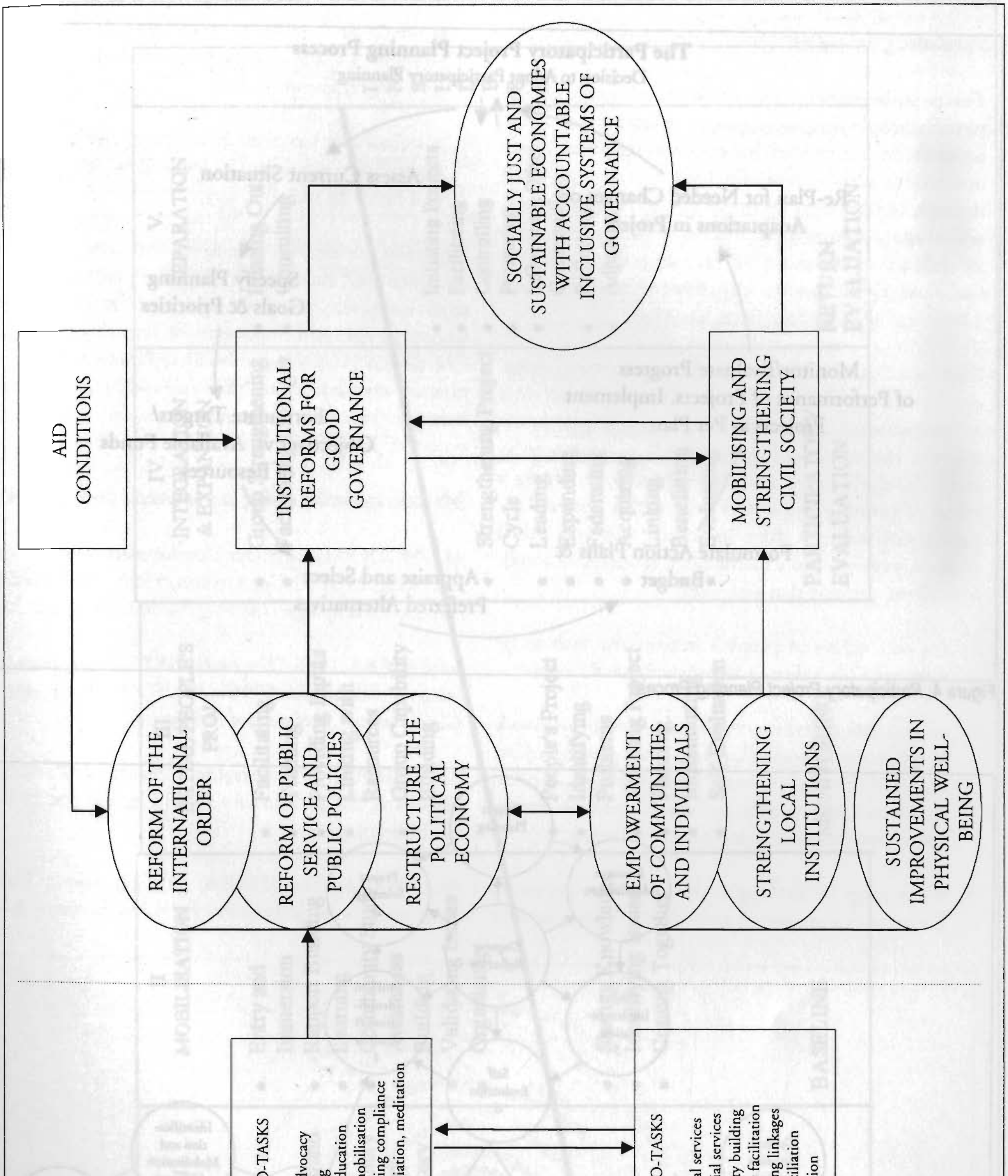

Figure 3: *Framework of Development Strategy*

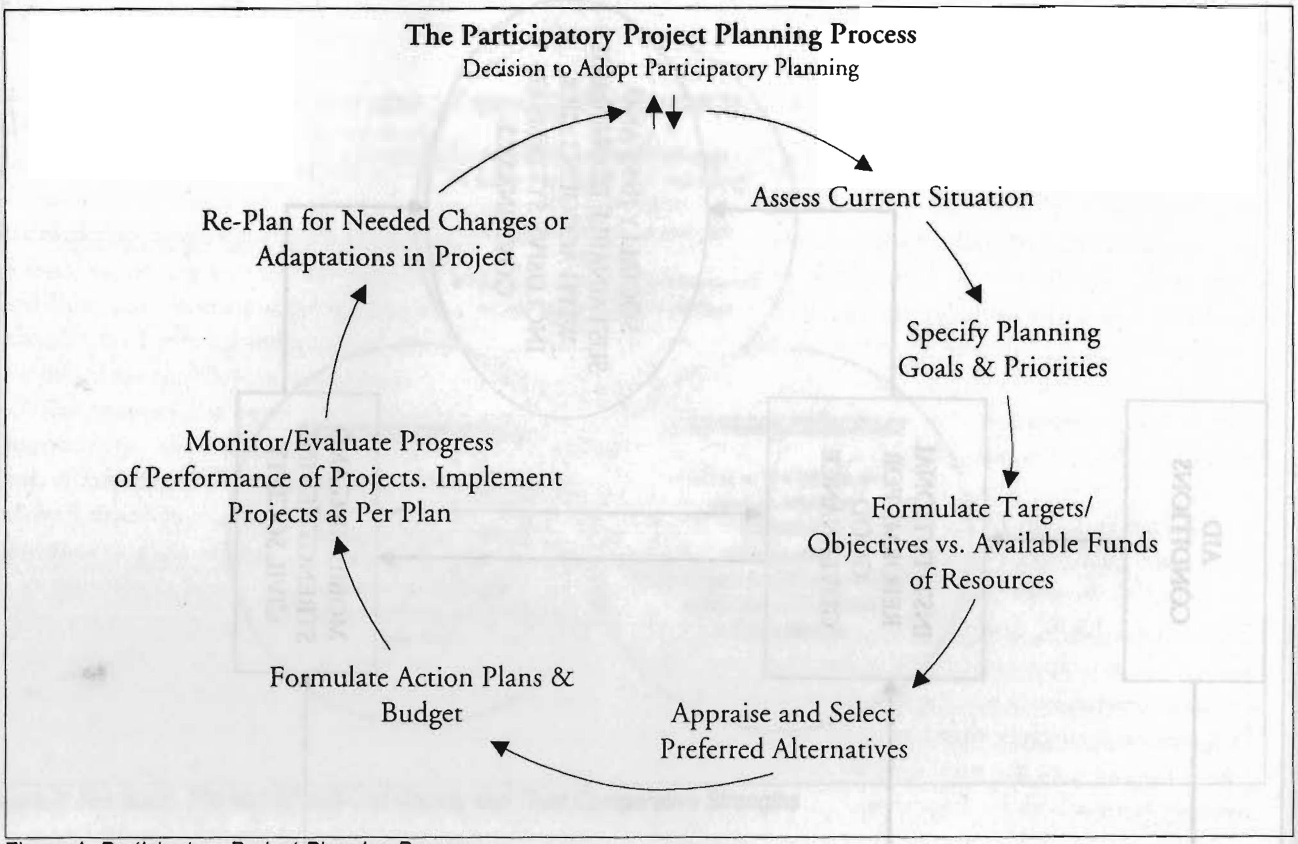

Figure 4: *Participatory Project Planning Process*

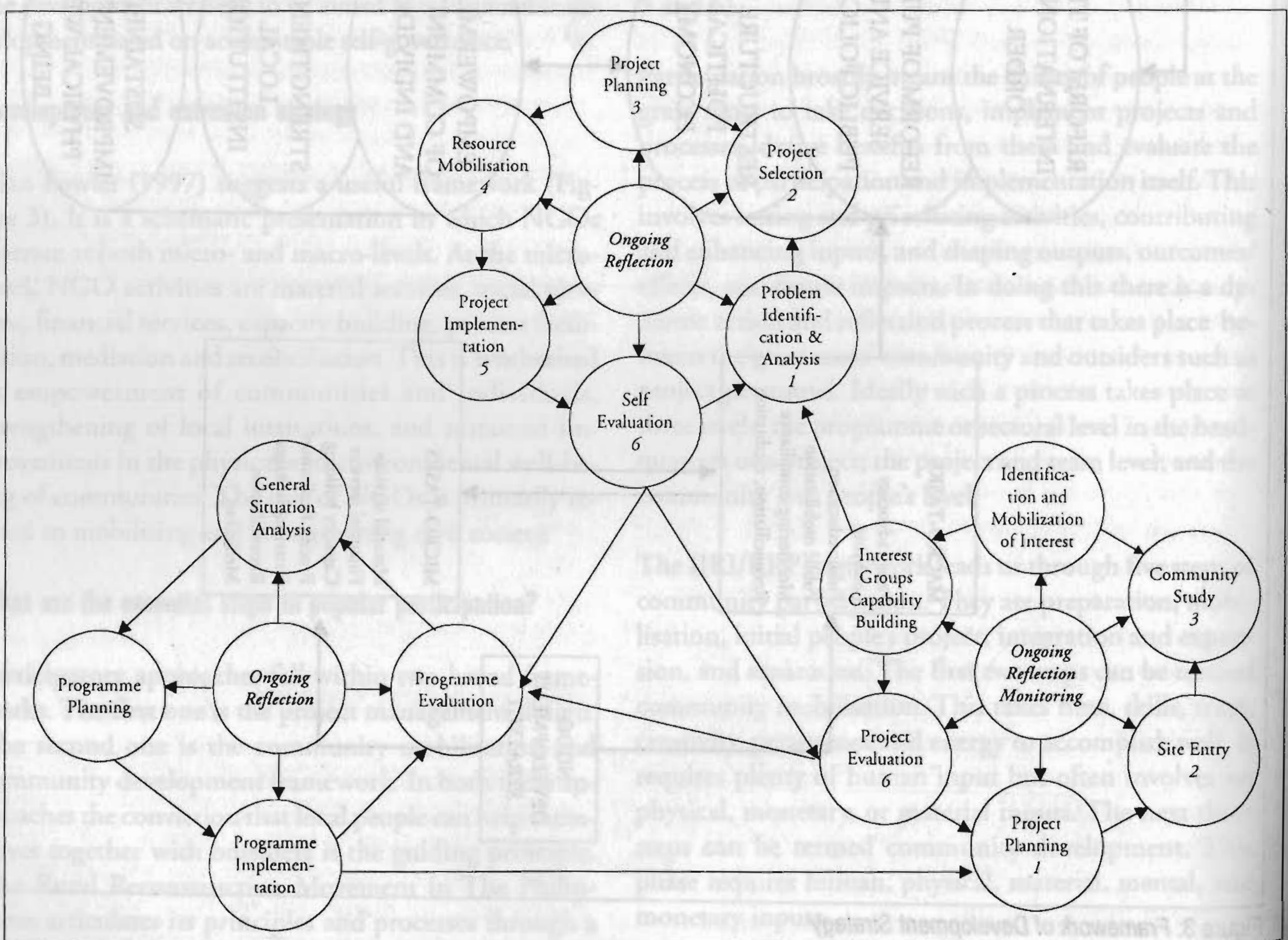

Figure 5: *Rural Reconstruction Programme Management Cycle*

	I PREPARATION	II MOBILISATION	III INITIAL PEOPLES PROJ	IV. INTEGRATION & EXPANSION	V SEPARATION
OUTSIDE	• Trainings of Facilitators • Clarifying Roles and Objectives • Visiting Community • Planning Strategy • Resource Inventory	• Entry and Immersion • Rapport Building • Learning • Community Study • Awareness Building • Validating Issues • Organising	• Facilitating • Training • Providing Inputs • Linking with Resources • Group Capability Building	• Group Strengthening • Facilitating Linkages	• Phasing Out • Consulting
INSIDERS	• Family Coping • Community On-going Efforts • Accept/Reject Projects	• Sharing Knowledge • Identifying Issues • Coming Together	• People's Project • Identifying Problems • Selecting Project • Planning • Implementing • Self-Evaluation	• Strengthening Project Cycle • Leading • Expanding • Federating • Acquiring • Linking • Benefiting • Evaluating	• Initiating Projects • Facilitating • Controlling • Pressuring • Influencing Other Communities • Reflecting • Adjusting
	GENERAL SIT. ANALYSIS	BASELINE	MONITORING	PARTICIPATORY EVALUATION	RETURN EVALUATION

Figure 6: *Phases and Roles in a Community Reconstruction Project*

Summarising the popular participation approach

The popular participation approach reinforces efforts towards people-first development. It calls for concrete actions at the micro-level that empower people and their institutions at the community level. It is accomplished through bottom-up empowering and an incremental self-reliant process model as opposed to a top-down service-delivery extension model. Its root is the conviction that local people are knowledgeable and can help themselves together with help from outsiders.

The Asian NGDO Consortium's organizational development model, developed in the 1990s, is based on a holistic systems' approach to enhancing and empowering the institutions of the people at the community level. Popularly called the *Chakra* Model, signifying a wheel of learning and energy points, this systems' approach encompasses three important concepts called systems, strategy, and sustainability. It comes in a well-articulated package that addresses:

- the core values of people's institutions such as vision, mission, values, and organizational culture;
- various systems and functional management areas such as governance, leadership and management styles, human development, financial management, conflict resolutions, information and communication, monitoring and evaluation, and project planning;
- the strategy by looking at the long-term prospects for people's institutions and helping to analyse their internal and external environment through a strength, weakness, opportunities' ,and constraints' (SWOC) framework; and
- sustainability issues such as process sustainability, institutional sustainability, programme sustainability, and financial sustainability.

Hopefully, the ideas introduced here on participatory development will encourage trainers and project personnel to put into practice some of the guiding principles of popular participation and empowerment. International NGOs and national NGOs have a wealth of information and experience on participatory planning and project management. Trainers are encouraged to liaise with such institutions and practitioners at the local and national levels.

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Figure 7: *Chakra Organizational Development Model*

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Module 1.5
Ethnobotany for Biodiversity Conservation

Pei Shengji

Objectives

- To understand the importance of biodiversity conservation in watershed management planning, monitoring, and development
- To explain the basic principles of the ethnobotanical approach for participatory biodiversity management in a watershed
- To demonstrate community-based biodiversity management activities using case studies in ethnobotany

Definitions

Biodiversity encompasses all species of plants, animals, and micro-organisms and the ecosystems and ecological processes of which they are a part (McNeely* et al. *1990). Although biodiversity manifests itself as a characteristic of the natural system, it is actually a product of the interaction of both social and biophysical systems. In this sense it can be defined as functional natural resources on which humans are dependent for their livelihood and socioeconomic development from ancient to present times and extending into future generations. The utilisation and conservation of biodiversity involves intrinsic interactions between species, genetic populations, communities, landscape, and natural ecosystems, on the one hand, and culture, technology, social, economic, and indigenous knowledge, institutions,and information on social systems on the other. Both natural and social systems are interrelated and interwoven in the evolutionary process of biosystems at different levels in a given area: human activities influence the level of biodiversity, either decreasing or increasing components of biodiversity in different conditions or settings (Pei and Sajise 1995).

Ethnobotany is the study of human interaction with the plant world. It is a multidisciplinary science of botany, ecology and anthropology. The fundamental structure of ethnobotanical research is to examine the dynamic relationships between human populations, cultural values, and plants recognising that plants permeate materially, symbolically and metaphorically many aspects of culture, and that nature interacts with human actions. Thus, ethnobotany is more than simply a study of plants useful to people, for it is devoted to understanding the limitations and behavioural consequences of human actions on the plant environment. To accomplish these objectives, the principles of classification of the plant world are used, and beliefs about plants as specific expressions of more generalised native ideas of world views are studied. Views are pursued to determine how plants structure human relations with plants, and how the composition of plant communities reflect human beliefs and actions. The genetics, phenology, chemistry, and productivity of specific plants and populations are a few of the factors examined (Ford 1987).

The importance of ethnobotany is that it has an important role to play in conservation of nature and culture, and, in particular, the biological diversity and the diversity of traditional human cultures. In fact, conservation of biodiversity and cultural diversity are linked. For instance, traditional medicine and food culture use of edible plants differs from one region to another and one ethnic group to another. Traditional knowledge systems are hundreds or even thousands of years old and involve not only knowledge of plants for medicine and food but also strategies of protection for sustainable utilisation of plant resources.

How are culture and biodiversity conservation linked?

Cultural diversity is largely dependent on the biological diversity that provides materials for humans to create the lifestyle of the society to which they belong. Cultural beliefs contribute to biological diversity and environmental protection. Along with material culture ,for example,food, medicine, and shelter, plants have been closely associated also with many social customs and religious rituals (Jain 1987).

Extensive deforestation and intensive farming on steep slopes, heavy population pressure on soil-land-water,biological resources, and the adverse impacts of large development projects have resulted in overall environmental degradation and loss of biodiversity. In the last few decades, concerns about the state of the environment and the poverty of mountain people in the Himalayas have prompted much discussion and a range of development interventions. Degradation of the Himalayan mountain environment not only affects the livelihood of the mountain people and opportunities for economic development in the future, but also has a significant impact on the adjacent plains (ICIMOD 1993).

Examples of interactions of bio-species and mountain people in the region include the development of both wet and dry rice cultivation, tea planting, domestication of barley, buckwheat, *cardamom*, agall (*Aquitaria agallocha*), yak, mithun, Tibetan goat, and Mugu silkworm; and the use of thousands of wild species to meet basic needs. Development of the mountain economy in the region will depend on sustainable use of biological resources, maintaining a high diversity of mountain crops in farming systems, and management of forest resources, pastures, and rangelands in the diverse mountain ecosystems. Particular interest is placed on non-timber forest products (NTFPs), medicinal plants, fruits, bamboo and rattan, livestock, and beekeeping. These are the visible means of increasing food production and income generation. The traditional utilisation of biological resources not only reflects a diverse resource-use pattern but also the way of maintaining biodiversity in mountain ecosystems by local communities. It is estimated that at least 70 per cent of the medicinal plants and animals in the region are wild species, and 70-80 per cent of the population depend on traditional medicine for primary health care (Pei 1987).

What is the role of indigenous knowledge in biodiversity conservation?

There are two global systems of knowledge: one being international knowledge systems generated by universities, research institutions ,and private firms and the other being the indigenous knowledge system (or folk knowledge) – knowledge that is unique to a given culture or society and is handed down from generation to generation, perhaps only orally. Indigenous knowledge systems are not only of value for the cultures from which they evolve, but also for scientists and planners striving to improve conditions in rural societies (Warren 1990). They can contribute to rural development, industrial development, health care and environmental conservation (Bellamy 1990). Ethnobiology is built upon the assumption that new ideas and methods can be generated through identification, documentation, and explanation of indigenous knowledge systems. Natural resource management systems are localised indigenous knowledge systems that form a basis for decision-making by farmers.

What is participatory biodiversity management (PBM)?

Culture-based conservation has a long tradition. The conservation of sacred plants, animals, forests, and mountains is a common phenomenon and can be effectively incorporated into modern conservation. Recognising that local people should be part of a conservation programme and understanding that *in situ* conservation should include conservation of biodiversity in different components of traditional agro-ecosystems, buffer-zone development could be a new approach to participatory biodiversity management (PBM) of protected areas. Since 1992, the International Centre for Integrated Mountain Development (ICIMOD) has been working in collaboration with national institutions and NGOs in buffer-zone development of national protected areas in China, Nepal, and Myanmar.

What are the recent methodologies for participatory biodiversity appraisal (PBA)?

There is growing recognition that sustainable resource management needs participation from local communities. Participatory biodiversity appraisal (PBA) can serve as a new approach to analysing, together with local people, information on preserving biodiversity and promoting sustainable use (Xu and Ruscoe 1993). PBA could be useful for assessing biodiversity that manifests itself in a range of functions for local communities in terms of ecological, cultural, and socioeconomic purposes. These include indigenous perceptions and values of biological resources in their surroundings, indigenous knowledge associated with species in agro-ecosystems, as well as priorities and decision-making in the use and preservation of biodiversity in the study area. Such information could be collected and analysed using various diagnostic tools such as interviews and observations. PBA is applicable also for ecological measurement techniques, such as field sampling and inventory, for identifying sample species and for understanding existing land-use patterns. It combines scientific and indigenous knowledge to present an interdisciplinary picture of human and biodiversity interaction.

Inventory

Ethnobotanical inventories can be viewed as a method of participatory inventory. Ethnobotanists conduct field inventories of human-use species such as medicinal plants, food, fodder, non-timber forest products, swidden crops, home-garden plants, religious plants and others usually involving a large number of local people. Inventories of this type document information on both natural and human-use aspects of the species surveyed, including scientific names, vernacular names, habitat, utilisation, preparation, properties, and maintenance. Various types of inventory are used as follow.

Complete list of species of regional and national biosystems. Species' composition and the geographic distribution of information are often documented in the publications of regional and national monographic studies on flora, fauna, and micro-organisms. These types of inventory are based on biosystemic approaches and should be considered authoritative documentation in the assessment of species' diversity at regional and national levels for biological resource management.

Species' checklists. Species' checklists record species' diversity in a certain geographical area or in a certain ecosystem. This type of inventory can be based on biotaxonomical groups, ecological units,or life forms, or can be in a comprehensive form covering species' elements of plants and animals in a particular area for a specific purpose in the context of natural resource and environmental management.

Ethnobotanical inventories. Ethnobotanical inventories include inventories of plant species used by indigenous people in a given area/region or by cultural groups; medicinal plants used under a certain traditional medicinal system; and natural products locally marketed. Inventories of this type include information on both natural and human aspects of the documented species, including scientific names, vernacular names, habitat, utilisation, preparation, properties, and maintenance, etc. Inventories based on indigenous knowledge will be extremely useful for rural development and the conservation of natural resources on a regional level.

Inventories of genetic diversity in farming systems. Under this category, farming and horticultural crops, trees for afforestation, domesticated animals, and insects are documented on a genetic level covering species, varieties, land races, eco-types, and other gene types of domesticated organisms.

Inventories of endangered and threatened species. Inventories of species endangered and threatened are used to assess environmental degradation and identify the priorities for natural conservation. This type of inventory is often documented in the Red Data Book on endangered and threatened species, at national level or on regional level, giving alarming indications of the extent of loss of biodiversity.

Agro-ecosystem analysis

Recently, new methods for quantitative studies of biodiversity in the agro-ecosystem have been developed, for instance participatory mapping, free listing of important species, and keystone species.

Cultural beliefs and biodiversity conservation

Biodiversity and cultural diversity, the linkage and impact on watershed management, religious linkage, and traditional labour and village regulations could be included.

Monitoring of biodiversity change

To monitor biodiversity change in a watershed, species' diversity changes and farming crop diversity changes are used as indicators along with forest-cover change and land-use pattern change. Forest products and NTFPs, water resources and soil erosion, and key species' distribution are also used as indicators. Levels of use of traditional varieties in the farming system are assessed in monitoring plots on selected sites.

Social structure of biodiversity management

Understanding of the social structure is important as it governs use of the natural resources. A number of social elements are involved in the process of biodiversity including :local institutions, policy impacts, economic incentives, and the impact of traditional culture on biodiversity. The role of local institutions is a key mechanism for PBM through community biodiversity conservation association.

Utilisation and conservation of biodiversity for poverty reduction

- Identify potential bioresources for economic development
- Integration of local practices and advanced technologies: agroforestry, local species, and NTFPs
- Rural women and biodiversity: biodiversity is gender sensitive (household kitchen and rural healthcare practices)
- Training and education: farmer-to-farmer exchange and native training materials for conservation

What are the main lessons learned?

- Biodiversity management is transformation: it is useful to learn from the traditional subsistence approach in order to refine the market-oriented approach to natural resource management.
- The role of local institutions is the key mechanism for participatory biodiversity management through community biodiversity conservation association.
- Utilisation and conservation of biodiversity can be used for poverty reduction.

What are the future directions ?

- Research: sustainable development models for biodiversity management of different eco-regions should be developed. Joint research and monitoring are essential.
- Policy: communities' and people's resource rights must be ensured and illegal trading on protected species controlled.

Recognition of ownership of resources is a key issue for conservation. Local people should be given the right to self-determination and be allowed to set their own development agenda. local communities should be encouraged to maintain traditional agro-ecosystems in the buffer zones and to preserve *in situ* repositories of crop germplasms. Support should be available to local communities for maintaining traditional 'sacred' forests and holy mountains for biodiversity conservation. There should be increased co-operation regarding enforcement of laws and policies with specific reference to transboundary conservation. Joint patrols, sharing of databases and monitoring methods, and coordinated customs and immigration activities can benefit protected areas and people. Participation of local communities in the development of transboundary conservation programmes and protected area management systems should be ensured. Information on transboundary conservation issues should be shared by governments and institutions. Mechanisms for exchange of information should be identified; for instance, regular joint technical meetings, seminars, and communications. Capacity building should focus on local institutions and the management staff of protected areas. Increased awareness is needed. This should include education and training. Training should concentrate on on-site training and development of native training materials.

Conclusions and recommendations

Biodiversity demands careful protection in order to enhance the process of economic development of mountain areas. In Chapter 12 of Agenda 13 of UNCED 1992 the following is stated: '*Mountains are highly vulnerable to human and natural ecological imbalance and most susceptible of all to climate changes in the atmosphere. Mountains are a source of key resources. As major ecosystems, they represent the complex and interrelated ecology of our planet. Mountain environments are essential for the survival of the global system.*' Biodiversity is a concern common to all mountain ecosystems. To ensure conservation at the local level, community participation in biodiversity management must be treated as an important component of integrated watershed management. Identification of local biodiversity resources to support community development and poverty reduction will help conservation. In addition, traditional culture can be usefully incorporated into modern conservation in all watershed management schemes.

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Module 1.6

Conflicts in Community Forestry and Mechanisms/Processes for Resolution – Some Examples from Nepal

K. B. Shrestha

Objectives

- To identify, analyse and discuss conflicts arising in community forestry
- To find ways of managing conflicts satisfactorily

Conflict

The word conflict denotes a relationship between opposing forces. The relationship may or may not be marked by violence. Conflicts are brought about by change and the way individuals or communities react to that change. Changes can be physical such as an increase in population and migration or in the degradation of physical environment. Alternatively, they can be social such as growing inequity in the distribution of natural resources. Conflicts are also observed when traditional practices, e.g., shifting cultivation, are considered not legitimate or consistent with national policies. They occur when external agencies try to do something according to their interest while ignoring the needs of local people. In all conflicts there is an element of change.

What role can conflict play? Can it be positive?

Individuals and communities react differently when confronted with change. Some may take it positively. They adapt to change and use the opportunity for good. Others may take change as a destabilising factor and try to resist, resulting in conflict. All development works, whether promoted by government, INGOs, or NGOs, propose change in one form or another. Such change contributes to the emergence of conflicts. These conflicts can be between individuals within a group, between groups, or even between institutions.

What are the major conflicts in community forestry?

In community forestry conflicts arise at different stages. The conflicts are seen within a forest users' group, between two or more forest users' groups, and between forest users' groups and forestry administration.

Conflicts within a forest users' group

Identification of users

The operational guidelines of the community forestry programme recognise investigation as one of the four phases of the planning process. This phase concerns, among other things, the identification of users of the prospective community forest. The staff investigates within the village, by discussion or by checking, to determine the real users of a particular forest. However, low-caste or disadvantaged people may be missed out from the users' group as they do not usually have a voice in a community dominated by higher castes. As a result, if such disadvantaged people are excluded, at the time of benefit-sharing, conflicts may surface. In another case, people living away from the forest may not be regular users but only use the forest seasonally, e.g., charcoal-makers. They are 'secondary users' who do not contribute to the protection of forests. Often, during the identification process these secondary users are not aware of the field staff's visit and are excluded from the list of forest users. This could possibly cause conflict later.

Sharing of benefits

Community forests are used for the production of fodder, fuelwood and so on. Conflicts arise over how the produce should be shared. A user with eight family members argues that, due to the size of his family, he has the greater need; that forest products should be shared according to the number of family members. Others argue that benefits should be shared on the basis of households irrespective of family size, because the contribution of voluntary labour for forest management depends on the household. There will be a difference between need on one hand and duty on the other — causing conflict.

Participation

All members of a users' group cannot actively participate in meetings or provide voluntary labour. Some members are bound to be inactive for various reasons. The active members may feel that, because of their limited participation, the inactive members should not enjoy benefits equal to those of active members. The inactive member, on the other hand, can counter that, as a member of a users' group, social compulsions not under his control should not bar him/her from benefits enjoyed by others. Such arguments give rise to conflicts.

The most visible form of participation in community forestry is protection work. In many community forests, the users decide that protection work should be carried out in turn. Protection requires a physical presence at the site, and strict vigilance. For most users, this is acceptable. However, because it demands a physical presence at the site, sometimes at odd hours, those of a higher social status may not participate to the desired extent, yet wish to enjoy the benefits. Their social status may prevent other members of the group from complaining openly but resentment and conflicts are inevitable. Similarly, some members of a group may live near the forest and others at a distance. In such situations, more participation is demanded from the former. Their proximity to the forest does not allow them to escape or overlook the responsibility of protection work and forces them to act if an offence is being committed, even though protection on that day could be someone else's duty. Thus, unassigned demand for vigilance could be heavier on members living close to the forest, and this may cause them to demand benefits commensurate with their work.

Leadership

In a village or community, people may want to enhance their social status by ostentation, by pursuing higher education, or by becoming a leader, and so on. Being nominated Chairman or Secretary in a users' group committee can elevate one's social standing in the village and act as a stepping stone to local leadership. Naturally, this is an attractive proposition; if two or more people compete for chairmanship and consensus cannot be reached, conflicts could arise. If the ulterior motive is political, these conflicts could take a dangerous turn.

Conflict between users' groups

Location of forest

In general, a patch of forest in one village development committee (VDC) is used by villagers from the same village. However, when the boundary of a VDC is redrawn (a common occurrence), that patch of forest is assigned to another VDC. The villagers from the second VDC then claim the forest as community forest, while the previous users make the same claim on the grounds that they are the traditional users and, thus, a conflict ensues.

Another potential conflict area is a patch of forest lying within more than one VDC. Users' groups from the VDCs request the District Forest Office to demarcate the forest prior to handing it over for community management. In the absence of a clear-cut boundary on the ground, conflict arises as to where the line of demarcation should be. Naturally, users' groups will claim and counter claim the better parts of the forest.

Nature of the forest

There are instances of villagers using more than one forest for forest produce. For some forest produce, such as fuelwood and leaf litter, the villagers may use a miscellaneous forest in their own village, but for other produce, such as timber, they may use a sal *(Shorea robusta)* forest that lies in another village but within the same VDC. When the users' groups are formed, the users' group claiming the sal forest refuses to give any rights to the users' group with the miscellaneous forest, arguing that the other users' group does not contribute to the protection of the sal forest. The other group claims that they are barred from their long-standing right to construction timber.

Conflicts between users' groups and the Forest Division Office/ Forest Department

Deviation from operational plan

When the operational plan is approved, and the forest handed over, a representative of the users' group committee, usually the chairman, and the District Forest Office sign an agreement to implement the operational plan without deviating from any of the provisions. Yet, instances of deviation have been recorded. Deviation has occurred due to either a lapse on the part of the district forest staff or because of the forest users' group's zealous pursuit of income for their community fund to build community infrastructure.

Deviation from the objectives of community forestry

Users' groups sometimes deviate from the objectives of community forestry as illustrated by the case given in Box 1.

Box 1
Stone quarrying in a community forest in Syangja District, Nepal

The case involved a mixed sal forest that had been handed over to a users' group. A section of this forest had only sparse vegetation of young sal because of a rocky outcrop that had been a stone quarry 30 years' previously. The users' group was protecting the forest without any problems. Subsequently, the government planned to build a major hydropower project of considerable national importance in the district and gave a private company the contract to construct an access road originating about a kilometre from this community forest. On the contractor's request, the District Forest Office issued a permit to quarry the rocky part of the community forest on the basis of a rule made 24 years' previously that authorised the District Forest Office to issue such permits for national forests. The contractor quarried the area.

The forest users' group did not challenge the validity of this permit but instead decided to levy a tax on the truckloads of stone. This continued for some time until it came to the attention of the centre, which at once ordered an enquiry and stopped the quarrying, thereby halting the construction of the access road to the hydropower project and prompting the Nepal Electricity Authority to request the Forest Department to permit quarrying of the area. The Nepal Electricity Authority cited the high quality of stone and stated that no other potential quarry of a similar quality existed within a radius of 100 km. Under community forestry rules, quarrying is not permitted.

The dilemma of the central forestry administration was whether to annul the right of the users' group to manage the whole forest and declare it a national forest, thereby allowing the forestry administration to issue the quarry permit for the project while, at the same time, punishing the users' group for wanting to earn money, or to deny the request to quarry the area, depriving the national hydropower project of its much needed stones.

Conflicting decision

With the hand-over of community forests during the last few years, many community forests have reached the harvesting stage. The Forest Act of 1993 allows forest users' groups to price, sell, and transport freely forest produce yielded from community forests across the country. However, a government decision tried to regulate conditionally the sale and transport of forest products from a community forest outside a district. The condition was that priority must be given to the needs' fulfillment of the forest users' group first and then to the needs of other forest users' groups within the district before the forest products could be transported outside of a district. This had evoked criticism and protest by forest users' groups that the rights of the forest users' group incorporated in the Forest Act are being encroached upon by the government. The government's decision tries to safeguard the interests of other forest users' groups who do not possess enough forest area to cater for their need for forest products. Conflicts are emerging on this issue.

Lack of trust

A prerequisite for handing over a community forest is the approval of an operational plan by the District Forest Officer. Cases have been observed in which the District Forest Officer does not agree to apparently liberal provisions in the operational plan for removal of trees from a community forest. This invariably is due to the suspicion on the part of district forest staff that the forest users' group's proposal is driven by the motive for making more money for the community fund rather than by the need for forest products.

In other cases (Box 2), when forest users 'groups have requested the hand-over of purely commercial forests, there has been a great deal of hesitancy on the part of field staff. This arises from the district forestry staff's lack of confidence in the abilities of forest users' groups and their apprehension that forest users' groups will be tempted to cut illegally such commercial timber, which has a high value in the market. Such low confidence has led to conflicts. The district forestry staff's suspicions are not without foundation. Recent cases of forest users' groups over-cutting commercial timber from community forests have compelled district forest staff to take back community forests from the groups. The resulting conflicts have attracted much attention across the country.

Amendment of the Forest Act

The Forest Act authorises the District Forest Office to take back community forest from a forest users' group if the forest users' group committee deviates from the operational plan or commits an offence in the community forest. There is no provision for penalisation of forest users' group committee members. The District Forest Office has no other option than to take back the community forest, an extreme step depriving the forest users' group of forest products. So the government has proposed an amendment to the Forest Act empowering

Box 2

Case of Koidim Community Forest

Koidim, a Community Forest predominantly of sal *(Shorea robusta)* ,was handed over to a forest users' group (FUG) consisting of 102 households in March 1994. The community consists mainly of an ethnic hill group of *Magar*, a simple and straightforward people. The chairman of the FUG, a former school teacher in Kathmandu, is a local political person. Other members of the FUG are poor and illiterate and depend upon him for any community activity. The FUG assembly under his leadership decided to cut trees (including green trees) from hill slopes and extracted 13,700 cubic feet of sal timber — when the permissible limit is 500 cubic feet annually of fallen and dead timber as prescribed by the operational (management) plan. Labour from poor people of the FUG was used for nearly two months for cutting and extraction of timber by providing them with a food ration taken on credit from a local shop with the agreement that the debt would be paid with proceeds from the sale of the timber. Local people informed authorities about the illegal cutting and an investigation team was dispatched to the field from the centre. Based on the report of the investigation team, the Forest Department suspended from duty the District Forest Officer and his deputies for negligence in duties.

The newly deputed District Forest Officer immediately seized all the timber, which was worth six million rupees (US$ 1 million), and dissolved the FUG. The community forest was taken back on the grounds that the decision of the FUG assembly was not approved by the District Forest Office and could be recognised as an amendment to the operational plan as was necessary according to the Forest Act. Another reason was that cutting of the trees had an adverse effect on the environment. The District Forest Office also filed a case against the chairman and 10 executive members of the FUG for breaching provisions of the operational plan. This provoked protests in the district headquarters by the FUG, led by the chairman, demanding the withdrawal of the decision and the handing over of the seized timber. It drew wide publicity and there was a lot of political pressure from a top politician on the District Forest Office to solve the case in favour of the FUG because the Chairman's community had the decisive vote bank for the politician. At the same time the FUG filed an appeal to the Regional Forest Directorate against the decision of the District Forest Office as provisioned in the Forest Act. The Regional Director upheld the decision of the District Forest Office.

The chairman made many sorties to the centre to build up pressure through the top politician on the Department of Forests to solve the case in the FUG's favour or at least to make available some money to compensate for the labour provided by the poor members of the FUG. However, to the dismay of the top politician, there is no legal basis for the Forest Department to accept such a demand. The Chairman did a lot of lobbying and reportedly extracted Rs 80,000 (US$ 1500) as a loan from the Federation of Community Forest Users' Groups to file a case in the Supreme Court against the decision of the Regional Director and the District Forest Office. However, the Supreme Court also upheld the earlier decisions. It was reported that the poor and innocent people of the FUG were used by the Chairman to fulfill his political ambitions. It was also reported that the FUG had earlier also illegally cut and sold 2,000 cubic feet of timber for 1.2 million rupees. The cutting of trees had gone unnoticed by the centre and had encouraged the FUG led by the Chairman to cut more than 13,000 cubic feet of timber later.

The conflict between the FUG and the District Forest Office has not been resolved yet, although the Chairman's effort to put pressure on forestry institutions continues. Because of the conflict, the forest cannot be used legally by the community and the timber cut illegally by users has not been utilised, but remains exposed to the elements.

District Forest Office staff to penalise the forest users' group committee members involved in the violation of operational plans. The proposed amendment, the government feels, prevents the need to take back community forest and, at the same time, acts as a deterrent for violations. The amendment to the bill is under parliamentary consideration, but the central organization of forest users' groups is lobbying against it — arguing that it will encourage District Forest Office staff to harass the forest users' group committee members. They also feel that it encroaches on the authority of forest users' groups to penalise any member not observing rules made in the operational plan. Conflict is brewing between the forestry administration and the central organization of forest users' groups.

What is conflict management?

Conflict management does not necessarily mean only conflict or dispute resolution. It also means preventing or minimising conflicts and covers all dimensions of conflict. Managing conflict demands promotion of participatory planning at all levels. It also seeks to raise awareness at all levels of 'conflict dimension' meaning how conflicts are generated, and how they can be avoided, mitigated, and resolved. It also seeks to develop the capacity of institutions at all levels through training in conflict resolution skills. Conflict should not to be ignored because it often threatens social harmony. However, it must be stressed that there is no single mechanism or formula applicable to all conflict resolution. Each conflict is a unique situation and conflict resolution is not a ready-made tool.

What are the mechanisms for conflict resolution?

There are different mechanisms or processes or techniques by which conflicts can be resolved. The voluntary problem-solving and decision-making methods most often employed in conflict management are as follow.

- **Facilitation:** In this technique, a neutral third party's assistance is involved. The neutral party helps in designing and conducting a productive meeting of conflicting parties. A facilitator may help in time management or keeping track of agreements, etc.

- **Arbitration:** Arbitration involves a neutral third party's assistance. The conflicting parties voluntarily submit the case to the neutral third party for decision-making.

- **Conciliation:** In this process, a neutral third party attempts to communicate separately with the conflicting parties. The main purpose is to reduce tensions and agree on a process for resolving the dispute. The conciliator merely facilitates the process and does not direct the parties.

- **Negotiation:** This is a voluntary process in which conflicting parties meet face-to-face to reach a mutually acceptable resolution of the issue. There is no involvement of a third neutral party. Negotiations are typically unstructured and often lack formal procedures such as 'rules of the game' or in what order issues will be addressed. Voluntary participation usually indicates a greater 'good faith commitment' to the dispute-management process.

- **Mediation:** Mediation involves the assistance of a neutral third party in a negotiation process where a mediator assists the disputing parties in reaching their own agreement. The mediator has no power to direct the conflicting parties or make decisions or to attempt to resolve the dispute.

These processes are often combined in practice. An effort originally focussed on conciliation may develop into a negotiation which may in turn be enhanced by mediation. Similarly, a conciliator may be asked to act as mediator at some stage of the conflict-resolution process. Mediation and conciliation can also be seen as an extension of the negotiation process involving the assistance of a neutral third party in negotiation once direct negotiations have broken down.

How can people and institutions play a role in conflict resolution?

It is important for people engaged in natural resource management to understand and recognise the role that local institutions play and the mechanisms used to deal with conflicts within and between communities. Local institutions and mechanisms are rooted in tradition and locally recognised.

Forestry staff do not have the necessary skills or capability to resolve all kinds of conflicts. They are not trained to undertake such assignments. Conflict resolution is a new field in renewable natural resource management, especially in community forestry. The forestry administration has lately realised the need to be sensitive to conflicts and develop resolution skills among field staff. As such, regular training programmes on conflict resolution are carried out for field staff in the forestry sector.

The need to build up such capability is not confined to forestry field staff only: NGOs and INGOs who are assisting in the management of renewable natural resources also require such skills. An innovative forum called *Nepal Madhyasthata Samuha* (Nepal Mediation Forum) has been formed with the involvement of government officials— including foresters, sociologists from NGOs and INGOs, and independent lawyers. It has prepared case studies, and held workshops and training activities to develop awareness about conflict and build capability for resolving conflicts that occur in natural resource management. Such a neutral forum, which is acceptable to conflicting parties, can play an effective role in resolving conflicts.

Water users' committees and community forestry

The community forestry programme is not limited to the hills and mountains of Nepal but is also implemented in the *Terai* (plains). The *Terai* Community Forestry Programme assisted by the World Bank was implemented in *Terai* districts in 1985. Under this programme one of the activities was to plant trees on the banks of irrigation canals. Thousands of sissoo *(Dalbergia sissoo)* seedlings were planted along hundreds of kilometres of irrigation canals on both sides and protected by paid watchers with some assistance from the local people. The project was terminated in 1992. Since then the sissoo trees have grown and are being looked after by district forest officers. As the land belongs to the Department of Irrigation there is ambiguity as to who owns the trees: the Irrigation Department by being the land owner or the Department of Forests by being the planter. It is an uneasy situation. The Department of Irrigation has formed water users' committees and entrusted them with management of irrigation canals— including maintenance. Recently, on the recommendation of the Department of Irrigation, water users' committees requested the Department of Forests to hand over the canal bank plantation for protection, management, and utilisation. Under the Forest Act, plantation on land not owned by the Department of Forests, can be designated as community forest if local communities form themselves into a users' groups and obtain the written permission of landowners of such plantations. On the requests of water users' committees and ,with the written permission of the Department of Irrigation, such canal bank sissoo plantations are being handed over to water users' committees for protection, management, and utilisation according to an operational plan approved by the District Forest Office. This novel arrangement is being adopted along irrigation canals in Nawalparasi and Sunsari Districts.

Lessons Learned and Recommendations

Experiences gained in implementing the community forestry activities have generated the following lessons.

- There is a growing need for forestry professionals, especially at field level, to build up capability and skills in conflict management. So conflict management should be included in training programmes at all levels.
- Many conflicts can be avoided or minimised if there is clear and good communication between forest users' groups and forestry staff. Communication mechanisms should be developed.
- Ambiguity in policy and legislation invites conflict. So, the government should formulate and disseminate clear policies and rules.
- There is no mediation mechanism existing between forest users' groups and forestry institutions. A mechanism for mediation should be developed.

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MODULE 2

Appropriate Technologies and Practices in Participatory Integrated Watershed Management

Rehabilitation of Degraded Lands

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Objectives

- To identify and understand better the causes and processes and the extent and consequences of land degradation
- To identify and understand the constraints and the opportunities available for rehabilitation of degraded lands and the major challenges to be faced
- To highlight experiences and lessons learned in rehabilitation of degraded lands in the Asian region

What is land degradation?

The term 'land degradation' is used widely in different ways. At its simplest, land degradation is the diminution of the biological productivity expected of a given tract of land. Degradation is keyed to human expectations which vary by land use. Indeed, each type of land—farmland , wild land or rangeland, for example—is nothing more than a set of expectations about the form its biota should take. The concept of degraded lands therefore is somewhat subjective, and a condition that constitutes degradation on a particular type of land may be considered normal elsewhere (WRI 1988-89). Typically, however, on degraded land soil is impoverished or eroded, less usable water is available due to increased surface runoff or contamination, vegetation is diminished, reproduction of biomass is lowered and biodiversity is reduced. The diminution that degradation embodies is expressed in many ways, depending on the type of land.

Degraded lands are either inherently unproductive or have been made so due to faulty land management practices. Degraded lands or wastelands rather loosely indicate a variety of deteriorated lands that are degraded due to various natural and biotic hazards and are unfit for productive use, primarily agriculture. In India, wastelands have been defined as degraded lands that have deteriorated for lack of proper soil and water management and can be vegetated with reasonable efforts.

Definitions aside, the fact is that such barren degraded lands/wastelands with little or no vegetation at all cover the landscape as unsightly reminders of past mismanagement of land resources and now pose serious environmental problems.

Rehabilitation, as the word suggests, entails making the degraded land useful to humans again. It seeks to optimise the production of usable biomass of a site. The main purpose is utilisation.

Restoration is much more ambitious, it aims to reinstate entire communities of organisms closely modelled on those occurring naturally (Jordan et al., 1988). Because it strives to optimise the biodiversity of a given site, restoration does not emphasise resource utility.

Rehabilitation makes no pretension about authenticity and admits of no philosophical preconditions favouring native over exotic species. In fact the choice may be economic; conceivably, rehabilitation could convert degraded lands to a completely new use, if that best served human needs (Cairns 1986). Rehabilitation is more relevant to the immediate needs of the people because it emphasises the fact that production can ameliorate hunger, fuel shortages, and poverty.

Are there different stages of degradation?

Degrees of degradation

Degradation may connote different meanings to different people and which land should be considered degraded or not may be debatable. But generally speaking any land that is not supporting its normal wealth of natural resources and is suffering from accelerated depletion and degradation is considered to be degraded land. This could lead to the deterioration and destruction of a particular spot or parcel of land itself ,which could affect adjacent lands and downstream lands. Degraded lands are generally denuded and dry and lose their productivity gradually in the early stages but rapidly later. Soil moisture and water-holding capacity is low. Low infiltration and increased runoff result in loss of nutrients and topsoil followed by rill, sheet, and gully erosion. In the beginning, degradation may be very slight and almost unnoticeable, but, as the decline and degradation accelerates and gains momentum, it can be colossal, chaotic, and irreversible. Degrees of degradation vary very widely from place to place and country to country and observer to observer but, generally, degradation can be broadly classified as follows.

- Pre-degradation/threshold stage

The normal natural state is under immense pressure and resources are being exploited to the uppermost limit of their endurance or carrying capacity or natural recovery. Natural resources are either not in an improvement or decline situation, or are in a *status quo* situation. The situation must not be allowed to go beyond this level. If this stage is diagnosed properly in time as a pre-degradation stage, degradation can be prevented by following appropriate preventive measures. Prevention is better than cure.

- Beginning of degradation or early stages of land degradation

First and early symptoms of degradation start appearing, e.g., thinning of vegetative cover, lowering of organic matter, decreasing soil moisture, hardening of soil, exposure of topsoil, poor regeneration, poor stunted growth, slight disturbance of upper thin layer of topsoil. At this stage, the process of degradation is very slow and if appropriate protective measures are taken degradation can be controlled effectively, easily, cheaply and quickly. 'A stitch in time saves nine' this adage applies fully.

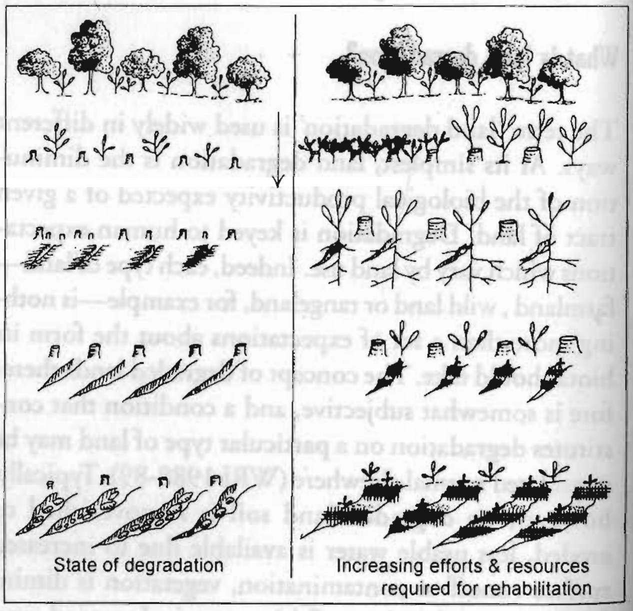
- Medium/moderate land degradation

Degradation is increasing in intensity, vegetative cover is very poor and in the gradual process of disappearing. Production is declining and soil erosion is taking place. Soil depth is diminishing but some soil is still available for plant growth. At this stage rehabilitation is still possible through biological means and vegetative growth.

- Seriously/critically degraded lands

No vegetative cover is visible. Topsoil has been eroded away by severe soil erosion. Plants cannot grow on their own without outside help. Formation of gullies and exposure of parent rock material are evident. The natural resources, particularly the soil, water, vegetation ,and biodiversity have disappeared, and economic and ecological conditions have reached the point of no return. At this stage biological means alone and conventional planting techniques cannot rehabilitate the land. Bioengineering and simple engineering structures for moisture retention and soil formation, and special plantation techniques with suitable plant species, need to be adopted. At this stage, the costs, effort and time needed for rehabilitation are quite high. The chances and degree of success are also much lower than they would have been if rehabilitatation had been undertaken at an earlier stage.The following proverb explains this simply and fully.

For the want of a nail the shoe was lost.
For the want of a shoe the horse was lost.
For want of a horse the rider was lost.
For the want of the rider the battle was lost.
In losing the battle the kingdom was lost
And all for the want of a nail



What is the extent of degradation? What are the major causes?

Land degradation is among the most chronic economic and environmental problems and burdens in the mountainous regions of Asia. In the past, pressures were few and well within the production, carrying capacity ,and restoration ability of the land. But now the demand and removals are heavy and well beyond the carrying capacity of the land. The result is that a vicious cycle of depletion, degradation, scarcity, and poverty is growing bigger and bigger year after year with very few exceptions.

The extent of land degradation and the major causes of degradation are given below in Table 1.

What are the major categories of constraints causing land degradation?

Four major categories of constraints causing land degradation can be broadly characterised as follow.

- **Geophysical:** includes conditions such as rocky outcrops, boulders, gravels in the soil, too steep slopes, salinity, alkalinity, waterlogging, landslides, exposed sites, poor nutrient and moisture conditions
- **Environmental:** includes interaction of rainfall, snow, temperature, erosivity of rain and wind, moisture and nutrient balance, overexposure to radiant energy.
- **Biological:** includes interaction of humans and animals with the resources, pests and diseases, and ecological imbalance.
- **Socioeconomic:** includes attitudes and reactions of the people individually or collectively.

What are the consequences of land degradation?

Land degradation in Asia is causing very serious and alarming consequences. The main pressures and consequences are shown in Figure 1.

Degraded land accelerates soil erosion and valuable topsoil is washed away from mountain slopes and gets deposited in streams, rivers, reservoirs ,and on prime farm lands damaging and destroying them. The costs of repairing, maintaining, and reconstructing them are almost impossible to bear. On degraded lands, a valuable resource—the topsoil—is removed from upstream where it is desperately needed and dumped downstream where it is absolutely unwanted, thus it is doing double damage and is a double disaster.

What are the main objectives and goals of rehabilitation of degraded land?

When degradation can no longer be tolerated the response to the problem is either abandonment and bear

Table 1: The Extent and Major Causes of Land Degradation in the Mountainous Regions of Asia

Country	Extent of Land Degradation	Major Causes of Degradation
Afghanistan	62 % of the land area (39.8 million ha of mountainous area) seriously affected	**Natural Factors** High potential for degradation – steep slopes, unstable geology, short periods of
Bangladesh	7 % of land area (1 million ha of hill area) affected	heavy rainfall, high-speed winds, flooding, drought
Bhutan	35 % of the land area (1.6 million ha of hill area) affected	**Demand Factors** Rapid increase in human and livestock population
China	22 % of the land area (209 million ha) affected	Unsound Management Practices
India	53 % of the land area (17.3 million ha) affected	Uncontrolled and excessive grazing, poor soil management practices, improper forest
Myanmar	2.6 % of the land area (17.6 million ha) degraded	harvesting, unmanaged mining activities, shifting cultivation
Nepal	13 % of the land area (1.8 million ha) estimated to be degraded	**Harmful Practices** Setting fires to forests, environmentally
Pakistan	25 % of the land area (20 million ha) estimated to be degraded	unsound infrastructural activities **Macro-policy-related factors** Land ownership problems, unplanned
Philippines	27 % of the land (8.2 million ha) is degraded	organization, inappropriate land-use practices, lack of environmental protection
Sri Lanka	10 % of the land area (0.7 million ha)	measures in infrastructural development
Thailand	19 % of the land (10 million ha)	activities

Source: Bhatta 1990

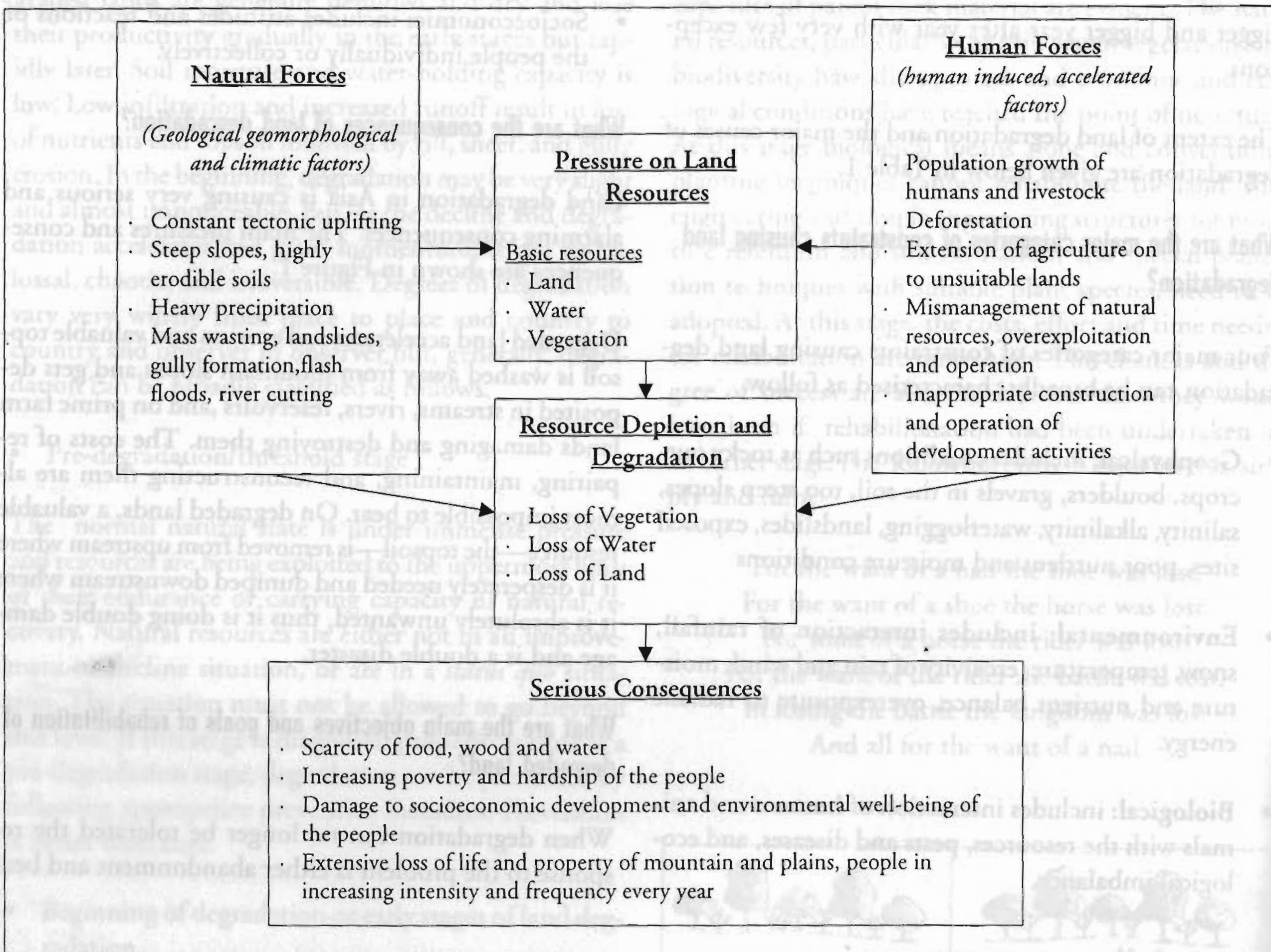


Figure 1: *Land degradation : pressures and consequences*

the serious consequences ahead or assisted recovery or rehabilitation. Abandonment is most prevalent. Short periods of abandonment of temporarily degraded lands ,such as shifting cultivation, nomadic pastoralism and seasonal migration, are practised.

The main objectives and goals of rehabilitation of degraded lands are fourfold

- to halt the depletion, deterioration ,and degradation of the resources;
- to regain and maintain the productivity of the land;
- to ensure sustainability and proper land use; and
- to establish equity in distribution of benefits from rehabilitation of degraded lands.

Fulfilling these four objectives is the key to the well-being of millions of people and sustainable utilisation of natural resources for the present and future.

What are the major challenges?

The major challenges to be faced and solved satisfactorily are as follow.

- How to halt immediately the depletion and degradation of the basic natural resources: soil, water and plants, and the wholesome natural environment; deforestation; soil erosion; nutrient losses; sedimentation; drying up of water springs; flash floods; biodiversity; and valuable environmental losses? How to contain and control the degradation effectively?
- How to rehabilitate the damage done: restore degraded and destroyed forests, rangelands, watersheds, farmlands, waste and barren lands, and restore lost biodiversity and degraded ecosystems?
- How to relieve the pressures on the resources from excessive numbers of people and livestock, bring it down to within the carrying capacity of the land and maintain it and increase sustainable supplies that meet demands?

- How to reduce the demand for and consumption of land-based products, minimise wastage, increase utilisation and efficiency, and adopt suitable alternatives?

- How to correlate removal of resources and their regeneration and develop an effective system so that the regeneration is always more than the withdrawal? How to reorient and equip policy-makers, planners, and implementors to accept concepts and strategies and change their attitudes to work for the above objectives and goals?

- How to optimise and make the wisest use of the existing available resources according to the land capability and resource productivity on a sustainable basis ,combining social needs, compulsions of the poor, and the needs of the environment?

- How to meet the increasing needs of man and animal, achieve economic growth, and alleviate the poverty of the people and raise their living standards while conserving valuable natural resources, fragile ecosystems, and the environment in the mountains? Currently we see a'cut and do not cut', 'exploit and do not exploit' 'use and do not use' 'cultivate and do not cultivate' syndrome, one purpose acting against the other, how to optimise the balance?

- How to increase production and productivity of forests, rangelands, and farms to meet the needs of the people and environment on a sustainable basis?

- How to produce and make available the needed agricultural, forestry, and rangeland products to the people according to their requirements and ensure just and equitable distribution?

- How to generate and enhance income and employment opportunities ,through conservation measures supported and supplemented by primary production systems (crops, agroforestry, pastures, horticultural crops, etc.); secondary production systems (animal husbandry, poultry, pigs, goats, sheep, rabbit rearing, apiculture, sericulture, etc); and tertiary production systems (processing for value-addition of the two) in a symbiotically integrated and developed manner in perfect harmony with the needs of the land, people, and the environment?

What are the major constraints to rehabilitation of degraded lands?

- Natural forces
- Human/induced pressures, development disasters
- Socioeconomic factors
- Lack of awareness and understanding regarding the multiple and long-lasting benefits to be derived from natural resource conservation and serious disastrous consequences of land degradation
- Inappropriate land-use practices and increasing the extension and intensity of cropping
- Policy, legislation, institutional and implementation weaknesses
- Lack of human resource development and mobilisation
- Lack of people's participation, particularly of women and disadvantaged people
- Inadequate and inappropriate education, training, research and extension
- Confusion and uncertainty of land ownership, tenure, use and management
- Lack of financial support and inadequate incentives
- Lack of immediate benefits to farmers and the longer time frame required

What are the major opportunities available for rehabilitation of degraded lands?

Mountainous regions, because of their geophysical richness, location, history and culture, geology, soil, water, agriculture, forestry, pasture, animal husbandry, fauna and flora, scenic beauty, and majesty ,together with vast manpower, hydropower potentials, and, as perennial sources and watersheds of thousands of rivers and streams, can no more be neglected. The people in the mountains and around them are now realising that sustainable development based on a three-dimensional approach—ecological, economic, and sociological—is required to halt depletion and degradation of the resources and to rehabilitate them quickly and effectively. Delays in repairing the damage and preventing injury will be too costly and at times may even become irreversible. In many cases repair might well be beyond the reach and capability of the countries in the region.

The time has now come to learn from experience and to build for the future on the basis of recent developments, knowledge , and new skills. The resources and opportunities available that can be used are as follow.

- The increasing awareness and growing political determination and people's active involvement in natural resource conservation and management
- Existing degraded land with forest, farm, and pasture land potential
- A set of policies and legal measures is being adopted and can be improved upon to act as simple and effective tools for rehabilitation, resource development, and resource management
- A wide range of indigenous and exotic trees, shrubs, grass, crops and other plant species to suit different climatic, soil and environmental conditions which can rehabilitate, protect, and produce required products in increasing volume and serve multiple objectives
- Good biophysical conditions, growing periods, potentials for restoring and increasing productivity and production, hungry consumers of products, and good markets
- A body of science, technology, knowledge and experience, new concepts, practices ,and new skills in participatory watershed management that are being enriched by growing research and development in the region and in the world
- Chances of obtaining local and external financial and technical resources
- Increasing local, national, regional ,and international collaboration and cooperation in rehabilitation of degraded lands, natural resource conservation, management and environmental improvement, closer networking and sharing of experiences through regional/international institutions such as PWMTA, FARM, WATMANET, ICIMOD, RAS, FAO/UNDP, SAARC
- Substantial comparative advantages of mountain specificities, attributes, and niches
- Immense energy of human resources and wealth of natural resources and great diversity
- Economic, land-use, agricultural, forestry and water resource policies, laws , and regulations that could be revised, rewritten, and reformed to meet the needs of the people and the environment and to aim towards wise management and use of natural resources on a sustainable basis through regional and international cooperation to benefit the entire Asian region by using and conserving genetic resources, biodiversity , and majestic mountain ecosystems and fauna and flora as a heritage of mankind and as a scientific and natural asset for present and future generations
- Forestry or agriculture or animal husbandry alone cannot improve the living conditions of the people and halt environmental degradation, therefore integrated resource-use programmes involving agriculture, animal husbandry, horticulture, apiculture, sericulture, and small-scale and cottage industries producing secondary and tertiary value-added products should be undertaken.

Experiences and lessons learned in rehabilitation of degraded lands

Land degradation is not only a local, national or regional problem: it is global. Land degradation in mountain watersheds has become an issue of worldwide concern. Almost 25 per cent of the population of the world lives in the mountain watersheds of Asia and the Pacific region. By some estimates, 27 per cent of the land area has already been damaged—much of it irreparably. Land degradation has inflicted heavy and far-reaching losses of life, property, and the environment in increasing intensities and frequencies year after year. Countries and people, GOs, NGOs and INGOs have realised the seriousness of the situation and are making efforts to address the problem in various ways and at various levels. Despite these efforts the enormity and scale of the problem is so complex and widespread that very few successes have been achieved and the problem remains far from being fully tackled. The rate of degradation far exceeds the rate of rehabilitation. However, there are some encouraging examples of recent concepts, knowledge, practices and skills and successful efforts and experiences in the region that can be cited, studied, and replicated with suitable modifications for creating successes in other parts of the region. Some of these are discussed below.

ICIMOD's and national collaborating institutions' (NCI) experiences in rehabilitation of degraded lands in the mountain ecosystems of the Hindu Kush-Himalayan (HKH) region

Degradation of the mountain environment and poverty of the people in the HKH region have been the focus of much discussion and development interventions. An acute crisis of food, fodder, fuelwood ,and water (too little during the dry season, too much during the monsoon) and a deteriorating natural resource base and biodiversity have been causing serious concern among the people, GOs, NGOs, and INGOs. Realising this, ICIMOD, in close collaboration with national partner institutions of the HKH member countries and with financial support from donors, has been engaged in developing an understanding of the extent of the forces and processes underlying land degradation in order to identify measures for restoring and developing degraded lands using options that are field tested and economically, environmentally, and socially viable; and which are owned and supported by local peoples' close participation. More details can be gathered from ICIMOD. NCIs' project sites and activities can be observed and studied and information updated.

Mountain Resource Management (MRM) Project, Nepal

The Mountain Resource Management (MRM) Project in the Jhikhu *Khola* Watershed (11,000 ha), Kabhre District in the middle mountains of Nepal was initiated in 1989. The project has three components.

- Baseline inventories were established for soils, forestry and agricultural land use, population dynamics ,and socioeconomic conditions. All information was placed into a geographic information system (GIS) for analysis and documentation of resource constraints and environmental degradation.

- An environmental monitoring programme was established to determine the rates of soil erosion, the rates of deforestation, soil fertility decline , and adaptations of indigenous knowledge to hydrology and soil and water management.

- Monitoring and understanding of socioeconomic conditions and relationships between biophysical conditions, soil fertility, and indigenous knowledge.

Steps were also taken to rehabilitate a degraded site and use it as a demonstration site, illustrating how alternative crops, fodder trees, and nitrogen-fixing hedgerows can be incorporated into traditional systems for greater benefits.

Main findings of the project

- Understanding the degradation process is the key to successful rehabilitation of degraded lands. Deforestation, soil erosion, and soil fertility are important biological-physical factors that need consideration.

- The key issues in environmental degradation of a micro-watershed have been identified as water management; soil fertility maintenance; rehabilitation of agricultural land, grazing land, and forest; and soil erosion control.

- Land-use changes were documented between 1947 and 1995 and the results showed that deforestation was significant between 1947 and 1972. Increases in the forest cover have occurred over the past 15 years but the quality of the forest (in terms of biodiversity, standing biomass, and understorey) has declined. Forest expansion—dominated by pine plantations—occurred mostly on intermediate slopes. At the same time, agriculture intensified from an average of 2.1 crop rotations per year to 2.7 crop rotations, and expansion of agriculture has occurred in marginal environments. This expansion occurred at the expense of grazing and shrubland. The former is of particular concern since animal feed was identified as one of the critical resource shortages (Schreier et al. 1991) and hill agriculture is heavily dependent on manure to maintain soil fertility (Shah et al. 1991).

- A significant finding is that between 55 and 80 per cent of the annual loss of soil occurs in two storms, and it is during the pre-monsoon season that the soils are most prone to losses. This was confirmed by the stream flow measures for which the sediment rating curves during the pre-monsoon season were significantly higher than during the monsoon season. Ground cover during the pre-monsoon period is the critical issue controlling soil erosion in upland agriculture in the watershed , and techniques to reduce this risk by alteration of ground cover at the time the first monsoon rains arrive need to be introduced. The soil losses appear to be of significant benefit to lowland farmers with irrigated rice land. The annual sediment input and dissolved nutrients in the water improve the nutrient status of these fields suggesting that poorer upland farmers are losing nutrients to rich lowland farmers.

- Soil fertility problems are widespread. Soils are acidic, low in cations and organic matter, and generally deficient in phosphorous. Since there is considerable litter transfer from forests to agriculture, it was shown that soil fertility in the forest is the poorest, followed by shrub and grazing land. Only irrigated land has a nutrient status that is considered adequate for sustained production, and higher inputs are needed in all other parts of the land-use systems in the watershed.

- Forest degradation cannot be measured effectively by forest cover but needs to include measures of biodiversity, biomass yields, site fertility, and other site conditions. The overall losses of forest land have been substantial and, combined with changes of soil fertility and biodiversity, the current situation is of serious concern in terms of maintaining production capacity and resilience. Major changes in policies were mainly responsible for the creation of a downward cycle.

- Soil erosion is of key importance since agricultural expansion has moved on to marginal lands that are more vulnerable to degradation.

- Active afforestation programmes should focus on degraded areas since they are the greatest cause of sediment transport. They are more effective if they are carried out in the context of agroforestry where nitrogen-fixing trees are planted on terraces between agricultural plots. This provides protection against soil erosion and improves the soil nutrient conditions on these sites and has the potential to improve animal feed production.

The Rehabilitation of Degraded Lands in Mountain Ecosystems' Project

ICIMOD, in collaboration with national collaborating institutions (NCIs) of four member countries (China, India, Nepal and Pakistan), initiated this project in 1992. The main objectives of the project are

- to develop a better understanding of the extent, forces, and processes underlying degradation and
- to identify measures for restoring and developing degraded lands in different mountain ecosystems by using options that are field tested and found to be economically, environmentally, and socially viable.

Table 2: Rehabilitation of Degraded Ecosystems' Project: Countries, NCIs ,and Site Information and Achievements

Country and NCI/ Site Location	Land Area, Land Use, Tenure and People	Achievements
China		
Kunming Institute of Botany, CAS; K.I. of Ecology, CAS; Chengdu Institute of Biology, CAS; Damai village, Baoshan, Yunnan Province Altitude 1,370-1,750 m	45 ha-denuded forest land, community forest, 136 households	Establishment of training and demonstration facilities; better understanding of role of communities and individual landowners in the rehabilitation of degraded lands
India		
G.B.Pant Institute of Himalayan Environment and Development, Arah Village, Almora, U.P. Altitude 1,490 m	9 ha, abandoned farmland 86 households under village *panchayat*	Identification of suitable tree, shrubs, grasses for rehabilitation of degraded lands; cooperation between research agencies, local government, NGOs, farmers; training and extension
Nepal		
Department of Forests, HMGN; forest user groups of two villages; District Forest Office.		
Site I. Godavari, Lalitpur District Altitude 1,550-1,780 m	Formerly government forest land, 30 ha degraded forest/shrubland transferred to ICIMOD for research and training	Various R & D activities are in progress and the site is being developed as a research training and demonstration area
Site II. Bajra Pare and Dhaireni Altitude 900-1,000m	7.8 ha and 15.9 ha denuded forest land, handed over to two forest user groups as community forest	Land-use management plan preparation and implementation; socioeconomic biomass surveys for assessing the status and monitoring changes in future
Pakistan		
Pakistan Forest Institute Sinkyari valley, Manshera District. Altitude 1,400-1,550 m	15 ha abandoned farm land and 18 households' private land	Actual rehabilitation and improvement of biological-physical conditions for demonstration and learning; direct benefit to local user groups and marginal farmers through improved land management practices, soil erosion control, water management and increased production of biomass

Table prepared based on ICIMOD 1993; Pei Shengji et al. 1993

Five field sites were chosen in four countries for this action research project. Countries, national collaborating institutions (NCIs), site-specific information and achievements are given in Table 2.

Major achievements/observations of the project

- Rapid population growth is the main factor causing mismanagement of land and inducing and accelerating land degradation because of very few non-land based income and employment opportunities.
- Meagre land holdings of less than 0.5 ha/capita, poor shallow soils, insufficient manure and fertilizer input, overexploitation of farmland and forest land, and declining production. Scarcity of food, fodder, and fuelwood and poverty of the people forcing them to extend farming on to marginal, highly fragile lands.
- Natural resources ,namely soil, water, and forests, are under immense pressure to meet the daily basic needs of the people. The mountain watersheds are caught in a vicious cycle of high population growth, poverty, underdevelopment—environmental degradation and deteriorating development prospects.
- Inappropriate land-use policies, development policies, tenure arrangements, land laws, customs, traditions ,and practices also have affected land resource conservation and utilisation badly.
- Excessive removal of forest products, excessive grazing, forest fires, deforestation and loss of biomass cover are inducing and accelerating land degradation.
- The scale and dimensions of degradation have been further exacerbated by ecological sensitiveness, natural pressures or fragilities and disturbances. The consequences could be irreversible.

How to cope with the problem of land degradation?

The need for viable options. The issue of land resource management is not just an environmental problem. It can be traced back to basic demographic, economic, cultural, technological, and natural forces. Thus its solutions also lie in the improved sustainable management of available natural resources, efficient and productive farming systems, a rapidly expanding infrastructural base, and expansion of non-agricultural employment opportunities and income generation.

It is usually the small poor farmer, the poorest of the poor, living in the upper watersheds who are suffering most. Given their extremely poor resource base it is very unlikely that they will willingly destroy the very basis of their survival. Then why are they doing it? What are the overwhelming compulsions for deforestation and the extension of agriculture on to marginal lands resulting in degradation? The search for the solution must begin with the mountain farmer. The interest and needs of the farmer; an understanding of the land users' design regarding allocation ,use ,and management of resources; and the users' problems and prospects must be well understood for effective and sustainable management of land resources. Identification of problems, measures adopted for rehabilitation of degraded lands, and the responses and results are summarised in Table 3.

Appropriate approach for rehabilitation of degraded lands. Not only is a biophysical approach required but it should also be economic, environmental, sociocultural, and people-based.

Rehabilitation of ecosystems and their sustainable development—more specifically the sustainable management of natural resources—are closely interlinked, interdependent, and integrated. The interplay of ecology, sociology, economics, anthropology and culture needs to be consolidated for a comprehensive rehabilitation strategy. The ultimate objective of rehabilitating the ecosystem is to manage natural resources in a manner that satisfies current needs as well as allowing for a variety of options for the future. Ecosystem rehabilitation and management are part of a dynamic process and should be monitored continuously to assess effects and impacts; to improve interventions, baseline surveys and monitoring systems should be established from the beginning of the activities.

The land ownership, tenureship, use, and management patterns and the basic resources of soil, water, forest, pasture, and farm land are of great importance. To whom the land and the resources belong—whether it is private, community, religious, government ,or unallocated or any combination of these patterns or confused or disputed ownership—is critical for identifying and designing rehabilitation strategies, approaches and technologies. Generally privately-owned lands are least degraded, followed by community-owned, government-owned, and disputed lands. Owner's, user's or manager's presence and care are vital in preventing, protecting, checking ,and rehabilitating degraded lands. Someone has to be responsible and accountable for the protection and supervision of the resource.

Table 3: Identification of Problems, Measures Adopted for Rehabilitation of Degraded Lands, and the Responses and Results

Problems	Rehabilitation Measures	Responses, Results
Policy and institutional		
1.1 People not involved in resource management. Lack of institutional mechanism.	People's participation from inception to project implementation and post-rehabilitation work. Training and extension of village rehabilitation committee, users' group formed under existing village-level organization. Co-ordination between Forest, Agriculture Departments, Village Committee, people and project.	Local people are the owners, managers and users, and trained manpower. Forest, land-use management plans prepared and implemented.
1.2 Uncertainty of land boundaries, extent, ownership, management and use, current status of degradation not exactly known.	Land areas clearly identified, determined and demarcated on ground and maps prepared. To assess the current status and monitor changes base-line surveys of vegetation, soil, water and socioeconomic surveys of local people undertaken.	Land limits and the land users well defined and determined; current status of resources well known and future changes are positive and are being monitored.
1.3 Resource-use policies, traditions, practices are weak, ambiguous and centrally controlled.	Local people decide about resource-use pattern, intensities, and practices among themselves.	Local resource-use rules, conditions prepared and strengthened.
2. **Biological**		
2.1 Overexploitation of land resources, deforestation, overcutting, overgrazing, forest fires.	Local people decide not to overexploit, overcut, and graze on the site, and fire protection measures taken. Preparation and implementation of forest and land-use management plans.	Forest protection, stall-feeding of livestock and fire protection is greatly helping natural regeneration and growth of plants; forest and land-use management plans are operational.
2.2 Serious soil erosion, difficulty in natural regeneration, very slow growth and high mortality of plants due to serious degradation.	Selection of suitable pioneer, colonising species that naturally grow well on poor degraded sites; nitrogen-fixing species. Sloping Agricultural Land Technology (SALT) and Other Appropriate technology (OAT) with plant hedgerows, trench and ditch planting, plant nursery establishment.	SALT, and knowledge of appropriate species and OAT very helpful.
2.3 Shortage of fodder, fuelwood and forest products, and difficulty in obtaining desired materials.	Seed sowing and plant nursery establishment of the most favoured suitable fodder, fuelwood, multipurpose tree species and grasses.	Availability of choicest seeds and seedlings for planting to meet the needs of the people.
3. **Engineering/ bio-engineering**		
3.1 Scarcity of water during dry season and excess of water during heavy rain causing soil loss, nutrient loss, gully formation and land degradation.	Simple, cheap water ponds and tanks to collect rainwater, irrigation channels, check dams, drainage ditches, vegetative protection belts, shelter belts, establishment. Check dams, silt traps conservation farming techniques, contour cultivation, alley cropping.	Availability of water during dry period improved and damage during heavy rains reduced. Simple engineering and bio-engineering practices very useful and effective.
4 **Economic**		
4.1 Poverty of people, low income, scarcity of food, fodder, water and fuelwood, unemployment	Socioeconomic surveys to assess status and needs of people. SALT/OATs. Models for food and biomass production and income generation. Rabbit rearing, goat husbandry, bee-keeping.	Adoption of SALT and OAT models encouraging. Increase in food, biomass availability, and income and employment opportunities.
4.2 Declining production, slow growth, shortage of fertilizers, manure, and nutrients	Biomass mulching, compost manure, organic fertilizer, biofertilizers. Nitrogen-fixing tree species in SALT and introduction of OAT.	Use of biofertilizers and organic manure and introduction of OATs/SALTs producing good results.

Table 3: Identification of Problems, Measures Adopted for Rehabilitation of Degraded Lands, and the Responses and Results (Cont'd)

Problems	Rehabilitation Measures	Responses, Results
5 **Ecological**		
5.1 Ecological degradation, loss of biodiversity and environmental depletion.	Reforestation, conserving farming practices, increasing vegetative cover and productivity due to soil and water conservation and improving measures ecological equilibrium.	Increased availability of protective and productive plant cover due to better conservation and utilisation of land resources.
6. **Lack of human resource development**	R & D activities, training, extension and demonstration activities.	Human resources development very useful and effective.

Table prepared based on ICIMOD 1993; Pei Shengji et al. 1994.

The impact of land degradation is felt not only in biological-physical terms but it extends deeply into the economy and environment. Rehabilitation ecology has to integrate effectively ecological, economic, sociocultural, and political dimensions of the social processes and perceptions. To achieve long-term environmental benefits and goals for the larger society, immediate and short-term benefits to on-site people must be preferred and given priority to ensure success, sustainability, and local people's fullest participation.

Main strategies for rehabilitation of degraded lands

A three-pronged strategy was adopted.

- Direct interventions on degraded lands (on-site). These consist of adopting appropriate land use, protective and productive activities such as establishing vegetative cover, desired changes in land use, and on-site activities affecting appropriate land use, soil conservation, forest management, agroforestry, etc.
- Indirect interventions. Policy and legislative reforms, population control measures, conservation education, development of suitable technologies, increase in awareness, training, extension, land-use planning, land ownership and tenurial rights, incentives for promoting positive land use and rehabilitation, and disincentives and punishment for inducing and accelerating land degradation.
- Interventions outside degraded land (off-site). These focus on off-farm employment, support and contributions from the lower watersheds and adjacent communities to reduce and minimise negative impacts, and help the affected site and people.

How to rehabilitate? What are the appropriate measures?

Socioeconomic measures: ensuring people's participation for success and sustainability. Awareness arousing by highlighting the problem of degradation and identifying its causes and serious consequences for the present and future generations. The urge and search for solutions must come from the sufferers and stakeholders after they realise that grave consequences result from not solving the problem and bright prospects for a better future proceed from the rehabilitation of degraded lands. People's own initiatives and efforts will ensure success and sustainability of the rehabilitation, maintenance and further development of land-based resources. Another major achievement is that once the people understand about the value of sustainable management they become the custodians of their resources and will safeguard them from degradation in the future. This knowledge is instilled not only in local people but is also disseminated throughout the neighbourhood quickly and effectively. In Nepal, a forest user group (FUG) was formed by the villagers so that they could own and manage their site. 3,000 m of high-density polythene pipe was provided to bring water to the village for a plant nursery and the FUG's drinking water supply. The pipe laying was completely done by the villagers themselves. Forest management plans were prepared and implemented by the FUG with the assistance of the Forest Department and the Project. People participated fully from inception to completion. Similarly, in China and India, local people were involved and land-use management plans were prepared and implemented. Income-generating activities such as bee-keeping, goat husbandry, and rabbit rearing were introduced. The growing of fruit trees, high-value cash crops, and medicinal and aromatic plants was taken up. Socioeconomic surveys were conducted to assess the status, needs, and interests of people and to monitor changes. Training and extension activities were conducted with excellent results of demonstration and dissemination.

Biological measures. Primarily consist of appropriate forestry, agroforestry, agrosilvicultural, silvipastoral, agrosilvipastoral, horticultural, pastoral, and sericultural systems and practices and their combination, adopted for socioeconomic and ecological benefits. These are permanent, sustainable, and cheap but need a longer time frame, better protection , and continuous monitoring and improvement. Biological measures are not only protective but are productive as well and are a growing investment providing economic and environmental benefits for all time.

Biological measures adopted are as follow.

- Biomass surveys and monitoring, studies of indigenous knowledge, useful and suitable species for nitrogen fixing, soil conservation, fodder, fuelwood, timber, multipurpose uses, medicinal and aromatic values, higher-income generation cash crops, fruit trees, flowers, grasses, live fencing, seed collection, plant nursery establishment ,and seedling production
- Species' performance trials, growth records, natural regeneration
- Natural forest, shrubland management practices
- Preparation and implementation of forest, land-use and management plans
- Shelter belts, protection belts
- Natural regeneration enriched by sowing and planting of suitable seedlings of plants, grasses, trees, fruit, growing of crops, crop rotations
- Sloping agricultural land technology (SALT) and other appropriate technologies (OATs)
- Biogas plant installation as an alternative energy source and to reduce pressure on forests
- Bee-keeping for income and better pollination
- Compost manure, fertilizer, mulching, biofertilizer

Simple and cheap engineering measures (including bio-engineering). These consist of simple engineering check dams, gully control structures, walls, water tanks, reservoirs, trenches, drop structures, etc. These are secondary, expensive, and costly to maintain. Use is limited generally, and utility decreases over time. These may be necessary under certain critical circumstances but should not be preferred over biological means.

Simple and engineering structures, including bio-engineering structures established, are as follow.

- Pipelines, water channels for drinking water and irrigation
- Drainage lines to divert and drain excess water safely; also channels and tanks to collect rain water in the ponds for irrigation and livestock use during the dry season
- Check dams and stone walls in gullies, silt traps, use of local materials such as stones, bamboos and indigenous traditional technologies undertaken
- Maintenance of abandoned and damaged terraces

People and Resource Dynamics' Project (PARDYP)

This project evolved from the above-mentioned successful ICIMOD/NCI projects. It builds on the achievements and lessons learned in the past. The goal is to improve the understanding of environmental and socioeconomic processes associated with degradation and rehabilitation of mountain ecosystems and to generate wider adoption and adaptation of proposed solutions by stakeholders.

This project became operational in 1996 on five sites in four ICIMOD member countries. In China, India, and Nepal, research and development activities are being conducted in close cooperation with national collaborating institutions and local people. Summary of the sites, NCIs, and activities is given in Table 4.

Appropriate Technologies for Soil-Conserving Farming Systems' (ATSCFS) Project

The main objectives of the project are the identification, testing, and proving of soil conservation technologies that can reduce soil erosion to an acceptable level (10-12 t/ha/yr), that can maintain soil fertility, and are simple, cheap, effective and acceptable to mountain farmers. ICIMOD, in close collaboration with the national collaborative institutions of six ICIMOD member countries—Bangladesh, China, India, Myanmar, Nepal and Pakistan—and the International Board of Soil Research and Management (IBSRAM) and the Asian Rural Development Foundation (ARLDF), and with financial assistance from the ADB, initiated and implemented the ATSCFS project on ten sites from 1994 to 1997 as the first phase (Table 5). The second phase is on-going. These project sites are now well established and successful examples of soil-conserving farming systems. They are being used as demonstration and training grounds for policy-makers, professionals, and farmers.

Table 4: PARDYP Project: Countries, NCIs, Site Information, Important Aspects and Expected Outputs		
Country and NCIs	Site, information	Important aspects and expected outputs
1. China/Kunming Institute of Botany, Chengdu Institute of Biology, Baoshan Hydrologic Research Survey Station, Baoshan City Bureaux	Xi Zhuang watershed, rural agrarian, patches of degraded lands, extensive area of scrubland and forests	• Research agenda widened • New local, national and international partners to provide specific contributions • A common framework for socio-economic and bio-physical interventions to be developed and systematically implemented
2. India/G.B.P. Institute of Himalayan Environment and Development, Kumaon University, Munch, CHEA, Tea Development Project, Kumaon Development Vikas Nigam, Block Development Council, Village Forest Panchayats	Bheta Gad. Garur Ganga watershed, 2,230 ha, several degraded lands, different land-use patterns	• Well-defined watersheds as study sites • All activities to be implemented under unified methodology. Expected Outputs: • Generation of information in the fields of hydrology, meteorology, soil erosion and fertility
3. Nepal/ICIMOD, HMGN Departments of Forestry, Hydrology, Meteorology, Soil Conservation, Nepal Agricultural Research Council, Tribhuvan University	Yarsha Khola watershed, 5,338 ha, farming, forestry, livestock, different land uses and degraded lands Jhikhu Khola watershed 11,121 ha, farming, forestry, and variety of degraded lands	• Improved understanding of natural resource dynamics in selected watersheds of the HKH • Agronomic initiatives to combat decline in soil fertility • Conservation initiatives to combat soil erosion and land degradation • Improved understanding of the role of communities in watershed management and planning
4. Pakistan/Pakistan Forest Institute, NWFP Agriculture University, District Forest Officer	Hilkot Sharkul watershed, agropastoral subsistence farming, different land uses and degraded lands	• Strengthening partnerships between local, national and international collaborators • Demonsrration, training, and dissemination of results and information for wider application
Table prepared based on ICIMOD 1996, 1997 (b)		

Table 5: ATSCFS Project: Countries, NCIs and Project Locations with Approximate Agroecological Zone and Successes and Achievements			
Country/NCI	Project site, elevation	Approx. agro-ecological zone	Successes/ achievements
Bangladesh/Chittagong Hill Tracts' Development Board (CHTDB)	Alu Tila (CHTDB), 500m	Tropical humid	SALT, OAT adopted by 1,000 families in shifting cultivation areas. Corn and potato yield higher with SALT
India/G.B.P. Institute of Himalayan Environment and Development	Mokochong, Nagaland 400m	Tropical-subtropical humid	SALT, OAT demonstrated and promoted, shifting cultivation farmers interested
China/Chengdu Institute of Biology, Ningnan county	Ningnan county, 1,000m	Subtropical sub-humid dry	29 nitrogen-fixing trees tested in hedgerows, mulberry in between, effective in gully control, soil loss from traditional farming is 6-21 times higher than with SALT
Myanmar/Myanmar Agricultural Service	Lashio, 1,000m	Subtropical humid	SALT models developed
Nepal/ICIMOD Nepal Agricultural Research Council (NARC)	Godavari, 1,500m Mugling, 400m	Warm temperate humid Subtropical sub-humid	16 nitrogen-fixing trees tested and best identified extending on to adjacent sloping farmlands soil loss reduced from 2.8 t/ha/yr to 0.4 t/ha/yr
Department of Soil Conservation, HMGN	Tistung	Cool temperate	SALT/OAT developed
Pakistan/Pakistan Agricultural Research Council (PARC)	Begowal	Dry temperate	Bean yield higher with SALT
Table prepared based on ICIMOD 1994, 1997 (a).			

Lessons learned from the ATSCFS Project

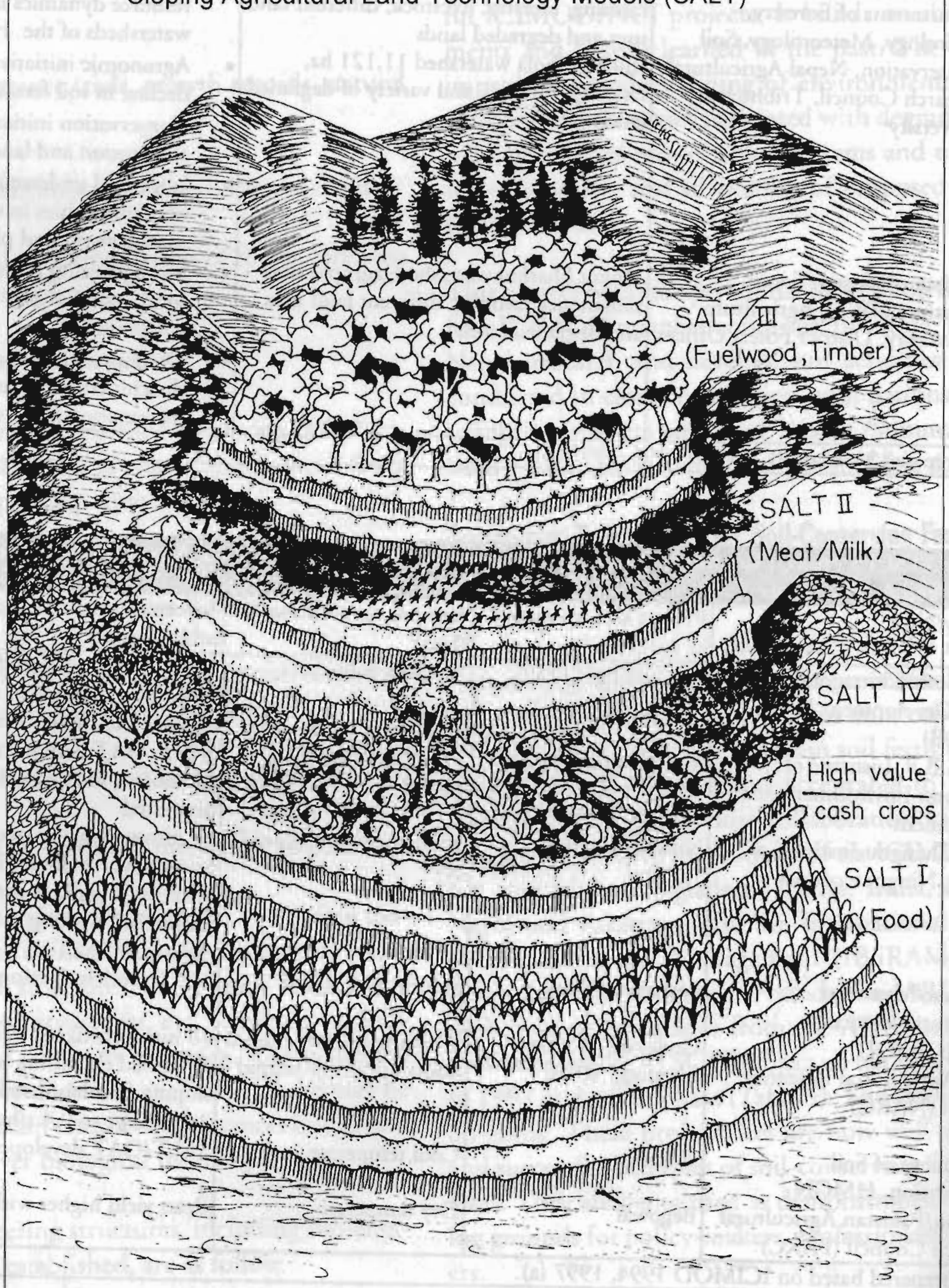
- SALT (Sloping Agricultural Land Technology) agroforestry system using hedgerow barriers of nitrogen-fixing plant species and its various following models are appropriate and suitable for controlling plant species' soil erosion. They also produce food, fodder, and fuelwood, and enrich soil fertility.

Models	Major products
SALT I	Food
SALT II	Meat/milk
SALT III	Fuelwood, timber
SALT IV	High-value cash crops

Combinations of cereal crops, horticultural crops, high-value cash crops, and most suitable nitrogen-fixing tree species (NFT), their planting techniques, pruning size, timings, and intensities have been determined. Runoff has been controlled and soil erosion reduced, infiltration increased. Increases in organic manure, moisture holding capacity of soil increase in nutrients particularly nitrogen, phosphorus, and potassium.

- **Other appropriate technologies (OATs) were the following.**
  - Polythene film technology
  - Water harvesting and management, irrigation and proper drainage

Sloping Agricultural Land Technology Models (SALT)



Mulching, compost-making, effective micro-organism (EM)
Biofencing/live fencing, appropriate species identified
Urea molasses block
Goat husbandry
Rabbit rearing
Bee-keeping
Protection belts/shelter belts
Fish farming
Duck raising
Pig raising
Floriculture

- Water has been identified as a key factor in all aspects of sustainable mountain farming systems. Both excess and scarcity of water is harmful and damaging. Safe passage and harvesting during excess to be used for scarcity period adopting local materials in simple, cheap, and environmentally friendly technologies are most useful and successful.

- Technologies for seed collection, storage, germination, and plant nursery techniques and plant propagation methods developed and used.

- Dissemination of knowledge and information through workshops, seminars, demonstration, training, literature, and video films from the grassroots' level to professional policy level undertaken. Farmer households, village level, country, national, regional and international institutions, GOs, NGOs, INGOs and other agencies and institutions all participated.

- Based on the success and achievements of the first phase of the project (1994-97) the second phase (1997-2000) has been extended to substantiate the preliminary research results and expand the demonstration, training ,and extension component.

- Better understanding of lowland and upland linkages/interactions/issues and appropriate action

- Policy and legislative improvement and implementation—institutional development and sectoral linkages

- Introduction of the concept and practice of conservation farming systems to minimise soil erosion, conserve moisture ,and improve productivity by water, soil and plant management.

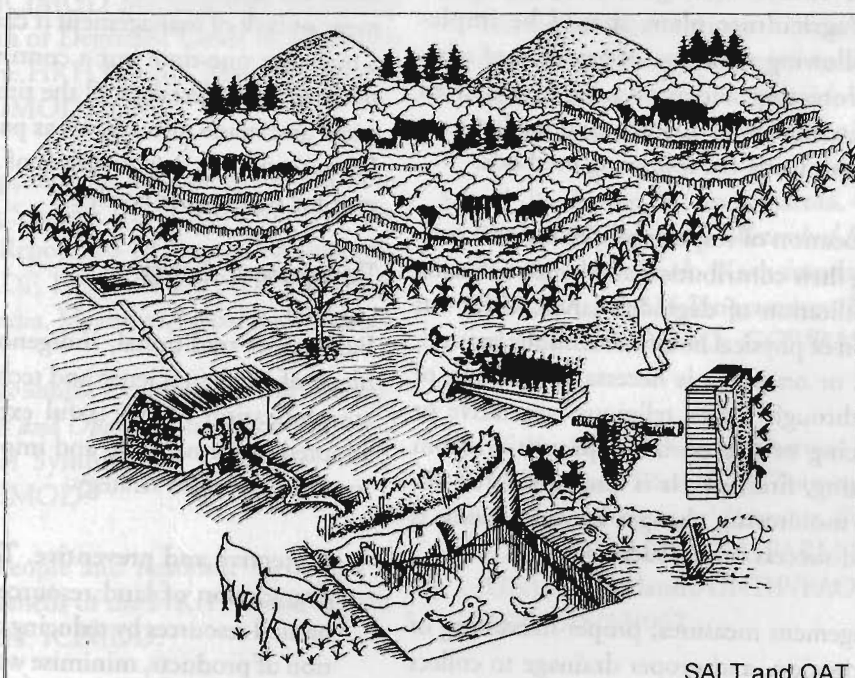
- Improving education, training, research, and extension.

- Human resource development and fullest mobilisation

- People's active participation and greater involvement of women and disadvantaged people

- Holistic, participatory integrated watershed management approach

- A complete production-cum-conservation farming package for the mountain farmer comprising appropriate means, materials, tools, and technologies for delivering socioeconomic and environmental benefits to increase land value



SALT and OAT

Key steps for rehabilitation of degraded land

1 The first step is to examine the historic events that led to the degradation, consider carefully the various constraints and assess the role of various processes in degradation. Analyse, diagnose and identify the main constraints and their importance.

2 The second step is to investigate the attitude and responses of local people regarding rehabilitation of degraded lands, and their interest, needs ,and commitments towards it. Clear identification of people involved and the determination of the area of degraded land must be established. Land ownership, tenurial rights, management, uses, people's cooperation in terms of protecting the land from cutting, grazing and fires, and maintenance and operation of plant nurseries, etc must be agreed upon.

3 The next step is to study and evaluate the effect of past rehabilitation measures taken, if any, their failures or successes, and people's experience and suggestions for improvement.

4 After the local people agree fully and decide to rehabilitate the degraded land the programme can commenc with a reasonable degree of success. Quick economic gains will be attractive to the people along with long-term social and environmental benefits.

5 After ensuring the commitment of people's fullest participation the rehabilitation programme should be prepared and implemented. Land-use management plans, forest management plans, and agroforestry/agriculture plans should be implemented by following a package of practices of rehabilitation, protecting and producing the desired bioproducts in increasing quantity and quality on a sustainable basis using the following methods.

- Clear-cut allocation of responsibilities of local people regarding their contribution and benefit-sharing in the rehabilitation of degraded lands. Clear-cut determination of physical boundaries on the ground, on the map, or on paper is necessary. Securing of boundaries through social, religious, vegetative or physical fencing or flag posts for protection from cutting, grazing, fires, etc. It is also useful for observing and monitoring changes because seeing is believing and success breeds success.

- Water management measures, proper harvesting of water for irrigation, and proper drainage to collect and drain excess water.

- Soil conservation measures.

- Vegetative conservation measures

- Construction of simple and cheap engineering and bio-engineering structures if needed.

- Selection of appropriate land use, forestry, agroforestry, agriculture or a combination of these to suit the land capability and the people's interest and needs. Indigenous species are more suitable than exotics because of certainty, sustainability and global biodiversity.

- Application of soil amendments to enhance growth

- Seed collection, storage, establishment of plant nursery, seedling production, seed sowing, planting, maintenance, protection and management

- Appropriate technologies: sloping agricultural land technology (SALT) and other appropriate technologies (OAT) can be adopted.

- Maintaining and improving the productivity of land and ensuring sustainable supplies— fair and equitable sharing of benefits by the stakeholders for success and continuity.

Conclusions and recommendations

Degradation and rehabilitation are not static or fixed but are dynamic and changing. With proper management the situation can improve and with mismanagement or lack of management it can deteriorate. It is not a one-shot one-time but a continuous and regular activity to be undertaken all the time. It should be inculcated and made into a habit as part of the customs, behaviour, culture, and practices of mountain people forever for sustainable results.

Three-pronged strategy

Full use of traditional, indigenous knowledge with a blend of modern science and technology and appropriate replication of successful experiences needs to be adopted in formulating and implementing the following three-pronged strategy.

- **Protective and preventive.** To protect and prevent degradation of land resources reduce pressures on natural resources by reducing demand and consumption of products, minimise wastage, utilise resources efficiently and adopt suitable alternatives. Follow the maxim 'prevention is better than cure'. Do not allow degradation.

- **Rehabilitative and curative.** Rehabilitation of the damage done to degraded land resources—soil, water, plants, ecosystem and biodiversity—by adopting appropriate measures and treating the wounds on time. Early treatment is cheaper and quicker, the response is better and the results are more successful. Remember the maxim 'a stitch in time saves nine'.

- **Productive and sustainable.** Increase productivity and production in a sustainable manner for economic and environmental gains.

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Agroforestry in Participatory Integrated Watershed Management

Tang Ya

Objectives

- To understand the role of agroforestry in PIWM and discuss various agroforestry systems, their practices, advantages and disadvantages
- To identify most suitable practices and incorporate them in PIWM

What is agroforestry?

Various definitions of agroforestry have been proposed. FAO (1996) defines agroforestry as 'the deliberate growth and management of trees along with agricultural crops and/or livestock in a system that aims to be ecologically, socially and economically sustainable'. Or simply as the 'integration of trees with farming systems'. But the widely accepted one is developed by ICRAF (1982) as 'agroforestry is a collective name for all land-use systems and practices in which woody perennials are deliberately grown on the same land management units with crops and/or animals. This can be either in some form of spatial arrangement or in a time sequence. To qualify as agroforestry, a given land-use system or practice must permit significant economic and ecological interactions between the woody and non-woody components'.

From the definitions it can seen that agroforestry encompasses all ways that trees and shrubs, intentionally integrated into agricultural land-use systems, provide tree products and protect, conserve, diversify, and sustain vital economic, environmental, human and natural resources. It has the potential to provide stable increases in and diversification of income sources, improved environments, and reduced risk of economic failures. The potential of agroforestry to provide simultaneously economic, environmental, conservation and social benefits to agroecosystems has been widely recognised.

A key principle in agroforestry is 'working trees' — the right trees and shrubs planted in the right place to do a specific job. Therefore the choice of tree or shrub species is an important concern in agroforestry.

What are the main aims of agroforestry?

The main aims of agroforestry are

- increased productivity and income,
- improved equity in benefit sharing,
- sustainable use and management of soil, water, forests and other natural resources, and
- sustainable environmental management.

Why is agroforestry important in participatory, integrated watershed management?

Water and wind erosion, excess nutrient and pesticide movement, declining fertility of farmlands, lowland productivity, lack of biodiversity on farms, and lack of active participation of local people in watershed management have become major problems for sustainable development in mountain regions.

Agroforestry can address these problems in the following three ways.

- Rehabilitation of degraded lands by conversion to alternative production agroforestry practices such as alley cropping, contour hedgerow systems, tree/pasture systems, fuelwood plantations, etc.
- Protection of sensitive lands by integration of windbreaks, riparian forest buffers, and other conservation agroforestry practices.
- Motivation of local people to participate actively in watershed management by increased income, combination of short-term and long-term benefits, and improved environments.

Since agroforestry combines agriculture and forestry technologies to create more integrated, diverse, productive, profitable, healthy, and sustainable land-use systems to meet the economic, environmental and social needs of people, it has the potential to improve agricultural productivity, diversify and increase farm income, conserve land, maintain biodiversity and contribute to poverty reduction.

Earlier afforestation/reforestation activities did not take local people's needs into sufficient consideration and lacked a combination of long- and short-term benefits. This probably explains why most governmental and non-governmental afforestation/reforestation programmes did not fulfill expectations. The introduction of agroforestry in PIWM will contribute to the sustainable use of soil, water, forests and other natural resources and improve the livelihoods of the people.

How many types of agroforestry system are practised?

Agroforestry practices are highly diverse and complex. They are classified on the basis of structure, function, agroecological and environmental adaptability, socio-economic and cultural characteristics, and management practices. Most agroforestry practices can be classified within the following major systems.

- Agrosilvicultural systems
- Agrosilvipastoral systems
- Silvipastoral systems
- Silvipisicultural systems
- Agrosilvipisicultural systems
- Silvi-medicinal plant farming systems
- Agrosilvi-medicinal plant farming systems

Some examples of each major agroforestry system are listed in Table 1.

What are the most suitable agroforestry practices for PIWM?

Agroforestry practices are diverse and vary in different regions. For the purposes of PIWM the following agroforestry systems may be used.

- Contour hedgerow systems
- Windbreaks
- Riparian forest buffers
- Multipurpose plants-crop systems
- Tea-nitrogen-fixing woody plants' systems
- Forest-cash plants' systems
- Mulberry-fishery systems

Contour hedgerow systems

Contour hedgerow systems are an agroforestry concept using single or double hedgerows of nitrogen-fixing trees or shrubs planted very densely along contour lines, with crops grown in the alleys between the hedgerows. The trees or shrubs include various nitrogen-fixing and multipurpose species.

Benefits of hedgerow systems

- Reduce water and wind erosion
- Improve crop production
- Improve soil fertility
- Provide supplemental income
- Provide wildlife habitat and corridors
- Provide aesthetic diversity

Table 1: Major Agroforestry Systems and Examples of Agroforestry Practices

Major agroforestry systems	Example of agroforestry practices
Agrosilvicultural systems	Shifting cultivation, *taungya* system, tree garden, alley farming, contour hedgerow system, multipurpose plants and crops system, windbreak, soil conservation hedgerows, fuelwoods and crops
Agrosilvipastoral systems	Home gardens, woody hedges for browse, mulch, green manure, soil conservation.
Silvipastoral systems	Fodder and crops, living fence of fodder trees and hedges, trees and shrubs on pasture.
Silvipisicultural systems	Trees and fishing farming.
Agrosilvipisicultural systems	Trees, crops, livestock and fishing farming.
Agropastoropisicultural systems	Sericulture and fishery system.
Silvi-medicinal plant farming systems	Woody plants and medicinal farming.
Agrosilvi-medicinal plant farming systems	Woody plant, crops, and medicinal plants farming.
Others	Apiculture with various woody plants.

Source: Air 1987, with modifications and additions

Considerations in contour hedgerow systems

Species to plant: In this system, the best plants are nitrogen-fixing woody plants that are fast growing and multipurpose. Planting more than one species in the hedgerows reduces risk from disease and insects.

Width of tree strips: Most contour hedgerow systems use double rows of trees or shrubs to control soil erosion efficiently and provide sufficient fresh biomass to improve soil fertility. Single row hedgerows will also function well if improvement of soil fertility is not a priority.

Space between strips: Widths of the hedgerows are determined by slopes and management options. Sufficient room must be allowed for crop strips. Studies show that a width of 4-6 m is reasonable for agricultural land, while 8-12 m is fine for cash plants' cultivation on sloping lands.

Orientation of strips: As indicated by its name, contour hedgerows of nitrogen-fixing plants should be planted on the contour to control water erosion.

Windbreak systems

Windbreaks are vegetative barriers of sufficient height to create a windless zone to their leeward or protected side. These barriers typically reduce open field wind speeds by 20 to 75 per cent at distances of up to 10 times their height. The effects of windbreaks are many and overwhelmingly positive. Benefits are as follow.

- Increasing income
- Increasing crop yield
- Conserving soil and water
- Protecting livestock
- Improving water quality

Riparian filter strips

Riparian filter strips include water-loving trees and other plants that grow near the banks of streams, rivers and lakes. Riparian vegetation is not only luxurious and beautiful but it plays many important roles in the ecosystem. A riparian filter strip may be natural or planted but it can offer generous benefits in return for minimal expense and care. A healthy riparian strip is evidence of wise land management.

The benefits of riparian trees are as follow.

- Yield wood products
- Reduce floods, erosion and bank cutting
- Trap nutrients and enhance aquatic environment
- Provide home for wildlife and enhance biodiversity conservation
- Store water

Multipurpose plants-crop systems

These are widely distributed and diverse and include numerous practices. Multipurpose plants include mainly fruit/nut trees, medicinal plants, tea, rubber, nitrogen-fixing plants. They are grown on farmlands or farm boundaries or separate woodlots for various purposes.

Benefits of the system are as follow.

- Increased income
- Combination of long-term and short-term benefits
- Stable income sources
- Improved environments
- Help conserve biodiversity

Considerations

- Appropriate space between multipurpose plants and crops
- Avoidance of biologically negative effects between plants and crops, e.g., few plants grow well under walnut trees
- Appropriate management to minimise competition

Some practices of this system include fruit/nut trees - crops; fodder trees- crops; timber trees- crops; mulberry trees- crops; and medicinal plants-crops.

Woody plants -cash plants' system

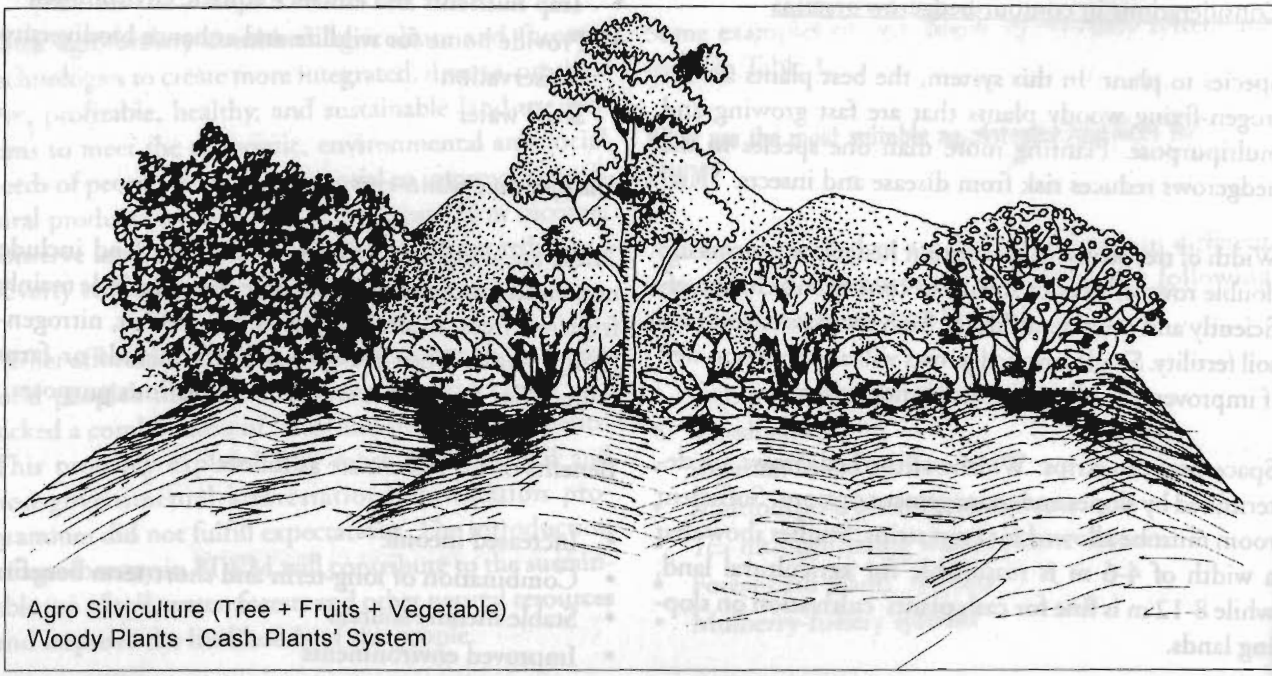
Woody trees or shrubs are planted for timber, shade, fodder or other purposes, and cash plants are grown beneath them in the forest. This may be a multistrata (tree/shrub/grass) structure.

Benefits of the system are as follow.

- Increased income
- Improved environment/climate
- Water and soil conservation
- Habitats for natural enemies of pests
- Wildlife and biodiversity conservation

Considerations of the system are as follow.

- Selection of marketable plants
- Others similar to the above systems


Agro Silviculture (Tree + Fruits + Vegetable)
Woody Plants - Cash Plants' System

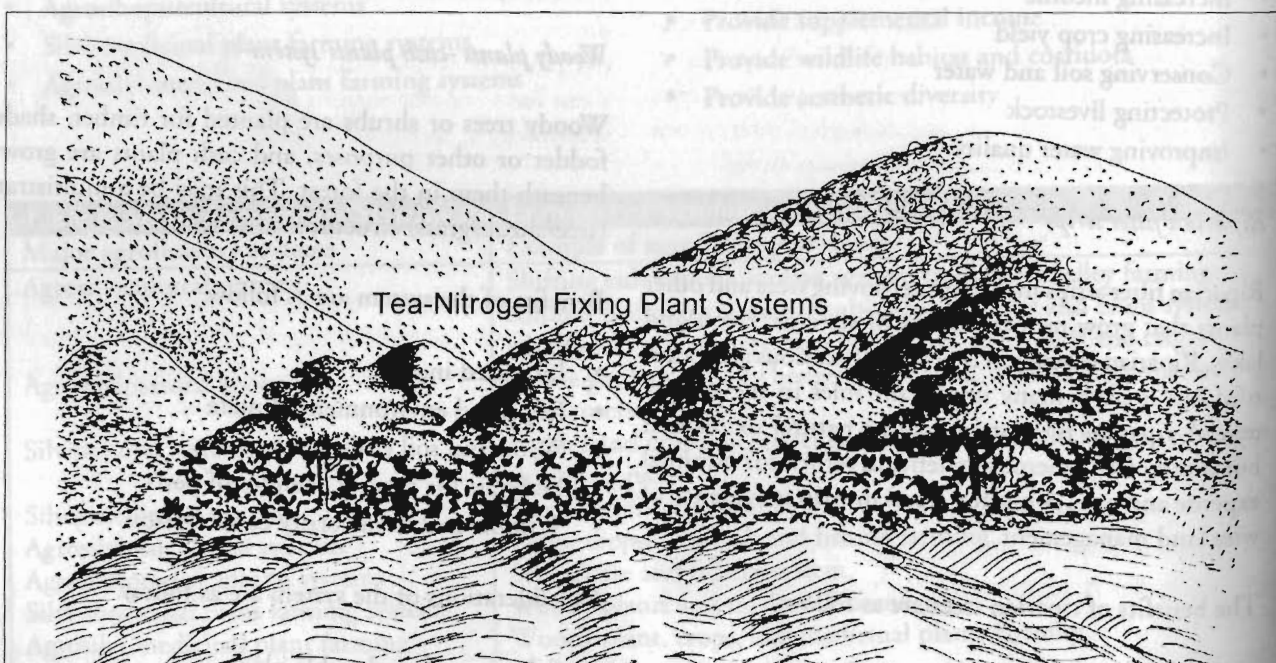
Some practices of the system include medicinal plants in Chinese fir forests; tea and other cash plants in rubber plantations (cash plants may include pepper, coffee, pineapple, cardamom, etc); cardamom in *Alnus nepalensis* forests; vegetables in *Paulownia* forests; medicinal plants in *Paulownia* forests; and ginseng in forests.

Tea-nitrogen-fixing plants' system

Tea production is a key economic activity for many Asian countries and many types of tea plantation have been developed, of which several are good agroforestry practices. In the system, nitrogen-fixing plants are sparsely planted in the tea plantation, mainly for shade. However, the nitrogen-fixing plants are also soil fertility improvers.

Forest farming

Forests are an important component of watersheds. As well as providing economic and ecological benefit to people, natural or planted woodlands also provide life-giving essentials for wildlife.


Tea-Nitrogen Fixing Plant Systems

Food: Woodlands produce seeds, berries, leaves, grasses, nuts and fruits, all of which can be food for different wildlife species.

Living space: Although some species will cover a large territory in their daily activities, woodlands provide places for nesting, brooding or rearing their young.

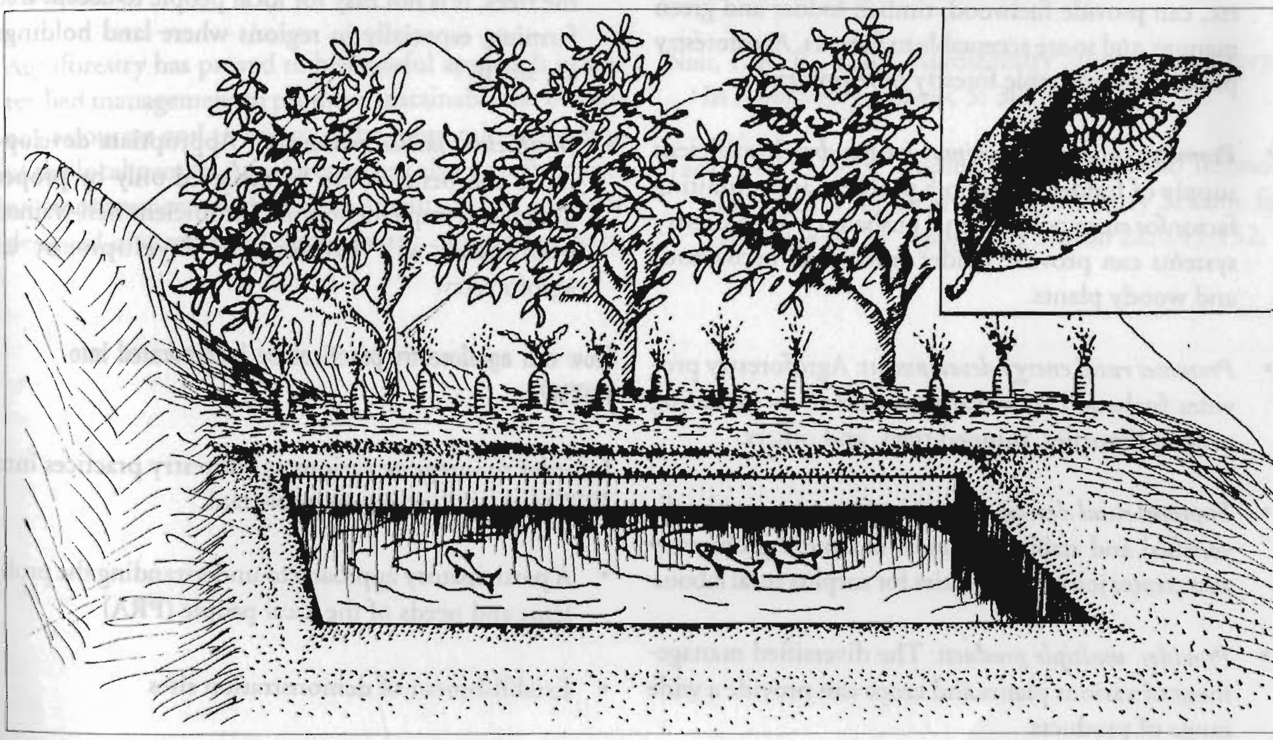
Cover: Trees and shrubs provide shelter and protection from predators, cold winds and snow, and summer heat.

Water: A nearby stream or pond can be an important source of water for birds and animals.

Woodlands in a watershed can also be used to produce food, vegetables, mushrooms, medicinal plants and others items. Because biodiversity has been declining due to habitat loss, the forests and woodlands can be managed for wildlife protection in the following ways.

Mulberry and fishery systems

This is a system in which mulberry trees are planted on farmland and crops or vegetables are intercropped. Mulberry leaves are fed to silkworms. The silkworm excrement and silkworm chrysalis are used to feed fish. After consummation by the fish, sediments in the fish pond are used to fertilize mulberry trees.



Mulberry tree plantation — fuelwood (pruned branches) 10,000-15,000 kg/ha/yr

|

Mulberry leaves (22,500 kg/ha/yr)

|

Silkworm — cocoon

|

Silkworm excrement (11,250 kg/ha/yr)

|

Fish (1,406 kg/ha/yr)

|

Fish pond sediments (249,000 kg/ha/yr) (N 1021.5 kg/ha/yr)

|

Mulberry tree plantation for sericulture and multiple benefits established.

In this system, food crop yield is 25-50 % higher than in a monoculture system. The fish yield is 1,500 kg higher than from a pure fish pond.

Source: Li and Lai 1994

What are the benefits of agroforestry in PIWM ?

- *Promotes sustainable agricultural development*: Many agroforestry systems ,such as windbreaks, tree and crop intercropping, and contour hedgerow systems, promote sustainable agricultural development. This can be achieved by improving habitat, conserving soil, improving soil properties, enhancing crop yield and reducing risk.

- *Promotes sustainable forestry development*: Pure afforestation/reforestation programmes have their limitations and usually are not acceptable to farmers. Inclusion of tree planting on farmlands or on farmland boundaries, tree and food/cash crop intercropping, etc, can provide fuelwood, timber, fodder and green manure, and so are acceptable to farmers. Agroforestry promotes sustainable forestry development.

- *Promotes sustainable animal husbandry*: Insufficient supply of fodder has been a problem and a limiting factor for sustainable animal husbandry. Agroforestry systems can provide fodder from both herbaceous and woody plants.

- *Promotes rural energy development*: Agroforestry provides fuelwood from various sources — including pruned branches, thinned trees, and others.

- *Improves rural development*: Agroforestry provides diversified and stable sources of income. Agroforestry also creates job opportunities for surplus rural labour.

- *Provides multiple products:* The diversified management of various plants and crops can provide a wide range of products.

- *Improves environment:* Agroforestry systems can improve the environment by sequestering and biodegrading excess nutrients and pesticides through biological and mechanical processes, by conserving soil and water, and by moderating micro-climates to avoid extreme situations.

- *Diversify habitats for wildlife and humans and help conserve biodiversity*: Various plants in agroforestry systems provide diversified habitats for wildlife and this will have a strong impact on biodiversity conservation.

What are the limitations of agroforestry practices?

- *Labour intensive*: Managing a diverse and complicated agroforestry system needs more labour compared with simple crop cultivation. This will hinder development in areas where labour supply is a problem.

- *Competition between trees and crops*: As an integrated system, competition for sunshine, water and nutrients is present between tree plants and crop plants. It is important, therefore, to select appropriate tree species with minimum competition with crops.

- *Low benefit in the first few years*: Crop yields may be low in the first few years due to competition, although the total benefits of agroforestry systems in the long run are much higher than in monocultural systems. Since it can take a long time to benefit from the trees, it is not easy for local people to accept tree farming, especially in regions where land holdings are small.

- *Insufficient skilled manpower*: Appropriate development and benefits can be achieved only by proper design and implementation. Insufficient well-trained manpower will hinder the development of agroforestry.

How can agroforestry practices be incorporated into PIWM?

In order to integrate various agroforestry practices into PIWM the following are important.

- A participatory approach to understanding the problems and needs of the local people (PRA)
- Establishment of demonstration sites
- Enhancement of education and training on agroforestry
- Appropriate extension programmes

What are the future directions?

Research: A pervasive barrier to agroforestry acceptance and extension is a lack of information on the tangible and intangible benefits of agroforestry to farmers, the ecosystem,and the public. Like any other conservation/land-use practices, agroforestry must be justified in terms of costs and benefits. Research programmes should be designed and conducted to obtain more information.

Training and education: As a relatively new discipline, agroforestry should be introduced to agricultural and forestry education systems as a formal subject, and informal training courses should be organized on specific agroforestry systems for technicians, extension workers, and farmers.

Capacity building: International and national organizations should work together to train enough personnel in the fields of research and extension.

Establishment of watershed-level demonstration sites: 'Seeing is believing' is the best way for extension and acceptance of agroforestry practices. In this regard, demonstration of various agroforestry practices should be a priority in watershed management programmes.

Conclusion

Agroforestry has proved to be a useful approach in watershed management to promote sustainable use of various resources and to improve the economic well-being of the local people. Agroforestry has also a great impact on improvement of the environment. When properly designed and managed, agroforestry can provide various benefits and has the potential to meet environmental and socioeconomic requirements.

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MODULE 2.3

Bio-engineering Practices for Soil and Water Conservation

Mohan Wagley

Objective

- To provide an overview of the concepts, knowledge and practices in bio-engineering technologies, and to highlight the low-cost and sustainable measures used for combatting watershed degradation processes

Definition

Bio-engineering connotes different things to different users and implementors. However, in general, the term bio-engineering is used to mean a technique in which living vegetation, either alone or in combination with non-living plant materials, or soft engineering structures are used to stabilise and protect slopes from erosion and landslides. In other words, bio-engineering practices are the integration of vegetative methods with normal engineering practices in order to protect the land. Terms like bio-engineering, vegetative engineering or vegetative structures are used synonymously.

Why bio-engineering practices in PIWM?

Past experience and knowledge from erosion and landslide control programmes have led us to believe that engineering practices alone are not always the solution to problems of slope stabilisation. In many cases, engineering practices are expensive and need high levels of skill and technology that are not always affordable by the users and implementors. Living vegetation can be used for their engineering, hydrological and ecological properties.

What are the functions of bio-engineering practices?

Vegetation or plants used for bio-engineering can be woody and non-woody. Both woody (trees, shrubs, bamboos) and non-woody (herbs and grasses) plants perform engineering, hydrological, and ecological functions.

Engineering function

Engineering functions of plants resemble the functions that civil engineering structures provide to support and protect the slope. These engineering functions of plants are as follow.

Catch - Process for holding a thin layer of moving soil particles and debris by multi-stemmed shrubs and bamboos.

Armour - process for protecting soil surface and soil particles from movement by providing protective cover (grass carpets).

Reinforce - mechanism for providing strength to bind the soil particles by densely rooted trees and grass.

Anchor - process for firmly fixing the soil particles and debris by the anchoring action of deep, long and strong roots of trees and shrubs.

Support - mechanism for providing support to soil mass and rocks from the mechanical action of the root systems of plants.

In bio-engineering systems, vegetation provides additional strength to the engineering structures with which they are integrated. Vegetation and engineering structures, if used in combination, co-exist and are compatible.

Hydrological function

The multiple stems and trunks of bio-engineering plants trap soil particles and debris moving down the hill slope. Root systems bind and hold soil particles, rocks and debris and reduce the rate of erosion and landslides.

Hydrology is important for slope stabilisation and erosion control. Vegetation plays a major role in manipulating the hydrological regime by changing the quantities of water circulating from land and water bodies to the atmosphere. Vegetation influences elements that are responsible for enhancing erosion and landslides. These elements are

- interception,
- leaf drip,

- stem flow,
- evaporation,
- transpiration,
- infiltration,
- soil water storage, and
- sub-surface flow.

Vegetation intercepts raindrops and protects the ground surface from the direct impact of falling rain. Leaf drip and stem flow reduce the velocity and direct impact of raindrops. Water evaporates from the leaf surface and some water is stored in the canopy and stems. Vegetation loses water from the surface of leaves through transpiration. Vegetation decreases surface runoff and overland flow and increases the infiltration process, soil water storage, and sub-surface flow.

Ecological function

Unlike engineering structures, bio-engineering performs an ecological function by tranforming the harsh environments of degraded slopes into better ecological conditions. Bio-engineering improves soil and moisture conditions, which, in turn, generate better micro-environments for the establishment and growth of plants, micro-organisms, and small animals. It also helps increase the biodiversity of the site.

What are the common bio-engineering techniques?

Various bio-engineering techniques can be used depending upon site conditions and availability of resources. Possible combinations or integration of vegetative methods with light and small-scale engineering structures are endless. However, some techniques that are commonly used are follow.

Planting trees, shrubs and grasses. Trees, shrubs and grasses can be planted on degraded slopes, either alone or in combination. A dense network of roots in the soil and a canopy overhead helps to protect the slope from erosion. Methods of planting should be selected depending upon the purpose, site condition and availability of resources. However, on hill slopes, contour line planting at regular intervals is the general practice.

Planting stumps/woody stems. Stump cuttings or woody vegetation can be planted along the contour to trap soil particles and debris falling down the slope.

Seeding grass, trees and shrub. Seeds of grass, trees and shrubs can be sown directly on site either alone or in combination. Methods and timing for seeding depend upon site condition and availability of resources. Seeds can be broadcast to cover large areas in a short time and at a low cost. This method can be used on steep, rocky and unstable slopes where seedlings and cuttings can not be planted directly.

Bamboo/amliso-broom grass (Thysolena maxima) planting. Rooted-culm cuttings, rhizomes and wild seedlings of bamboos and *amliso* can be planted directly on slopes. Bamboo and *amliso* perform slope stabilisation work effectively once they are established.

Wattling. Bundles of live branches with buds are put into a trench along the contour and covered with a thin layer of soil. When the branches put out roots and shoots a strong vegetative barrier is formed that is effective in holding soil particles moving down the hill slope. This technique is not popular since it is expensive and works only on gentle slopes.

Brushwood check dams. Brushwood check dams using bamboo and wood are commonly used to stabilise gullies on slopes. After the construction of check dams, grass and shrubs are planted on side slopes and on the gully head.

Vegetated rip-rap. Side slopes of gullies and gully beds are sometime protected by constructing dry stone walls and then grass seeds are sown or planted in the gaps between the stone in order to reinforce toe walls and gully beds.

Loose stone and gabion check dams. Construction of loose stone and gabion check dams is very common for stabilising slopes. After the construction of check dams, seedlings of trees, shrubs and grasses are planted either separately or in combination on gully heads, side slopes, gully beds, and in and around the structure for reinforcement.

Brushwood embankments/spurs. Construction of brushwood embankments and spurs helps to protect stream banks from erosion. Bamboo and wood are used to construct the embankment and spurs. On the backside of the structures, trees, shrubs, grass seedlings or woody cuttings are planted to provide vigour and anchorage to the brushwood structures. These techniques have shown effective and promising results in the torrents and small rivers of the *Churia* and *Terai* regions.

Jute netting. jute netting is another way to protect the slopes using grass slips or seedlings. This method can be useful on steep and hard slopes where establishment of vegetation is difficult. Although this method is expensive it is commonly used in Nepal. Results have not been evaluated yet.

Lifespan/longevity of bio-engineering systems

In bio-engineering systems, soft engineering structures and vegetation should be integrated. This is because soft engineering structures are temporary; they loose strength over time and re-construction is always necessary. However, vegetative structures are permanent once the plants are established. Plants will reproduce and rejuvenate. If there is no human interference vegetation serves its bio-engineering purposes permanently.

Selection of appropriate plant species for bio-engineering

The correct selection of suitable plant species is essential for the success of bio-engineering practices. Identification of engineering function and structural characteristics of the plant is required before selection for bio-engineering. The following criteria should be taken into consideration while selecting the plants suitable for bio-engineering.

- Purpose, site condition and local situation
- Physical and climatic factors
- Engineering function required
- Bio-engineering techniques required
- Structural characteristics of plants
- Availability of planting materials
- Identification of various alternatives (species choice, methods, etc)

Selection of plants should be based on careful studies of engineering functions such as armouring, anchoring, reinforcing, matting, etc and the structural characteristics of plants such as size, shape, form and structure of leaf, canopy, stem, root, etc.

General characteristics of degraded land are a low level of soil nutrients, stoniness, drought and harsh environment. Plants selected for bio-engineering should be able to withstand these stresses. They should

- establish rapidly,
- grow vigorously,
- have dense and deep root systems,
- resist drought,
- propagate easily,
- resist insect and diseases, and
- withstand harsh environment.

The most suitable plants are usually pioneer/xerophytic species, leguminous species and local species.

How to plan and manage bio-engineering programmes?

Planning bio-engineering programmes is complex. It needs careful study and design of both vegetative and soft engineering techniques. The interaction and interrelationship of these two techniques in terms of time

and space and their primary and secondary functions should be well understood. Planning aspects such as application, site condition, technical requirements, geographical circumstances, scope of benefits, cost sharing, participatory mechanism, resource availability, human interference, etc should be assessed. The following also need to be considered.

- Causes of instability and consequences
- Outline of landslide/erosion
- Site condition and description
- Severity of problem
- Technical mechanism
- Alternatives

Planning should also evaluate the cost-effectiveness of the bio-engineering programmes. For example, the selection of unpalatable plants will reduce the cost by avoiding the problem of grazing. Similarly, plant species that generate income or have an economic value will yield benefits to the people. People's cooperation and their participation can be obtained if species' selection contributes to solving socioeconomic problems.

What are the lessons learned?

Although the establishment of bio-engineering measures on degraded land following erosion is not easy, the technologies can be environmentally friendly, cost-effective, socially advantageous and effective at reducing instability of slope. However, some constraints and limitations do exist. For example, they may be less effective at controlling active gullies, slope stabilisation can take a long time to establish and yield intended results, and they may need extra care and frequent replacement of plants. One great advantage is that measures are based on indigenous knowledge and local resources can be used widely. The best possible way to replicate and disseminate such technology is through the 'seeing is believing' approach by conducting study tours and on-site training to technicians and farmers.

Bio-engineering techniques should not only be based on technical aspects, but should also address socioeconomic aspects. Techniques should be selected in such a way that they help uplift the socioeconomic condition of the rural poor by providing fuelwood, fodder, fruits and nuts, and biomass for compost making, and by reducing drudgery for women farmers.

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Bio-engineering for Landslide Control in Upland Watersheds

Li Tianchi

What is a landslide?

A landslide is generally defined as the failure of a slope mainly under the action of its own weight in which the displacement has both vertical and horizontal components of considerable magnitude. A landslide consists of downward and outward movements of slope-forming materials composed of natural rock, soil, artificial fill or a combination of these materials. The moving mass follows any one of three principal types of movement: falling, sliding, flowing or their combinations. The rate of movement may vary from slow to rapid.

Bio-engineering is a specialised branch of engineering in which living plants and plant parts are used as building materials for erosion control and landslide stabilisation. Bio-engineering methods are the most important stabilisation techniques for watershed management in the upland where the use of other stabilisation techniques is neither economically justified nor technically possible. It makes bio-engineering the most appropriate alternative for upland watershed management in developing countries.

The process of movement downslope of soil particles, stones, rocks and soil masses is called erosion and landslide. Erosion and landslides are natural phenomena but can be accelerated by human activities such as road construction and environmentally destructive land use. In recent years, the risks have become greater due to upstream erosion and downstream sedimentation as human populations increase.

How many types of landslide are there?

Types of landslide

Landslides vary in both occurrence and characteristics, ranging from small slumps to enormous masses involving huge volumes of earth materials. They range in displacement from vertical to nearly horizontal, in shape from sheets and slabs to blocks, wedges and tongues, in duration of activity from a few seconds to years. The velocity of landslide movement may range from a few millimetres per year for creep movement to several dozens of metres per second for falls and avalanches.

Different criteria are used for classifying the types of landslide, such as form of sliding surface, types of materials involved, rate of movements, type of movement, age and state of activity. However, the classification proposed by Varnes (1978) is the most commonly used around the world (Table 1).

Table 1: Varnes (1978) Classifications System

Type of movement			Type of material		
			Engineering soils		Bedrock
			Predominantly line	Predominantly coarse	
Falls			Earth fall	Debris fall	Rock fall
Topples			Earth topple	Debris topple	Rock topple
			Earth slump	Debris slump	Rock slump
Slides	Rotational	Few units	Earth block slide	Debris block slide	Rock block slide
	Translational	Many units	Earth slide	Debris slide	Rock slide
Lateral spreads			Earth spread	Debris spread	Rock spread
Flows			Earth flow	Debris flow	Rock flow
			(Soil creep)		(Deep creep)
Complex			Combination of two or more principal types of movement		

Components of a landslide

Generally a landslide has distinct parts. Recognising and assessing these individually helps to understand the characteristics of the landslide, in particular, its severity.

A landslide occurring on a steep slope generally has four zones.

- Cracking zone: above the crown of the landslide and sometimes around its sides.
- Failure zone: the head scar (crown) and failure surface which may occupy only a relatively small area at the top of the slide.
- Transport zone: a damaged slope, scarred by the passage of debris on its way down the slope, this part of the slope may be stable and may recover on its own.
- Deposition zone: failed material deposit area (the moved, detached material).

If the landslide occurs at the foot of a slope, it usually does not have transport zone; the failure zone and deposition zones are joined together.

Depth of landslide

The depth of a landslide varies from dozens of centimetres to some dozens of metres and it is controlled by topography, geology and its structure. In bio-engineering, it is considered that shallow landslides below 0.5 m deep can be treated. This is the depth to which vegetation can be used for stabilisation because 60 per cent of a tree's roots are found in the top 0.5 m of the soil. For planning and designing of bio-engineering, landslides can be classified into five types by depth: (1) very shallow slope surface failure up to 25 mm; (2) shallow slope surface failure, 25 to 250 mm; (3) deeper slope surface failure, 250 to 500 mm; (4) deep slope mass failure, 500 to 1,000mm; (5) very deep slope mass failure, more than 1,000mm.

What are the interactions between vegetation and civil engineering structures?

Measures for landslide stabilisation

In the past 40 years, many methods have been developed to stabilise landslides. These measures can generally be divided into the following three categories: heavy hard structures, light soft structures and 'living' structures.

Heavy hard structures are mostly large civil engineering and geo-technical methods such as reinforced concrete walls, anchored retaining walls, dilled horizontal underground drains, etc. They need sophisticated calculation and design and skilled workers for implementation. They are used to stabilise large and complex, deep landslides.

Light soft structures are mostly small-scale civil engineering works such as gabion surface and sub-surface drains, small walls, stone arches, anchored wire netting, etc. They do not need sophisticated calculation for construction. These methods are suitable for stabilising failures of steep slopes with shallow topsoil layers where bio-technical stabilisation alone is not successful for which initial support is needed.

'Living' structures are called bio-engineering or biotechnical slope stabilisation structures or vegetation structures.

Functions of vegetation in slope stabilisation

The manual written by Howell et al. (1991) identifies seven functions that vegetation fulfills in the context of bio-engineering. These are summarised below.

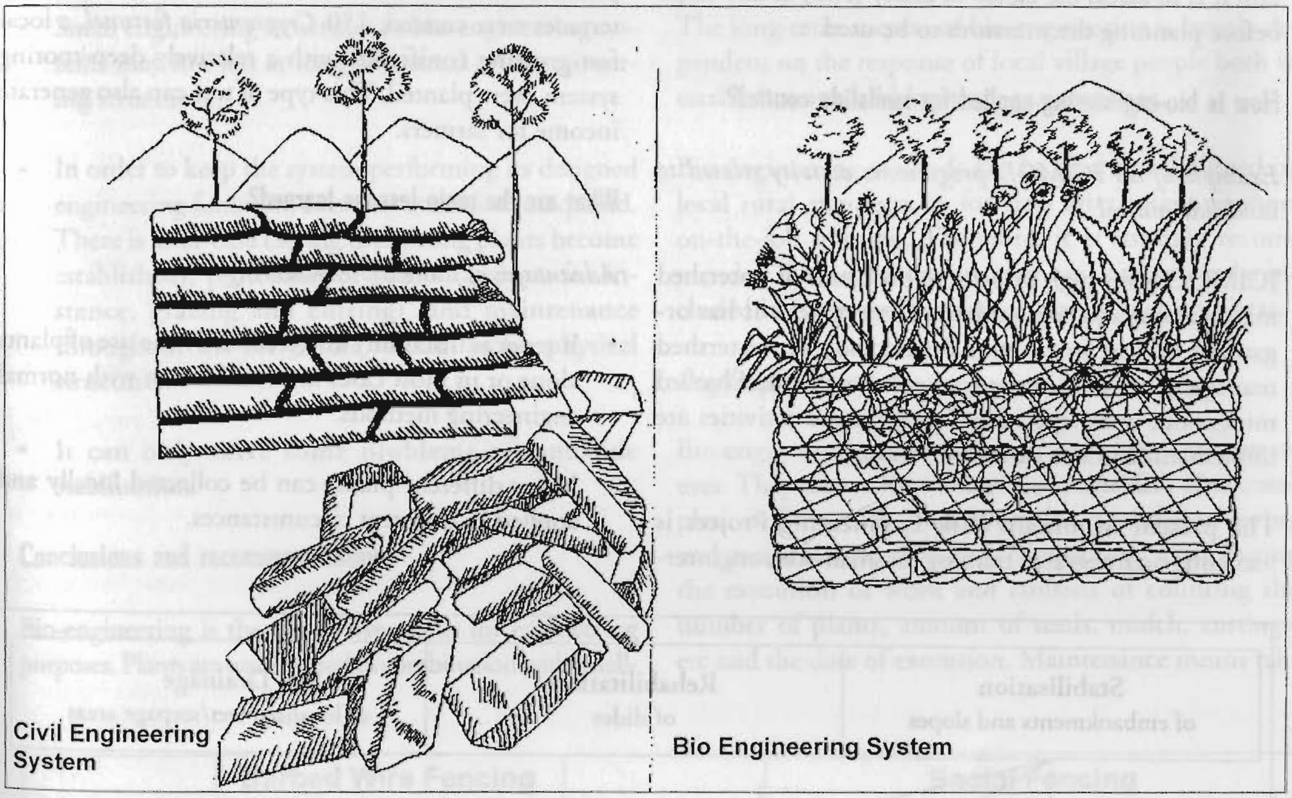
- Catching material that is moving down the slope in the process of erosion. This is done by the stems of the vegetation.
- Armouring the slope against surface erosion from runoff and rain splash.
- Supporting the slope by preparing from the base. This requires large, mature plants such as fully grown bamboo clumps or trees.
- Reinforcing the soil by increasing the shear strength of the soil. This depends on the strength of plant roots.
- Drainage of the soil profile to avoid slumping of saturated surface material.
- Limiting the extent of slope failure by binding soil.
- Improving the soil and micro-climate and so encouraging regeneration.

Functions of vegetation compared to civil engineering structures

Civil engineering structures have six main functions. Bio-engineering systems work in the same way as civil engineering systems (Table 2).

Table 2: Main engineering functions of vegetation compared to civil structures (after Geo-environment Unit, Department of Roads, Nepal, 1997)

Function	Civil engineering system	Bio-engineering system
Catch	Gabion wire bolsters	Contour lines (grass lines, brush layers)
	Catch walls, catch fences	Shrubs and bamboo (many stems)
Armour	Revetments	Mixed plant storeys giving complete cover
	Surface rendering	Grass carpet (dense, fibrous roots)
Reinforce	Reinforced earth	Densely-rooting grasses, shrubs and trees
	Soil nailing	Most vegetation structures
Anchor	Rock anchors, soil anchors	Deeply-rooting trees (long, strong roots)
Support	Retaining walls	Large trees and large bamboo (deep, dense root systems)
	Prop walls	
Drain	Masonry surface drains	Downslope and diagonal vegetation lines
	Gabion and French drains	Angled fanciness



Apart from the six main functions, there are three more benefits of vegetation.

- Environmental improvement: a cover of vegetation encourages other plants and animals to live on the slope.
- Limiting the lateral extent of instability: the rooting system of trees can interrupt the shear plane and stop it spreading further in the current phase of active instability.
- Plants provide useful products such as thatch, fruit, and fuelwood.

Interaction between vegetative and civil engineering structures

The strength of a civil engineering structure varies at different stages of its life. It has its maximum strength as soon as it has been completed. The strength of vegetative structures will build up rapidly from no strength during the first year and will reach full strength in about four years for shrubs and in about six years for trees. There is a great risk for all vegetative structures in the first few years of planting. A combination of both accounts for the decreasing strength of the civil engineering structure and the increasing strength of the plants: by properly selecting the functions of the two structures, the function of the engineering structure will be handed over to the plants. This hand-over of function from an engineering system to a vegetative system is important in the design of bio-engineering works. This application, starting with small-scale engineering structures and adding bio-engineering structures, has proven to be suitable for landslide stabilisation. Therefore, bio-engineering is most commonly used in combination with civil structures. It does not replace any form of civil engineering. The art of using vegetation in engineering is to combine it carefully with civil works to give the best results in terms of cost and effect. Figure 1 shows certain aspects of slope stability as they relate to the use of bio-engineering in combination with other engineering measures. This demonstrates how important it is to assess the factor of safety (FoS) of any slope before planning the measures to be used.

How is bio-engineering applied for landslide control?

Example of an ICIMOD programme activity related to landslide control

ICIMOD gives high priority to problems of watershed management and natural hazard mitigation. It has organized its first international workshop on watershed management. Within the framework of natural hazard mitigation, more specialised programme activities are implemented under various divisions.

The present Mountain Risk Engineering Project is focussing on integrated training on small-scale engineering and bio-engineering practices for junior technicians, farmers ,and community leaders.

Yujiago bareland rehabilitation

The purpose of the work implemented at this location was to reclaim the disposal talus of an old quarrying site situated at the side of a still exploited quarry and to create a sustainable example of land reclaim for this area. The disposal material was too coarse (though bearing some topsoil) to reclaim as farmland and the only possibility was to afforest the area. The measures consisted of terracing the talus and planting pioneer trees. Terracing was completed using cordon construction since this method fits well with the irregular terrain and is appropriate for soil and water conservation. Twelve 2-m wide terraces were created. 150 *Cryptomeria fortunel,* a local fast-growing coniferous with a relatively deep-rooting system, were planted. This type of tree can also generate income for farmers.

What are the main lessons learned?

Advantages of using bio-engineering

- It reduces instability and erosion by the use of plants alone or in most cases in combination with normal engineering methods.
- Many different plants can be collected locally and applied in different circumstances.

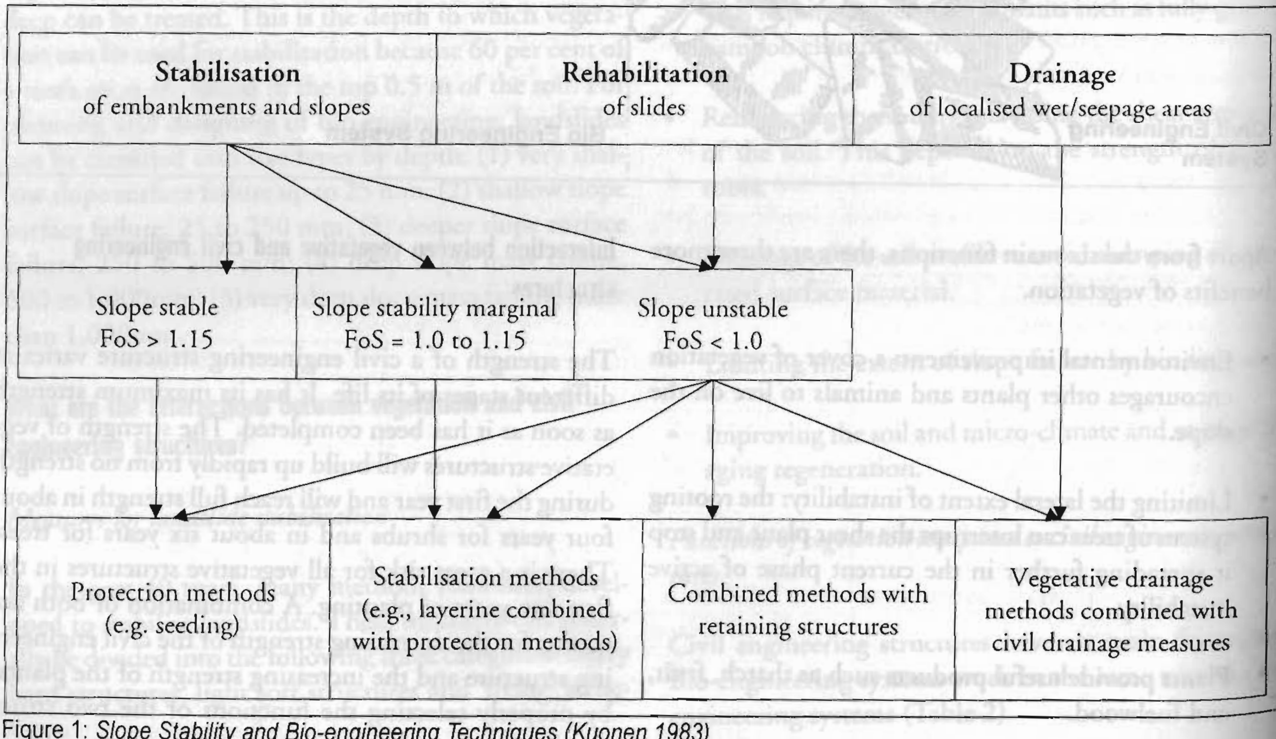


Figure 1: *Slope Stability and Bio-engineering Techniques (Kuonen 1983)*

- Bio-engineering is cost effective and can be applied without a high degree of technical knowledge.

- Bio-engineering improves habitats for greater biodiversity and reduces siltation of streams.

- Implementation of bio-engineering uses local labour and the production of by-products is of benefit to the local community.

Disadvantages of using bio-engineering

- It takes time for the plants to reach maturity: in the meantime they make no contribution to slope stability and only strengthen year by year.

- Small engineering structures in bio-engineering systems may not last as long as normal civil engineering structures.

- In order to keep the system performing its designed engineering function, constant attention is required. There is after-care (seeing that young plants become established), protection of plants (against, for instance, grazing and cutting), and maintenance throughout the life of the system, as for physical structures.

- It can only solve some problems of landslide stabilisation.

Conclusions and recommendations

Bio-engineering is the use of live plants for engineering purposes. Plants are usually used in combination with small-scale engineering structures. Bio-engineering represents an additional set of tools for the engineer, but does not normally replace the use of civil engineering structures.

Bio-technical slope stabilisation methods are cost effective and can be applied without a high degree of technical knowledge. They use mostly local materials, such as plants, plant material, and rocks, that can be collected at the site itself.

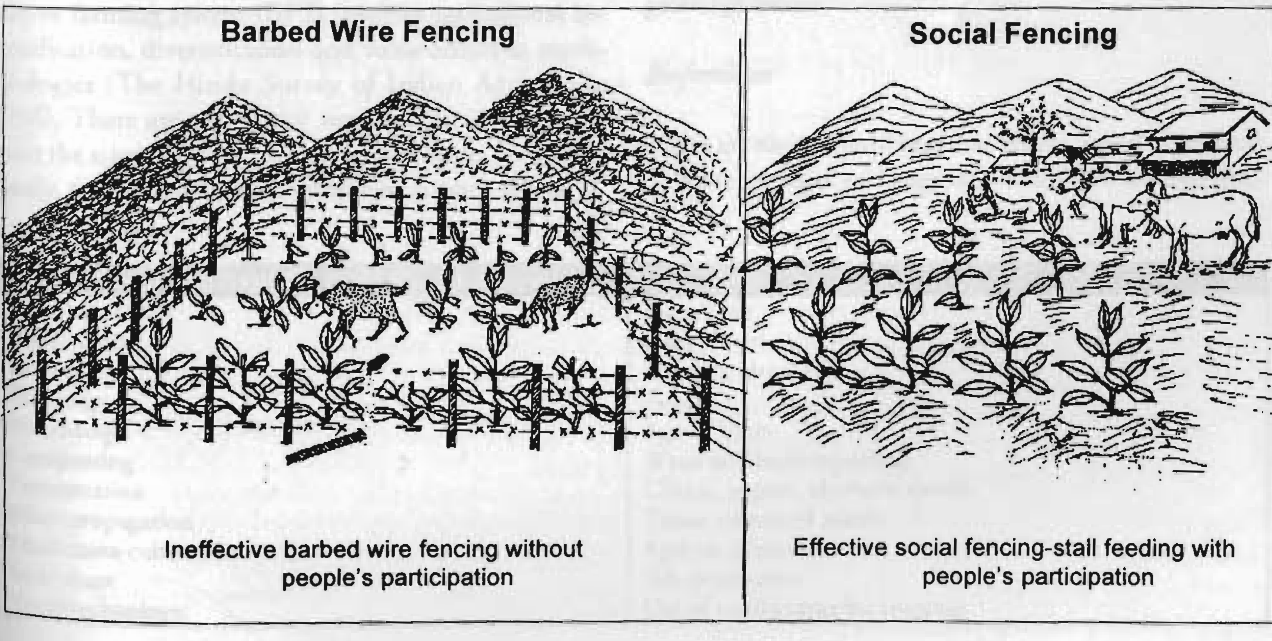
Bio-engineering methods are typically long-term measures. They need careful maintenance of all structures for 3-5 years after execution of the work. Maintenance consists of replacement work, repair, cutting back of trees, etc.

The long-term success of bio-engineering is largely dependent on the response of local village people both in establishment and long-term maintenance.

Bio-engineering methods can be used and designed by local rural engineers or foresters after receiving short on-the-job training. Therefore, it is strongly recommended that an on-the-job training component be included in integrated watershed management projects.

People's participation

Bio-engineering methods are normally long-term measures. They take at least two years to establish after completion of the work. This fact makes careful monitoring and maintenance necessary. Monitoring starts during the execution of work and consists of counting the number of plants, amount of seeds, mulch, cuttings, etc and the date of execution. Maintenance means tak-



Ineffective barbed wire fencing without people's participation

Effective social fencing-stall feeding with people's participation ing care of all structures and plants for at least five years after execution of the work. Maintenance consists of replacement work, repair, cutting back of trees, cutting of shrubs and grasses, watering, fencing, and running the nursery.

Monitoring and maintenance should be part of every bio-engineering project. They can be done by skilled project labour and local people with a supervisor or the bio-engineer in charge. The involvement of local people is important in order to build up their expertise/experience, since these people will have to continue maintenance for several years after execution of the work. For the active participation of local people in maintenance, the following approaches may be used.

- Raise awareness among the local community concerning the problem associated with monitoring and maintenance of bio-engineering.

- Some kind of management committee or group may be formed. These are normally associated with local forest management and are invested with special powers by the local forest or soil conservation department together with the project.

- Private planting (management) is the most direct and, perhaps, the easiest way to maintain the bio-engineering structures. The site is often close to farmers' houses which is convenient for both the farmer and he project.

- An arrangement can be made with local people to monitor and maintain bio-engineering sites. This is often the most long-lasting situation, but it is also the hardest to achieve.

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Biotechnology for Natural Resource Management (NRM)

N. Joshee

Objectives

- To discuss and understand the importance of various biotechnologies in natural resource management (NRM) and diffuse and propagate their adoption
- To identify the most suitable biotechnologies that can be introduced into NRM and to blend them with indigenous technologies and knowledge to form a complete chain of technologies to increase production on a sustainable basis in an environment-friendly manner

What is biotechnology?

The US National Science Foundation defines biotechnology as 'the controlled use of biological agents, such as micro-organisms or cellular components, for beneficial use'.

Why is biotechnology important in NRM ?

With growing concern over food security and sustainable agriculture, the use of eco-technologies for food production has become imperative. The integrated intensive farming system (IIFS) involves agricultural intensification, diversification and value-addition methodologies (The Hindu Survey of Indian Agriculture 1996). There are two major responsibilities that confront the scientific community in developing countries. Firstly, to search for and develop new science and technology that can be blended with the wisdom of indigenous people to form a complete chain of technologies for rural people to raise their productivity. Secondly, to diffuse and propagate scientific and technological knowledge that fosters and encourages environmentally-friendly entrepreneurship among rural people, particularly the young. To be ecologically sustainable, such intensification should be based on techniques that are knowledge intensive rather than capital ,intensive and that replace, to the extent possible, market-purchased chemical inputs with farm-grown biological inputs (Swaminathan 1994). Biotechnologies (Table 1) being practised at farm level in many countries include micropropagation, bio-fertilizer, integrated pest management and bio-control, vermiculture, bio-energy (biogas), mushroom culture, aquaculture, etc.

In a particular ecosystem or bio-climatic zone, e.g., watershed, these technologies play an important role in making the system sustainable. There is a realisation that an integrated participatory approach is required for sustainable management.

A brief description of some of the biotechnologies is provided below.

Biofertilizer

These are natural fertilizers that are microbial inoculants of bacteria, algae or fungi individually or in combina-

Table 1: Tested and Available Rural Biotechnologies

Apiculture	Honey bee
Aquaculture	Fish, prawn
Biocontrol	Biopesticides, IPM
Bioenergy	Biogas
Biofencing	Agave, Vitex
Composting	Weed and biocomposting
Fermentation	Cheese, yogurt, alcoholic drinks
Micropropagation	Tissue culture of plants
Mushroom cultivation	Agricus, Pleurotus
Sericulture	Silk production
Vermitechnology	Use of earthworms for compost

tion that augment the availability of nutrients for plants. *Rhizobium* is the best known example. It fixes atmospheric nitrogen symbiotically with legumes. Other biofertilizers are *Azotobacter*, *Azospirillium*, blue-green algae and *Azolla*. Another good example is an actinomycetous bacteria, *Frankia*, which fixes atmospheric nitrogen in a symbiotic relationship with the roots of non-leguminous plants, e.g., *Alnus*, *Casurina*, *Myrica*, etc.

Biocontrol

It is well established that chemical pesticides pose serious threats to the environment, cause imbalance in the ecosystem, and are hazardous to humans. Biological control through the purposeful employment of natural enemies is a possible alternative. These agents are generally known as biopesticides. The term is used to include plant extracts, nematodes, micro-organisms and viral agents that are marketed as formulated products. In India, the M S Swaminathan Research Foundation is trying to make this programme ecologically and economically viable at the rural level. They have focussed on the mass culturing of *Trichogramma* sp (Figure 1), the mass production of *Helicoverpa* NPV (nuclear polyhedrosis virus) and *Spodoptera* NPV, and the production of plant extracts. One of the bio-insecticides on which extensive

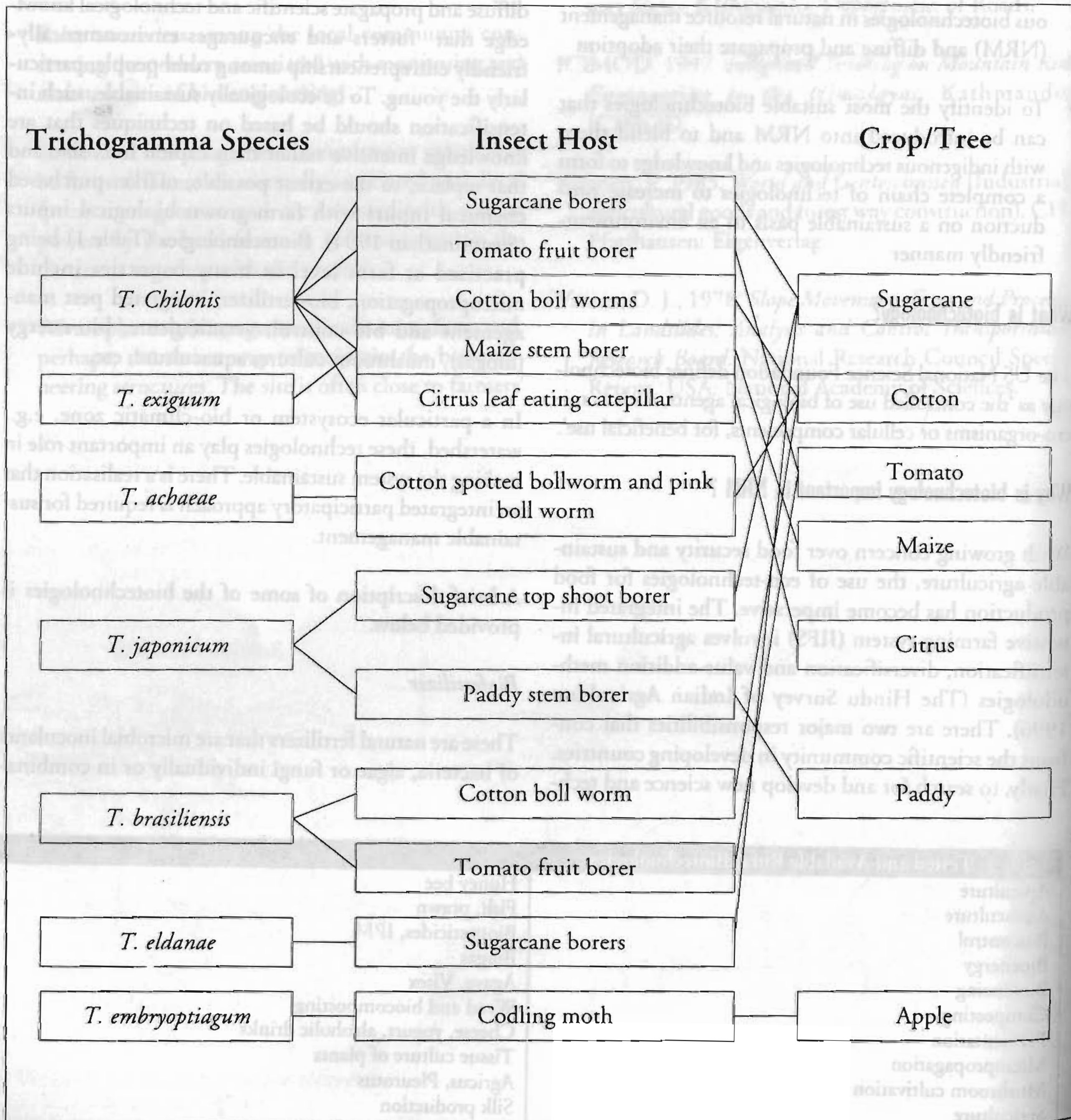


Figure 1: *Trichogramma species used for biocontrol in India (Singh et al. 1994)*

studies have been carried out is the bacterium, *Bacillus thuringiensis.* This bacterium can be used against caterpillars. Shoot-borers in cardamom, ginger and turmeric can be controlled by four sprayings of the commercial preparation of *B. thuringiensis.* At present about 75,000t of pesticides are used by the agricultural sector in India. According to recent estimates, the neem (*Adzadarichta indica*) and other plant products can replace 50 per cent of this. As of now, 86,000t of neem oil are extracted from 200,000t of neem seed kernels. Other plants of importance are *Lantana camara* (lantana), *Nicotiana tabacum* (tobacco), *Chrysanthemum cinerarifolium* (pyrethrum), *Ruta graveolens, Derris elliptica, Quassi amara* and *Ryania speciosa.* Of these, the preparations of the last four plants have already been authorised for use in organic farming for pest and disease control. Spices ,such as *Allium sativum* (garlic), *Piper nigrum* (black pepper), *Curcuma longa* (turmeric) and *Brassica nigra* (black mustard), have also been reported to have insecticidal properties.

Vermiculture

Vermiculture biotechnology harnesses earthworms as versatile natural bioreactors. Earthworms can be used for waste water treatment and solid-waste management, known as vermicomposting. Earthworms help nature in overall soil-building and plant-growth processes by particle break down. It is desirable to have 0.2 to 1.0 million earthworms per hectare to maintain the fertility of soil regularly supplied with organic matter. They are also a rich source of a protein, vermitin, and hence are being used in feed for poultry and pigs (The Hindu Survey of Indian Agriculture 1996).

Bio-energy

The generation of biogas, which is a mixture of methane and carbon dioxide, by anaerobic fermentation has long been recognised as an appropriate rural technology. The relevance of biogas technology for the subcontinent lies in the fact that it makes the best possible use of cattle dung, producing a clean cooking fuel and a valuable fertilizer. In Nepal 42,000 biogas plants are in operation; more than 60 per cent of these are located in the *Terai* region. The most immediate need is to develop cheaper designs of biogas plants and achieve better efficiency under cold climatic conditions.

Mushroom culture

Mushroom cultivation is carried out indoors and hence little land is required. It also provides employment for both educated and illiterate people. In many countries it has been accepted by rural women as an additional source of income. Mushrooms can be grown on substrates based on various agricultural wastes, which in turn are recycled. They are a good source of vitamins, niacin, pantothenic acid, and biotin. These are retained well during cooking, canning and dehydration. The most important cultivated mushrooms are white button mushrooms (*Agaricus bisporus*), paddy straw mushrooms (*Volvariella* spp), oyster mushrooms (*Pleurotus* spp) and shitake mushrooms (*Lentinus edodes*). During 1995-96 China produced 2.64 million t of mushrooms and India produced 30,000 t.

Aquaculture

Aquaculture development is gathering momentum and its credibility is growing steadily. No doubt, predicted production of 20 to 25 million t by the turn of the century will be an underestimate. In China, scientists using biotechnology produced female carp all the progeny of which are female. The sex gland of male carp develops earlier than the female and results in smaller fish.

Apiculture

Due to small land holdings and other inherent problems of mountain areas ,such as undulating physiography, cold and harsh climatic conditions, and limited sunlight, farming alone is not sufficient to make an adequate living. Bee-keeping could be a suitable off-farm, food and income-generating activity for small farmers. Apiary products are honey, beeswax, pollen, royal jelly and bee venom. Pollen, royal jelly, and bee venom are used for medicinal purposes. So far, China is the only country in the Hindu-Kush Himalayan region that has developed a technology for the commercial production of these bee products. Apiaries also enhance pollination efficiency, improve the growth of plants and increase seed output (Partap 1997).

Sericulture

Over 60 countries at present are engaged in sericulture. World silk production in 1993 was over 100,000 t. The demand for raw silk has increased significantly recently but the present production is much lower than the requirement. Moreover, the area under mulberry has not increased.

Livestock production

Improvements in the efficiency of reproduction in farm livestock, using techniques such as super-ovulation, embryo transfer and cloning are already having an impact on the livestock breeding industry. Daily growth hormone administration to young stock has been shown to increase daily live-weight gain and feed conversion in cattle, sheep and pigs; with pigs, and most probably with ruminants, the increased daily gain is associated with a higher content of protein at the expense of fat.

Micropropagation

Why is micropropagation important in the context of PIWM? Micropropagation represents optimum efficiency in terms of vegetative plant propagation and allows a large number of propagates to be produced in a relatively short period of time under controlled conditions, throughout the year, in a relatively small space. The basic tissue culture process is provided in Figures 2 and 3. Micropropagation has the following advantages.

- When classical methods of *in vivo* vegetative propagation prove inadequate, *in vitro* cloning is an important tool in speeding up propagation.

- Adult plant material that often cannot be cloned *in vivo* can sometimes be rejuvenated *in vitro* and then

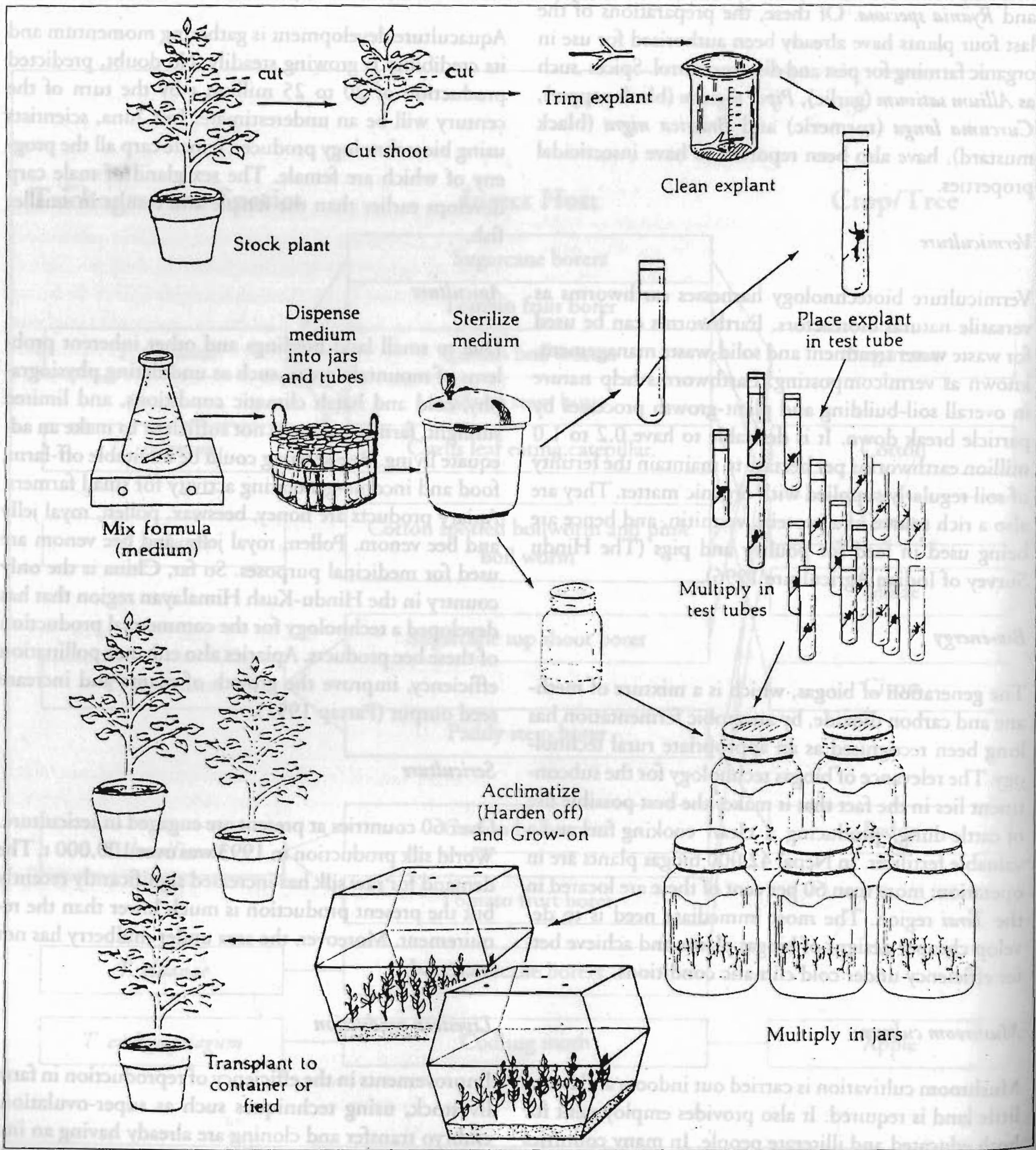


Figure 2: *Sequence of shoot tip micropropagation*

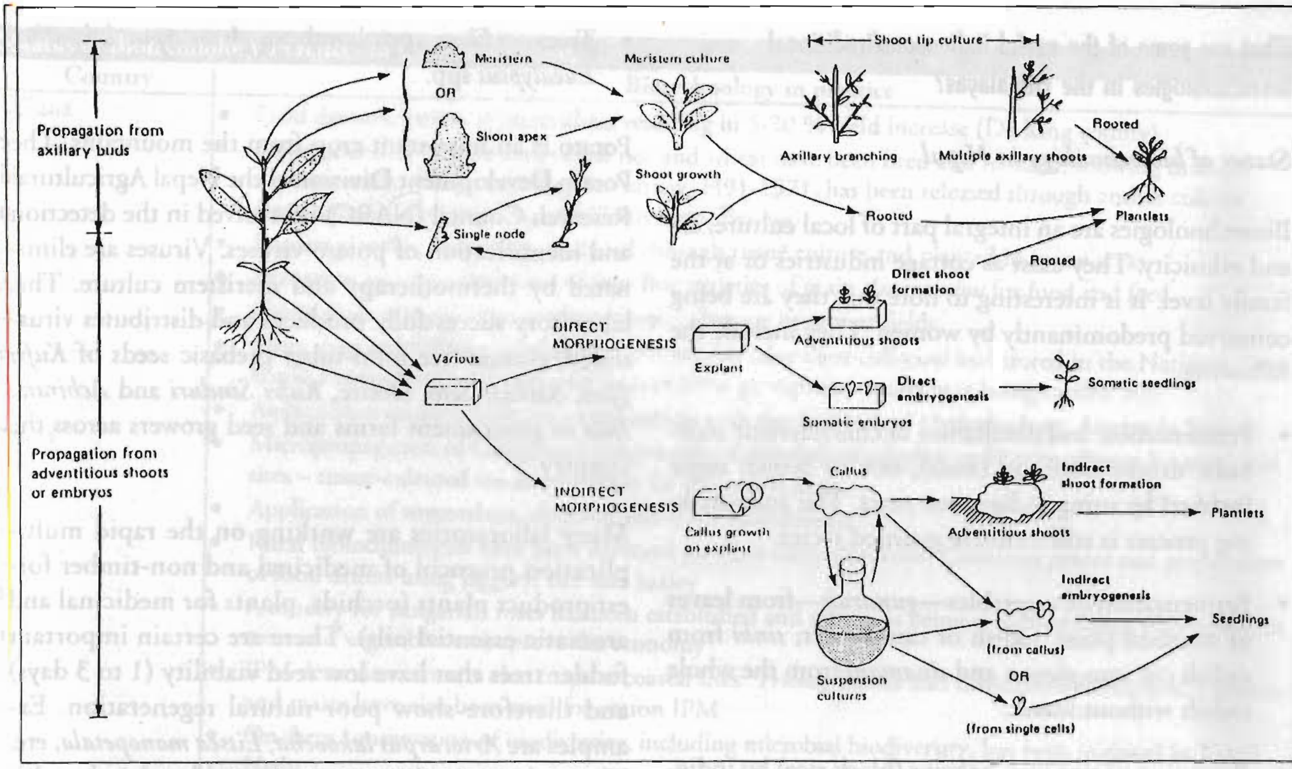


Figure 3: *Principal methods of micropropagation*

subsequently cloned. It has special significance in forestry sector.

- Growth of *in vitro* propagated plants is often stronger than in those cloned *in vivo*. This is mainly due to rejuvenation and/or the fact that they are disease free.

- When the existing methods of cloning are too slow or too complicated to be profitable, *in vitro* cloning can be applied to produce large number of plants more quickly and at a competitive price.

- By *in vitro* cloning, expensive methods such as grafting or budding on a rootstock can be rendered obsolete.

- *In vitro* cloning enables the uncovering of chimeras, and the isolation and cloning of spontaneous or induced mutants. Mutation induction and regeneration of adventitious buds *in vitro* makes it possible to obtain solid mutants.

- In contrast to *in vivo* propagation, *in vitro* cloning of herbaceous plants can be continued all year round and so become independent of the seasons.

- *In vitro* cloning enables the production of disease-free plants and thereby facilitates phytosanitory transport from country to country.

- In forestry, quality seed production and availability is difficult. Proven elite plants can be cloned to establish orchards for high-quality seeds.

Different phases in micropropagation

Phase 0: This covers correct pretreatment of the starting material, e.g., keeping the plant in a disease-free state, etc.

Phase 1: This deals with sterile isolation of a meristem, shoot tip, explant, etc. It is important to accomplish non-contaminated growth and development.

Phase 2: The primary goal in this phase is to achieve propagation without loosing the genetic stability.

Phase 3: This involves the preparation of the shoots and plants obtained in phase 2 for transfer into soil. It involves shoot elongation. Subsequent root formation must be induced, either *in vitro* or later *in vivo*.

Phase 4: This covers the transfer from test tube to soil and the establishment of plantlets (hardening).

The process of acclimatisation or hardening is the most critical phase of plant tissue culture. The process of hardening is usually done in greenhouse and hardening tunnels.

What are some of the useful indigenous/traditional biotechnologies in the Himalayas?

Status of biotechnology in Nepal

Biotechnologies are an integral part of local culture, art and ethnicity. They exist as cottage industries or at the family level. It is interesting to note that they are being conserved predominantly by women. They include the following.

- Fermentation and distillation of characteristic alcoholic drinks from rye (*kodo*), rice or brown sugar (*sakhar*) by using indigenous yeast. The yeast-making process is still a closely guarded secret.

- Fermentation of vegetables—*gundruk*—from leaves of mustard plant, radish or cauliflower; *sinki* from radish cut into pieces; and *sinamani* from the whole radish without leaves.

- Browning of rice into *hakuwa* (black rice) by indigenous techniques of fermentation.

- Pickling of fruits by fermentation.

- Production of jute from the bark of the hemp through the process of biological decortication.

- Preparation of yogurt and hard cheese (*churpi*).

- Plant materials such as *timur (Xanthoxylum indicum)* powder and *bojo* (*Acorus calamus*)/ *titepati* (*Artemesia vulgaris*) are commonly used as insect repellents in grain storage in the hills.

What are the new successful biotechnologies in Asia?

Among the new biotechnologies, tissue culture and related techniques have done quite well during the past few years. Tissue culture is now being carried out at government, non-governmental and private laboratories in many countries. The main products (crops) from different climatic zones include the following.

- Fruit—banana, strawberry, shoot-tip grafted sweet orange

- Cash crops—ginger, cardamom, sugar-cane

- Vegetables—potato

- Flowers—orchids (*Cymbidium*, *Dendrobium*, *Paphiopedilum*, etc.), carnation, chrysanthemum, African violet, etc.

- Trees— *Ficus* spp, bamboo, *Artocarpus lakoocha*, *Eucalyptus* spp.

Potato is an important crop from the mountains. The Potato Development Division at the Nepal Agricultural Research Council (NARC) is involved in the detection and identification of potato viruses. Viruses are eliminated by thermotherapy and meristem culture. This laboratory successfully produces and distributes virus-tested, disease-free mini-tuber prebasic seeds of *Kufri Jyoti*, *Sarkari Seto*, Desire, *Kufri Sinduri* and *Achirana Inta* to government farms and seed growers across the country.

Many laboratories are working on the rapid multiplication protocol of medicinal and non-timber forest product plants (orchids, plants for medicinal and aromatic essential oils). There are certain important fodder trees that have low seed viability (1 to 3 days) and therefore show poor natural regeneration. Examples are *Artocarpus lakoocha*, *Litsea monopetala*, etc. These plants can be mass-produced by clonal multiplication. Production of artificial seeds using somatic embryos could be another alternative. Important plants, such as papaya, *Choerospondias axillaris* (lapsi) and poplar, are strictly dioecious. Male and female plants produced through tissue culture may help in establishing plantations of such species.

In many countries of South and South East Asia, various tissue-cultured products are already available. Indigenous technologies and locally available substitutes have brought down prices for the farmers.

- Anther-culture-derived varieties of rice and wheat (Varieties thus generated and field-tested have shown multiple superior traits such as dwarfing, greater spikes and more grains, resistance to disease and early maturity. The yields are also higher).

- Increase in the cover of plants used for biopesticides

- Application of mycorrhiza at the rooting stage of micropropagated shoots

- Germplasm conservation for future use

Which are the priority areas for biotechnology development in future?

The following are suggested as priority areas for biotechnology. If the technologies are promising, they may be commercialised by non-government or private organizations.

Status of Biotechnology Practices in the Asian Region

Country	Biotechnology in practice
China	• Field demonstration of biofertilizer resulting in 5-30 % yield increase (Da Xing county) • Series of anther-culture varieties of rice and wheat have been bred and released, showing multiple superior traits. A high-yielding rice variety, H91-1371, has been released through anther culture (Institute of Crop Breeding and Cultivation, Beijing). • Banana plantlets have been produced through tissue culture and planted in many areas. • Extension and demonstration of four fine varieties of grain *Amaranthus* for food and feed. • Use of *Beauveria bassiana* to protect insect damage in peanut fields • More than 180,000 accessions of crop resources have been collected and stored in the National Gene Bank. Research into the characteristics of these germplasm resources is being carried out. • Aquaculture country-wide (in collaboration with the Institute of Hydrobiology, Academia Sinica).
India	• Micropropagation of *Calligonum polygonoides, Commiphora wigghtii* and *Chlorophytum* for semi-arid sites – tissue-cultured tea and bamboo for mountain areas • Application of mycorrhiza, rhizobia and other biofertilizers • Rural biotechnologies have been surveyed for fibre extraction from *Crotolaria juncea* and preparation of local drinks using jaggery, rice and barley • A nursery for Bulgarian roses has been established and saffron is being evaluated along with new fruit trees and vegetables to improve the economy • IPM demonstrations in rice crops at coastal sites. *Trichogramma* and *Chrysoperla* for cotton. Tobacco and maize have also been used for cotton IPM • On-farm conservation of biodiversity, including microbial biodiversity, has been initiated in Tamil Nadu
Nepal	• Tissue-culture protocols for more than 60 plants are available. In the *Terai* region more than 25,000 banana plants are being cultivated. This year the number is expected to reach 50,000 (Nepal Biotech Nursery, Himalayan Floratech, Microplant—all private organizations). Floriculture-related tissue-cultured plants (orchids, carnation, chrysanthemum, African violet, etc) will be marketed soon. • Site-survey activities have been initiated in association with FARM. Training of farmers' groups and workers is being done on-farm. • Mushroom production at rural level and training of women (National Agricultural Research Council) • Biofertilizer application trials on demonstration sites (National Agricultural Research Council)
Philippines	• Establishment of biotechnology village at the FARM site in Infanta Quezon. • The main technologies practised are biological nitrogen fixation, hybrid plant varieties, micropropagation by tissue culture, biopesticides, monoclonal antibodies for disease detection, aquaculture, etc.
Vietnam	• In Chieng Dong – to improve household incomes, coffee and silk work programmes have been strengthened. • 100 ha of orchards of mango, citrus, orange, banana, etc have been planted. • A target has been set to double the head of cattle by the year 2000 to increase meat production.
Thailand	• Biofertilizer application • Successful export-oriented micropropagation-based floriculture industry • Aquaculture for fish and prawns

Source: Asian Biotechnology and Biodiversity Newsletter 1995-96.

- Research and application of biotechnological tools for producing high-quality, genetically superior planting materials for biomass production, especially for wastelands.
- Conservation of elite germplasm through low temperatures or cryopreservation.
- Studies of polymorphism and molecular mapping of endangered and commercial crops.
- Selection of naturally occurring mutants among somatic cells—somaclonal variants. Mutants can be selected for tolerance/resistance to disease, unfavourable soil and environmental conditions, etc.
- Identification of medicinal plants with a proven record, e.g., *Taxus,* and study of active chemical compounds, germplasm conservation, micropropagation and biotransformation.
- Development, validation and scaling up of protocols for plant regeneration through plant tissue culture for economically important plants. A complete technology package to be handed over to the end users.

- Biotechnology programmes that benefit a target population by employment generation, upgrading of skills and improving standards of living.
- Biotechnology-based activities that involve women scientists and benefit women.
- Human resource development programmes that cover inaccessible and remote regions, facilitating training at all levels.

What are the limitations for implementing biotechnology programmes?

There are no guiding policies for setting priorities for biotechnology research that responds to national needs. Decision-makers should create a policy environment that allows biotechnology to thrive in national R & D institutions and in commercial and industrial sectors.

- There is no effective policy and legislation to protect Nepal's right to its genetic resources and to ensure any flow of benefits to the Nepalese people.
- There is no biotechnology department as such.
- Research institutions are not technically equipped.
- Lack of understanding and no inclusion of Intellectual Property Rights (IPR), Farmers' Rights (FR) and Breeders' Rights (BR) in rules and regulations (law).

Constraints in general

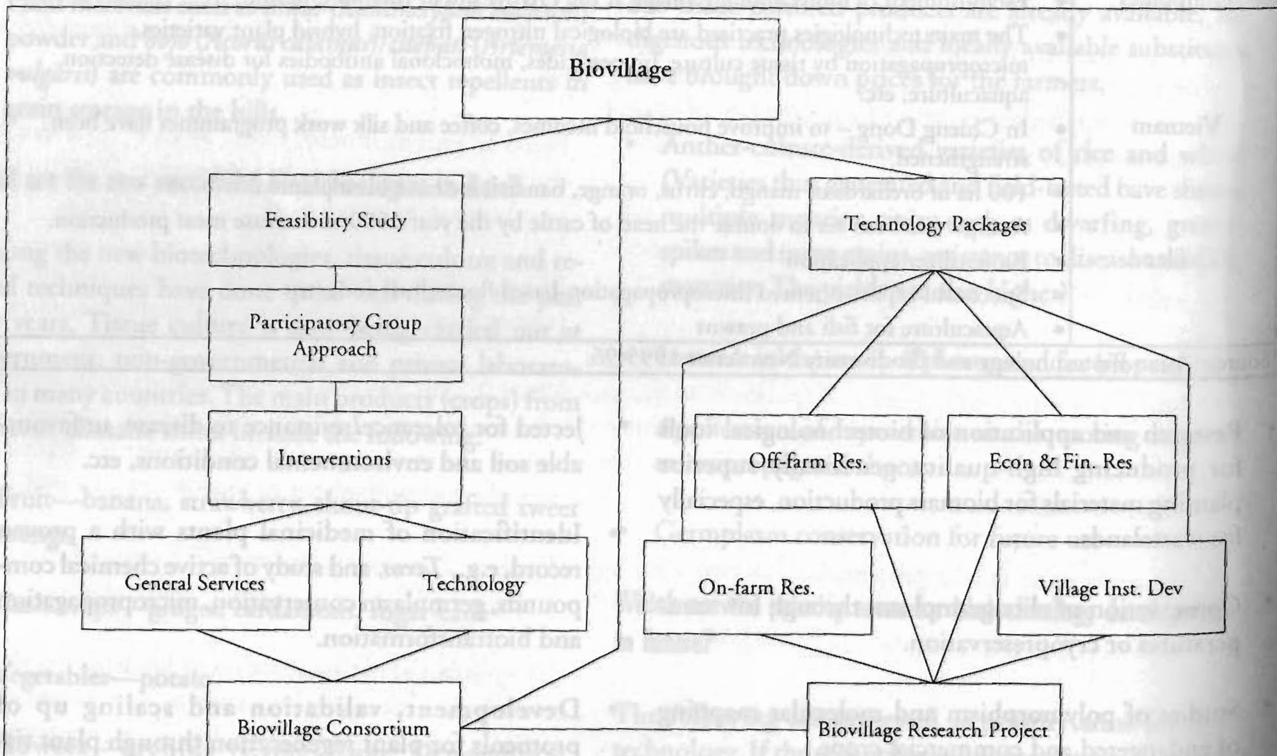
- Without the incentive of a strong market, potential private firms are unwilling to take the risk of production and marketing.
- Certain biotechnologies are expensive for farmers; research and financial mechanisms are yet to be worked out.

Can biotechnology be useful to all sections of society in the village (biovillage)? How?

The development of biotechnology should proceed with caution and critical thinking to ensure that results are responsive to end users, generate income, are ecologically sound and benefit society. A particular biotechnology in isolation is unlikely to change the situation. We need to use various technologies in an integrated fashion involving various sections of society. To propel all these efforts in the right direction political will and the support of financial institutions are necessary.

The basic paradigm of the biotechnology biovillage should include consideration of the following.

- Ecological sustainability
- Participatory research and development
- Economic efficiency with equity



Methodical Approach for Biovillage Projects (Hossain 1994)

- Employment and income generation for men and women
- Attraction and retention of educated youth in the village

A baseline survey (eco/agro/socioeconomic) through participatory research will have to be undertaken for qualitative and quantitative understanding of the resource base (physical, natural and human) and the current status of use, agroecology of farming systems, and an in-depth understanding of the constraints to sustained productivity of possible interventions. Some possible technological and institutional interventions are given in the following passages.

For assetless farmers

Value-adding activities utilising biomass available within the village (raising plant nursery, compost making, processing fruits and vegetables, feed preparation for poultry and livestock, mushroom production, micropropagation, repair workshop for agricultural machinery, etc), and development of common property resources including utilisation of wastelands, roadsides, embankments, derelict tanks and ponds, as may be available.

For marginal and small farmers

Labour-intensive production activities such as dairying and poultry raising, vegetable growing, flower production, hybrid seed production, integrated resource management systems (including waste recycling), value-added agricultural products, etc.

For medium- and large-scale farmers

Technological inventions including those that would save off-farm inputs. These may include the use of biofertilizers, biopesticides, integrated pest management systems, and inter-, multiple-, and relay cropping systems, etc.

A case study of the successful incorporation of biotechnology in a watershed is presented in Box 1.

Box 1

Successful case study of Haigad Watershed, Almora, India

The **watershed** is comprised of seven villages (1180 m to 2338 m). The total population is 1,553 with an annual growth rate of six per cent. The average family size is six persons. Twenty-nine species of medicinal plants grow in the watershed (45 % herb, 17 % shrub and 38 % trees).

Activities undertaken

1. Identification and survey assessment
2. Introduction of useful species
   a. Vegetables and fruits: use of high-yielding varieties for own consumption and income generation. Introduction of these varieties into traditional stock produced a surplus.
   b. Bulgarian rose: for oil production, market price US$ 4000/kilo. Other products are rose water and gulkand. 3,500 plants introduced.
   c. Large cardamom: 1,975 plants distributed for plantation along with *Alnus nepalensis*, *Bauhinia variegata* and *Crotolaria* sp to provide shade, enrich soil fertility by fixing nitrogen and adding leaf litter, and as a source of fodder, fuel and timber.
3. **Silvipastoral system using fodder/fuel trees:** fodder and fuel trees were planted keeping in mind the hilly terrain, geological conditions and susceptibility to erosion.
   a. Clonally raised and micropropagated plants of *D. hamiltonii* and *D. strictus* were introduced along the stream banks.
   b. A perennial grass, *Thysanolaena maxima* (broom grass) was introduced along field bunds and irrigation channels. It is a good source of fodder, useful as a soil binder and the dried inflorescence can be made into brooms.
   c. Napier grass introduction for fodder and soil conservation.
   d. High-value fodder plants, *Grewia oppositifolia*, *B. variegata* and *Morus alba,* were planted.
   e. Seeds of red clover, rye grass, lucern for cultivation along field bunds
4. **Multipurpose tree plantations:** source for wood, fuel, fodder, fibre, medicine and other products of local importance, e.g., *Sapindus mukorossi* (soap nut) *Ougeinia oojeniensis* for fuel, making utensils and fodder, *Diploknema butyracea* (Indian butter tree), etc. The butter tree provides good quality oil and is also used for the treatment of headache and arthritis.
5. **Biofencing:** *Agave* can grow on dry soils and the leaves yield fibre. Decorticated refuse is used for making paper boards.
6. **Plantation:** *Crotolaria, Alnus* and *Bauhinia* sp were planted on degraded slopes for site improvement.
7. **Bio- and weed composting:** a supplement to traditional manure and vermicomposting.
8. **Introduction of biofertilizers:** *Azotobacter, Azospirillum.*

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Integrated Plant Nutrient Management (IPNM) and Biofertilizers for Watershed Management

S. L. Maskey and S. P. Panday

Objectives

- To understand the concept, importance and utility of IPNM and biofertilizers in watershed management (WM)
- To identify components of IPNM and indigenous knowledge
- To understand the constraints and opportunities and the action needed for IPNM development in the context of WM in Asia

Why are IPNM and biofertilizers important in the Asian context?

IPNM and biofertilizers are important because of the following problems.

- Nutrient mining
- Unbalanced use of fertilizers
- Depletion of natural resources
- Soil erosion/nutrient loss
- Decrease in use of organic manure

The most crucial issues facing Asian countries today with regard to raising agricultural productivity by increasing plant nutrients through the use of fertilizers are

- fertilizer use cannot be increased much more because high prices and unavailability make it inaccessible to many farmers; and
- the natural resource base traditionally used for organic manure production has been degraded, and this degradation process cannot be reduced without raising and sustaining yield levels.

However, the demand for plant nutrients continues to increase due to intensification of cropping systems and cultivation of high-yielding varieties. This further accelerates nutrient mining in the soil leading to deficiencies.

Massive soil erosion is a major factor causing loss of soil fertility and plant nutrients. This problem is more acute in hill and mountain regions. Soil loss depends on land use, cropping pattern, terrace type, soil type and rainfall intensity. Results from various studies (ODA-NARC 1995; Carver and Nakarmi 1995; Maskey and Joshy 1991) show that soil erosion has caused the loss of topsoil ranging from 0.1 t/ha/yr to 87 t/ha/yr. As topsoil erodes, associated organic matter and plant nutrients are also lost.

An analysis of this situation reveals that it will be a great mistake to consider the sustainability of soil fertility and agricultural productivity with the use of fertilizers or organic manures alone without understanding the integration of all other related biophysical and socioeconomic factors.

What is the basic concept of IPNM and how is it defined?

The use of mineral fertilizers is an efficient way of increasing crop production. However, their rising cost, unavailability and improper use mean that it is not advisable for farmers to depend only on them alone. Hence a combination of mineral fertilizers with locally available organic and biological sources of plant nutrients is recommended. Such combined application of organic materials benefits the soil by supplying nutrients, improving physical and biological properties, and increasing nutrient and water-retention capacities.

As defined by FAO (1995) the basic concept of integrated plant nutrition management (IPNM) is the maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity through the optimisation of the benefits from all possible sources of plant nutrients in an integrated manner. In other words it is an appropriate combination of mineral fertilizers, organic manures, biofertilizers, crop residues, etc, with proper crop rotation, soil conservation and agronomic practices — including water management.

The overall purpose of IPNM, therefore, is to supply and manage the required plant nutrients from different sources on a sustainable basis. In principle, it should embrace a total management plan based on balance sheets within a watershed. Use of fertilizers, manures, biofertilizers, crop residues, legumes, and losses such as leaching, gaseous losses of ammonia, erosional losses, crop removal, etc must be considered. Thus IPNM should focus on the farming system as a whole. We can also say that it is a balance between organic and inorganic fertilizers, traditional and modern technologies, and agriculture and the environment.

What is the importance of IPNM in PIWM and what are the components of IPNM?

The cropping pattern and intensity of land use in a watershed have many on-site and off-site implications for the farmer as well as the community. Farming is usually the most prevalent land use in a watershed followed by forest, rangelands and others. The products from these different land uses are interrelated as the farmer has to manage food, fuel and manure from these systems.

Within a watershed, farmers follow various farming/cropping systems. Each cropping pattern differs in its nutrient requirements within specific biophysical and socioeconomic conditions. The nutrient balance for a particular cropping pattern in a particular watershed may vary depending on farmers' soil and water management interventions and the natural resources' base. Plant nutrients are the basis for maintaining the biodiversity as well as bio-intensity which in turn helps to protect the landscape and conserve natural resources. Supply of required plant nutrients from a single source is impossible in the long run; an integrated nutrient management approach, therefore, plays an important role in watershed management.

Component of Integrated Nutrient Management

Biofertilizers

Biological nitrogen fixation occurs through the medium of bacteria which convert nitrogen from the air freely or in symbiosis with leguminous crops, shrubs or trees or with *Azolla* in wetland conditions. Potential microbial fertilizers are as follow.

Azotobacter: Recommended for cereal crops in the higher hills in association with organic manures. Yield increases of 3-29 per cent are expected. It is not useful in combination with mineral fertilizers.

Rhizobium: Recommended for pasture and grain legumes. A number of effective strains are identified and distributed. Yield increases of 10-70 per cent are expected in legumes. It can have significant residual soil fertility effects on succeeding crops. It is estimated that with legumes—soybean, chickpea, lentil— it derives 50-100 per cent of its requirements from the atmosphere. Division of Soil Sciences, NARC, Nepal distributes about 10,000 packets (200 gm each) of *Rhizobium* inoculant annually.

In India, goverment institutions, universities and private enterprises are involved in the development of bacterial and algal biofertilizers. Efficient nitrogen-fixing strains have been developed. At present about 800 t of rhizobial biofertilizers are produced and distributed. In addition, 15 million ha of rice-land are inoculated with blue-green algae. However, these efforts are still under research and at the pilot-plant stage (Biswas 1994). In the Philippines, microbial biofertilizers are marketed under the name of Bio N (*Azotobacter, Azospirillum*) and Nitrogplus (*Rhizobium*).

Mycorrhiza: In Nepal, work on mycorrhizal inoculants is still at the research stage. However mycorrhizal products are commercialised in India, the Philippines and Thailand. Mycorrhizal cultures are used in cereal and vegetable crops. Mycorrhizae are associations between soil fungi and plant roots. Approximately 126 genera of mycorrhizal fungi have been isolated. The most important species are *Glomus*, *Gigaspora* and *Acaulospora*.

Organic manures: A package on better methods of farmyard manure (FYM) compost preparation, storage and application is available. Also, technology for rapid composting (20-30 days) through the use of fungi *(Trichoderma)* is available. There is ample information on the synergistic effect of combined use of organic manures, fertilizers, and green manuring and fertilizers on various crops. Responses to 5 t/ha poultry manure, 20 t/ha FYM/compost and 100:40:30 kg/ha NPK fertilizer were found comparable. Improvement in quality of compost using various micro-organisms is worth exploring.

Legumes in rotation: Incorporation of legumes into the cropping system is beneficial. It is reported that legumes, at about a yield level of 1 t/ha, can provide a residual 20-40 kg N/ha to succeeding crops depending on the quantity of biomass returned to the soil.

Intercropping of maize with legumes is common practice in the hills of Nepal. However, the introduction of high-yielding varieties of maize and the use of chemical fertilizers mean that intercropping of legumes with maize is decreasing. In some districts, legumes are relayed with maize and, in western Nepal, relaying of lentils with rice is common.

Green manures: 30-60 kg N/ha can be supplemented through green manuring with *Sesbania canabina* in rice crops. Several plants have been identified as potential green manures. *Azolla*, a water fern, can be used where water management is good.

Inorganic fertilizers: Ample information has been generated in fertilizer use and crop responses. Increased fertilizer efficiency through integration with organic sources, balanced use, better methods of application and soil amendments should be given priority. Fertilizer recommendations for the major crops of Nepal on the basis of crop responses and soil analysis are given in Table 1.

Indigenous knowledge in INM

Farmers in Asia follow a number indigenous integrated plant nutrient practices for reducing soil erosion and maintaining soil fertility. Some of them are listed as in the following passage.

For soil fertility maintenance

- FYM/compost application
- Green manuring
- Terracing and slicing of terrace risers
- Flood water diversion to rice fields
- Inclusion of legumes in the cropping systems
- Slash and burn in shifting cultivation

For reducing soil erosion

- Terracing
- Retaining wall
- Intercropping
- Growing fodder tree on terrace riser
- Zero tillage soil management
- Intercultural operation
- Maintaining grass fields

Most farmers now use mineral fertilizers since traditional practices alone do not increase crop yields to meet their expectations.

What are the main constraints and opportunities in the application of INM?

The following are the main constraints (Pandey, 1995) limiting the implementation of IPNM at farm level.

- Already depleted natural resource base due to deforestation.
- Lack of institutions to regulate the production, supply and distribution of IPNS inputs.
- Lack of well-defined policies and plans of action.
- Lack of appropriate extension methods.
- Lack of adequate research information.
- Laborious and time-comsuming technology.
- Lack of appropriate and well-defined land-use policy.
- Increased compulsion to burn dung for household fuel purposes.

These constraints can be changed by making use of the following opportunities.

- Improvement of composting technology
- Utilisation of farmers' indigenous knowledge

Table 1: Fertilizer Recommendations for the Major Crops of Nepal

Crop variety	Optimum dose (kg/ha)			Expected yield (kg/ha)
	N	P^2O^5	K^2O	
Rice				
- Improved	100	30	30	3,811
Local	40	20	30	2,541
Wheat				
Improved	100	40	30	3,287
Maize				
- Improved	120	50	40	3,359
Barley				
- Improved	60	30	30	2,479
Sugarcane				
- Improved	120	60	60	65,300
Jute				
- Improved	60	30	40	3,231

- Promotion of high-value crops
- Promotion of agroforestry (fodder tree crops) and methane gas plants
- Promotion of soil and water conservation practices in agricultural lands

Conclusions and recommendations

It is recommended that future soil fertility improvement programmes should be oriented to IPNM with the following initiatives and approaches.

- Building on indigenous knowledge and skills
- Increasing farm incomes
- Reducing soil erosion
- Supporting biomass regeneration and livestock development
- Incorporating legumes into the farming system
- Increasing water availability
- Optimising external inputs such as fertilizers
- Improving compost quality
- Exploring and promoting production of organic fertilizers on a commercial scale
- Increasing nutrient-use efficiency
- Maintaining/enhancing agricultural productivity as well as environmental stability
- Agro-ecological zone model sites should be established for farmers' participatory innovations, verifications, training and demonstration of integrated soil fertility and plant nutrition management practices.
- IPNM trials/demonstrations should be designed to assess the plant nutrition balance sheet of dominant farming systems.
- Farmers should be motivated and organized to promote biomass-centred, local-resource-based and regenerative soil fertility management practices in combination with mineral fertilizers.

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Water Harvesting

S. A. Sial

Objectives

- To highlight the role of water harvesting in PIWM.
- To elaborate how water harvesting can help in PIWM.

What is water harvesting? How can a catchment be made more impervious to runoff?

A water harvesting system may be defined as the use of artificial methods to collect and store precipitation until it can be used beneficially. The catchment is made more impervious to runoff than it is in its natural state, and a storage facility is constructed unless the harvested water is to be used immediately.

A catchment can be made more impervious using the following methods.

- Land surface alteration: clearing and smoothing, shaping, compaction.
- Chemical treatment: silicones and sodium salts.
- Soil cementation treatment: mixing of asphalt, cement, resins and polymers with soil.
- Ground cover modification:-butyl-, plastic- and asphalt-exposed membranes, gravel-covered plastic sheeting, reinforced cement-mortar-coated plastics, sheet metal, concrete, reinforced asphalt and asphalt planking (Harwood 1975).

Socioeconomic and ethnic aspects of water harvesting systems

In addition to biophysical considerations, socioeconomic and ethnic aspects are of great importance in the context of sustainability of water harvesting systems. The site for construction of a water harvesting system should be surveyed for social aspects which include availability of construction labour at an appropriate time of the year; availability of local skills needed for construction, operation and maintenance; social acceptability of the project and people's participation. Considerable thought should be given to modifying existing techniques wherever possible rather than trying to introduce altogether new ones, and care should be taken to make the system compatible with existing social patterns.

What are the main water harvesting practices and skills?

- *In situ* water harvesting
- Catchment-based water harvesting systems
- Dugout ponds
- *Tanka* (covered underground tank generally constructed for storage of runoff)
- *Nadi* (small excavated or embanked village ponds)
- *Khadin* (system of growing crops on harvested and stored water by constructing earthen bunds across the slopes of farms in valley bottoms)
- Check dam and percolation tank
- *Ahar* and *bhundi* (similar to *khadin*)
- Rooftop water harvesting or rainwater cistern system
- Fog and ground cloud collection

Main lessons emphasising trends and approaches

Community participation, institutionalisation and policy issues

The delivery of programmes of watershed management with or without water harvesting is replete with difficulties. World-wide, many projects fail primarily due to a lack of people's participation. The consequence is wastage of public funds invested in structures that fail and have to be reconstructed. Unless beneficiaries are committed to operating and maintaining water harvesting programmes by investing their energy and money, soil and water conservation projects cannot perform sustainably.

How to achieve people's participation in water harvesting?

- High priority should be placed on first implementing programmes that generate quick and visible returns such as water harvesting ponds, irrigation systems, income-producing cropping systems, and income generation from common property resources by diversifying into industrial grasses, fuelwood, timber, etc.
- Subsidies and incentives to the community for locally unavailable materials
- Emphasis to be given to the development of capabilities of local farmers
- Training to develop awareness of problems and knowledge and skills of local users
- Regular and frequent visits of experts to observe and discuss community organization and visits of field-based staff to farmers' houses are essential.
- Resolution of social conflicts (Samra et al. 1996).

What are the important policy issues in water harvesting?

Policy issues should be considered by government (central and local) and sectoral departments, farmers and users of the land. Technology demands joint and simultaneous management of arable and non-arable land, whereas laws such as the Forest Act have not incorporated this concept.

Normally soil and water conservation programmes go beyond the boundaries of individual farms and require the investment of funds with or without immediate returns, the maintenance of structures, and the sharing of long-term benefits. Therefore, strong legislative support for the success of such programmes is also needed (Samra et al. 1996).

Rainwater harvesting should be integrated into the programmes of agencies involved with water resources, agriculture, forestry/soil conservation, housing and settlement improvement, and road conservation wherever feasible. Research and pilot studies should be conducted to arrive at technologies for rainwater conservation that are appropriate for the location. Technologies should be disseminated and implemented through community participation and the mobilisation of relevant NGOs and INGOs (Dhungel and Bhattarai 1997).

What are the major constraints and opportunities in water harvesting?

The cost, particularly the initial investment, as well as the skills required are limitations for undertaking water harvesting projects. However it can mean the difference between life and death in some places, making economic aspects of minor importance.

Water harvesting will never be used in some areas because other water sources are more economical, or because annual precipitation is very low. Since water harvesting depends on natural rainfall, it is no more reliable than the weather. Without adequate storage facilities the system will fail in drought years. In locations with an average annual rainfall of less than 50-80 mm, water harvesting will probably never be economically feasible. Lack of rainfall data, especially intensity and variation information, in many areas makes it difficult to design a water harvesting system. Annual precipitation in excess of 280 mm is generally required to assure successful vegetation management. Potential for increasing runoff yield increases as annual precipitation increases (Dawud 1975). Less than 30 per cent of the runoff may be collected in dugouts to avoid hydrological imbalances (Sardar Riaz n.d.).

Benefits that may accrue from water harvesting systems

- Protection to eroding uplands
- Protection to downstream fertile lands from silt flow, floods and sand casting
- Land development in the command area of structure
- Flood moderation and drought alleviation
- Irrigation in winter and summer seasons
- Improved cropping pattern and increased production
- Increased biomass production from degraded or waste common lands

- Improved environment
- Generation of casual and regular employment

Advantages/ disadvantages

Surprisingly, the livestock or wildlife carrying capacity of many arid rangelands is limited more by water than by field limitations. Improvement and proper management of drinking water supplies increase the value of grazing lands and allow available feed to be better utilised (Martin and Ward 1970). Conventional methods of providing additional water to many arid areas, such as importation, require large amounts of energy. Water harvesting for both drinking water and crop production, however, requires only minimal energy inputs, most of which are associated with material production and construction (Morn and Mattock 1975). Overharvesting could result in destruction of water canals and other water bodies due to reduced surface water runoff.

Future directions

Research

A survey of natural watershed/catchment areas should be made in high, medium and low rainfall areas.

Pilot projects may be developed in watershed areas for developing and demonstrating rainwater harvesting techniques and soil moisture conservation practices that can serve as models for farmers from similar areas.

The feasibility of decreasing infiltration rates and increasing runoff on catchment slopes for greater water yields with less erosion can be studied by removal of vegetation cover, compaction, use of sealants or water repellent materials on the runoff area.

Research on selection of crops, cropping patterns, and production technology for runoff agriculture under various farming systems may be developed (Sardar Riaz, n.d.).

Integrated location-specific packages for rainwater harvesting should be developed to provide water for domestic livestock or agricultural purposes.

Site-specific hydraulic and structural configurations need to be evolved and standardised for different water harvesting structures.

Monitoring and data collection for creating a database, self evaluation of the system, improving design indices and assessing watershed responses.

Training

Technical assistance for designing shapes and types of catchments and suitable catchments for cultivated area ratios to allow maximum runoff on the catchment slopes and harvesting in the lower reaches for sustained crop production should be given.

Farmers, especially in medium and low rainfall areas, should be advised about *in situ* water harvesting techniques based on the principle of maximising infiltration rates and minimising runoff.

As the supply of water for household use is traditionally the responsibility of women, they should be trained in rainwater collection from rooftops/treated catchments and storage in tanks.

Training of technical manpower from government and non-governmental organizations engaged in such programmes is necessary to ensure proper implementation.

Policy

National and local water harvesting programmes should be formed to identify the resource base, components of work, selection and development of research cum demonstration sites. These sites should be used for obtaining necessary data and training of technicians, government officials and farmers in the programme.

As a matter of policy, small and micro water harvesting structures should form an essential component of water resource planning, development and management at the national/regional levels. Accordingly, resources and priorities should be allocated for water harvesting structures in watershed management plans.

Capacity building

New approaches and priorities should be geared towards integration of traditional knowledge, meeting local needs, and building capacities/capabilities at all levels. A community organizes itself to perform a particular task if the group as a whole stands to benefit from the intervention (Prema Gera 1993).

Conclusions and recommendations

Project sustainability can be ensured through establishing an appropriate environment and strengthening the capacities of institutions and strengthening the technical foundation and knowledge base of water harvesting.


Water wasted
Water harvested and managed

Sustainability can also be improved through collaborative (community) pilot water harvesting schemes that have a positive impact on socioeconomic conditions of local people and by protection of quality of harvested water from pollution.

More effective partnerships among government, private sector and community-based organizations are needed to promote and facilitate conditions in which people can actively create their own development responses.

There is a need for better understanding of the technical, organizational and managerial aspects of local water harvesting systems (LWHS) in micro watersheds.

Exploration of the feasibility of establishing water users' associations as the institutional mechanism for sustainable use of local water resources based upon the experience of LWH bodies.

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Water Management

M. M. Shrestha

Objectives

- To highlight present processes, trends and approaches in developing water resources and describe strengths and weaknesses in managing water for sustainable development of watersheds
- To describe the issues and complexities of water management problems in the present context of development
- To develop an appropriate strategy for water management in participatory integrated watershed management

What is water management?

Water management develops the physical and institutional control mechanisms necessary to make the water available for a specific purpose. Now, with increased competition for a given limited supply, the emphasis is shifting towards multiple purposes and sequential uses with the growing concern for water quality, pollution and the environmental system.

Definition

- 'Water management is the space-time-quantity-quality alteration of the water resource in and between various uses to meet societal goals.' Within this definition, all aspects of water development and use can be included. Both what is done with and to water influence the quality of life and the environment. There are five major levels of management: international, national, state, local and user.

What are the major users of water?

Nature

Nature is without doubt the largest consumer of water for only a small portion of the water falling as precipitation reaches the rivers or other manageable surface or subsurface supplies. Nature uses water to maintain all life and natural processes such as energy transfer, mineral deposits, climate, etc.

Culinary

Water used for drinking, bathing, washing, cooking and other household uses. Probably these would have priority over all of humanity's other uses.

Agriculture

This is, and undoubtedly will remain, the largest consumer of water managed by man. Evapotranspiration from lands with growing crop averages more than 50 t/ha/day. From 500 to as much as 5,000 t of water are required per ton of crops.

Other users

- Industry
- Energy
- Navigation
- Transportation
- Flood control
- Municipal
- Recreation
- Mining
- Aquaculture
- Land building
- Pollution and quality control
- Aesthetics

Water management problems are complex. Physical, economical, legal, sociological, biological, chemical, political, ecological, emotional or religious components occur at all levels of management for any of the major uses. During the 1980s, the public became increasingly aware that demands for fresh water and unchecked pollution of rivers and aquifers were putting many catchments and their dependent inhabitants in peril. Diversity of mountain environments and a lack of understanding make the search for solutions a challenging task.

What is a farmer-managed irrigation system (FMIS)?

In Nepal, FMISs exist traditionally on a self-help basis. They have contributed to the evolution and development of irrigated agricultural systems in Nepal. Two important characteristics of these FMIS are that they are developed and operated in a demand-driven mode, and they have assured participation of users at every stage. Many of these FMIS are performing satisfactorily, although some do not operate optimally. There may be several reasons for this.

What are the principles of the participatory approach?

The participatory approach embraces the principle of involving users at all stages of development and management: project identification, planning, design, construction, and operation and maintenance.

Major elements of the participatory approach include fostering feelings of ownership; decentralised joint decision-making; transparency in budgeting, planning and expenditure; user group empowerment; joint responsibility and accountability; sustainability through local resource mobilisation; and improved operation and maintenance by water users.

As a successful model for a turn over and joint management programme, the Irrigation Management Project (IMP) began in 1986 under USAID financing (Figure 1).

The implementation process for participatory irrigation management (PIM) has three phases (Figure 2).

Phase I: Initial organization: Establishment of an *ad hoc* WUA
Baseline assessment: Initial baseline characteristics of the system to be studied.
Formation of WUA: Water users are organized into multi-level organizations with institutions, elections, and legally registered associations.

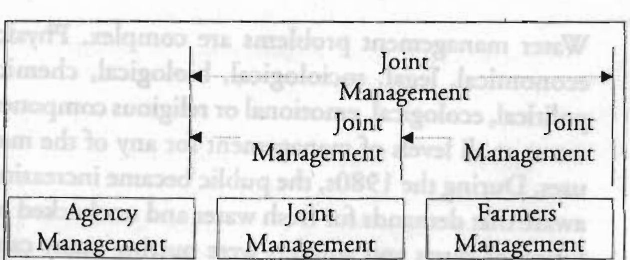

Figure 1: *Joint management and turn over in the management transfer continuum (Laitos and Rana 1992)*

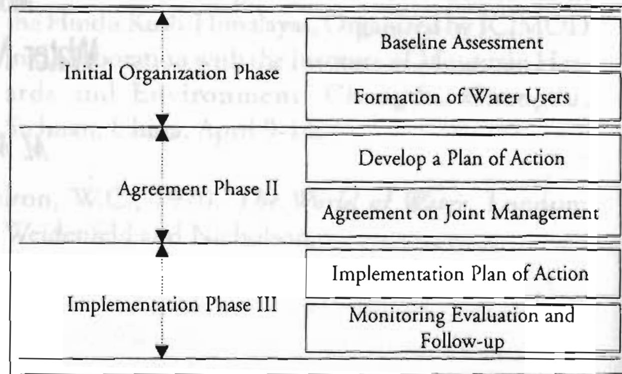

Figure 2: *Framework for joint management and turn over*

Phase II: Joint agreement between WUA and the agency
Joint development of action plan
Agreement of joint management activities: who does what and when ?

Phase III: Implementation of programme (three to five years).
Implementation of plan of action
Monitoring, evaluation and feedback developed and implemented by both WUA and agency

The incentives to be provided to farmers to assume management responsibilities sustainably are as follow.

- Extending the right to fix and collect service fees — including incentives on prepayments and collection rates
- Access to information and participation in decision-making processes on systems' operation and maintenance
- Explicit water rights for the WUAs
- Transfer of required government machinery and assets to WUAs
- Programme, budget and outcomes transparent to WUAs
- Involvement of WUAs in all the stages of development
- Technical advisory services provided by the agency
- Training of WUAs and farmers

Examples of farmer-managed irrigation system

Case studies of the Chhattis Mauja Irrigation System and Pithuwa Irrigation System

While the Chhattis Mauja Irrigation System was initiated by farmers, the Pithuwa Irrigation Scheme was originally developed by the Department of Irrigation (DOI). Subsequently users took over the operation and management of the system.

Membership defined by property rights: The FMISs in most cases are found to exercise some kind of property right in defining membership and irrigation access. In Chhattis Mauja, membership in the system is defined by *kulara* (one person-day of labour for canal maintenance) entitlement. The resource mobilisation, obligations and participation in decision-making are also tied to irrigation entitlement. In Pithuwa, the size of the branch canal outlet has been the basis for irrigation allocation and resource mobilisation. Such a link has been the basis for collective obligations and compliance to the rules in use.

Local control of institutional innovation: In FMIS the rights, roles and duties are entirely under local control with users themselves defining the roles and duties for operation and management. The rules and roles of the users are tailored to local needs and the interests of the users. They are not rigid. They are developed, modified and tried again, matching the system dynamism and changing the needs and preferences of users.

Prompt decision-making and effective enforcement: Prompt decision-making and effective communication of decisions ensure a higher degree of compliance to the decisions. In Chhattis Mauja, the *mukhtiyars* and messengers (officials of the village-level organization elected for a fixed term by villagers) at different levels of the system have the responsibility for communicating decisions. In Pithuwa, the communication of decisions is through the functionaries of the WUA at the main and branch canal levels. Also, the mechanism of irrigators being pressured by neighbours to comply with rules in both these systems has led to the evolution of collective obligation on the part of users. The enforcement of the rules is backed by a system of penalties that match the severity of the defaults.

Equity in resource mobilisation and irrigation access: Equity in resource mobilisation and irrigation access has been the basis for prompt and assured mobilisation of resources and compliance to rules. Users are assured of a share of water in return for their investment of time,

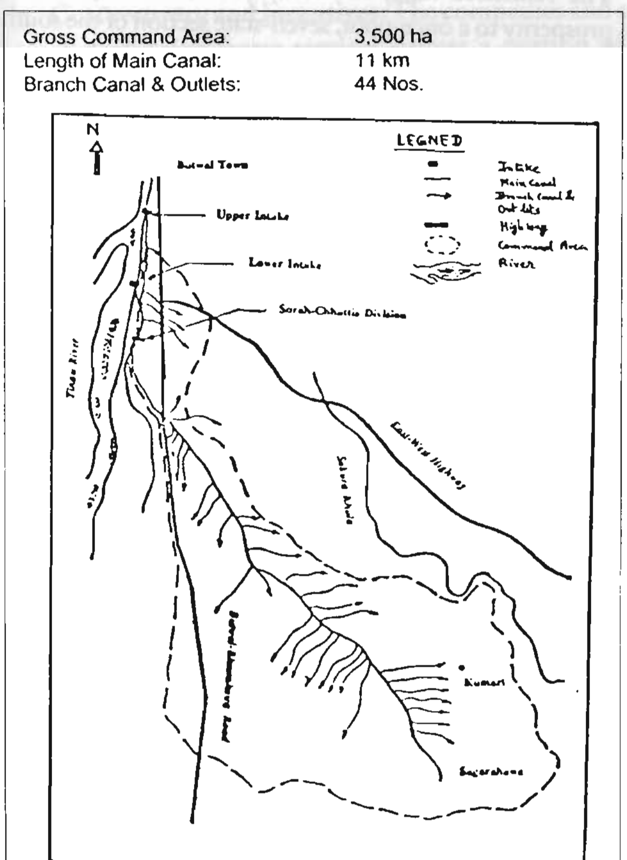

Figure 3: *Chhattis Mauja Irrigation System*

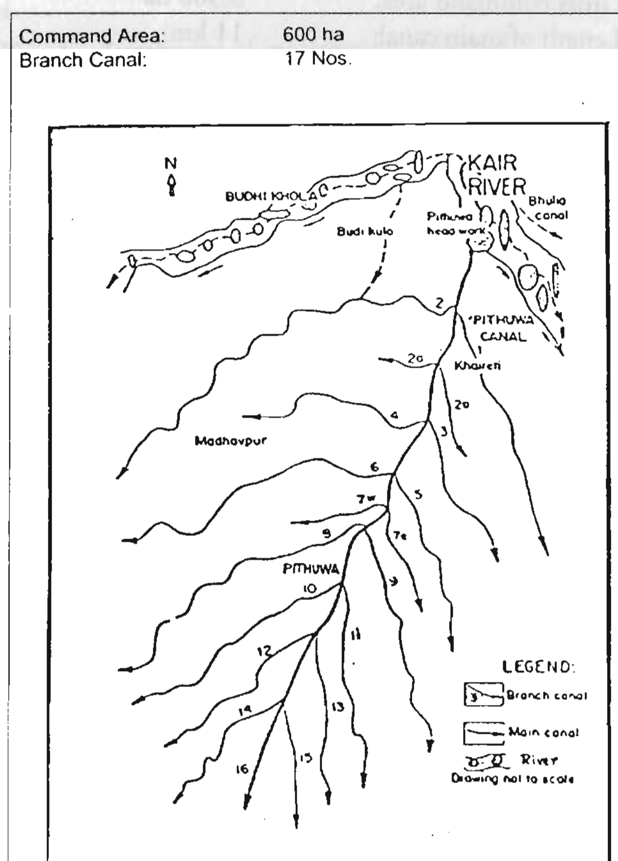

Figure 4: *Pithuwa Irrigation System*

labour and money during construction, operation and maintenance of the system. In Chhattis Mauja and Pithuwa, water allocation in each branch canal and therefore irrigation entitlement is determined by the size of the branch canal inlet. The inlet size is also used as a basis for cash and labour resource mobilisation during repair and maintenance. Within the branch canal, timed rotation of irrigation delivery ensures equitable distribution. Equity in both the systems is also ensured by regular monitoring of branch canal inlets. The inlet openings are adjusted to ensure equitable allocation. Regular monitoring of outlets eliminates the chance of free riding. Rotation among the branches is the usual practice of ensuring equity in water delivery between head and tail reaches during the period of diminishing water supplies.

Transparency and accountability: The FMISs maintain transparency in rules and regulations, accounts and book-keeping. The functionaries of the WUA are accountable to the users and therefore the chances of favouritism and fraudulent behaviour are minimised. In Chhattis Mauja and Pithuwa, the general assembly of the users provides an open forum to expose problems. Any functionary may be questioned if his/her function and performance are inconsistent.

Gross command area:	3,500 ha
Length of main canal:	11 km
Branch canal & outlets:	44
Command area:	600 ha
Branch canals:	17

What are the principal failures in agency-managed water resource systems?

Fragmentation between sectors and institutions: Water management within an agency system is fragmented among sectors and institutions with different agencies developing the same water source for different uses.

Heavy dependence on centralised administration: The agencies charged with water management are severely over-extended and have limited technical capacity to provide quality services. They take the leading role in participation and in managing water resources. The result is unreliable projects that produce services that do not meet consumers' needs and for which they are unwilling to pay.

Water is not treated as a an economic good: Most countries do not treat water as an economic good. The absence of financial discipline has an especially negative impact on the incentives and accountability of public authorities to provide high-quality services; water has the least cost recovery (World Bank 1994).

Water is not linked to health, the environment and economic development: Environmental degradation of water resources causes human suffering and burdens future generations with the cost of remedial actions. Integrated water management based on the perception of water not just as a basic human need, but also as an integral part of the ecosystem, a natural resource, and a social and economic good.

The new approach calls for policies that take into account the interdependencies among sectors and protect aquatic ecosystems. Incentives for financial accountability and improved performance should be created through greater use of pricing, decentralisation of administration and services, financial autonomy, user participation, private sector investment, consistent rules and regulations, and co-ordination among agencies responsible for water services.

How to manage water in multiple jurisdictions?

Managing water in multiple jurisdictions with an integrated approach (large-scale development)

The Tennessee Valley Authority (TVA) has helped bring prosperity to a once-poor, seven-state section of the southern United States. The TVA has promoted the linkage of land and multipurpose, real-time water management in an integrated manner as a way to conserve natural resources and improve water resources' management and restore the basin's ecosystem. The TVA serves as a facilitator to co-ordinate fragmented interagency actions and encourage local co-operation to improve the co-ordination of separate land management programmes. In conjunction with the new approach, TVA is facilitating interagency co-operation, on a federal, state and local government level to co-ordinate management of land and water resources. Through this programme, which is operated by an interagency steering committee, water pollution and environmental impacts caused by agricultural, mining, forestry and urban development are being reduced.

France's 'Model' System

The French system of water resources' management, adopted after many years of study and debate, includes many excellent features that could serve as models to help industrial and developing countries as they look for the best way to put a comprehensive approach into action (World Bank 1993). There are several key elements.

Well-defined laws and regulations: The Water Acts of 1964 and 1992 are the foundation of the French system. The earlier law describes specific quality objectives and regulations for pollution control, while the latter act is designed in part to meet stricter European directives on water management.

Hydrographic basin management: The system is organized around six major hydrographic basins, with appropriate national policy direction. These correspond to the country's four main catchment areas and to two areas of dense population and intense industrial activity.

Comprehensive management decentralisation and participation: Each of the six basins has a basin committee and a corresponding executing agency, a water board. The basin committee also known as a 'Water Parliament', because of its representation and powers, reflects regional rather than central government control and is designed to promote the role and responsibility of different interest groups in the basin. The water boards, while executing the committee's directives, are also responsible to the central government for certain technical matters (such as upholding national standards). Water and sewerage services are provided by either public or private firms (increasingly through competitive bidding) and are chosen by communities.

Cost recovery and incentives: The companies and entities operating water services deliver a portion of the charges they collect to the basin agencies. In addition, a 'pollution fee' (a penalty) is collected by the basin agency. Most of these revenues are reinvested into the system to provide technical assistance and to help the public or private sector ensure that water is safe and purified.

Supporting research: About 14 per cent of the water boards' expenditures in 1992-1996 were budgetted for research and development.

Managing water resources with a new approach (small-scale appropriate technology development)

Greater private sector and user participation offers an effective means to decentralise water resources' management and increase the responsibility of users for managing and financing water resource projects.

Four different approaches to introducing private sector incentives as are follow.

- Forming water users associations
- Transferring management functions from government authorities to water users' associations
- Introducing irrigation service fees
- Developing private wells

Some important concepts in achieving the above tasks are as follow.

- People's participation
- Poverty alleviation
- Strengthening policies on land use and management
- Water conservation technology
- Low-cost technology for protecting against disaster

BASIN approach planning in a comprehensive framework for PIWM

The adoption of a comprehensive framework for analysing policies and options would help guide decisions about managing water resources throughout a basin. The framework would facilitate the consideration of relationships between the ecosystem and socioeconomic activities in the watershed (Figure 5).

- Basin-wise information collection
- Assessment of information collected
- Strategy formation
- Integration, control, and implementation of strategy
- Network development for dissemination
- Network development

B: Basin-wise information collection
A: Assessment of information
S: Strategy formation
I: Integration of strategy
N: Network development

Conclusion and recommendations

- Project planners should carefully assess water resources within a comprehensive framework before the design and implementation stage.
- More detailed guidelines, training and information should be provided to the implementor, especially

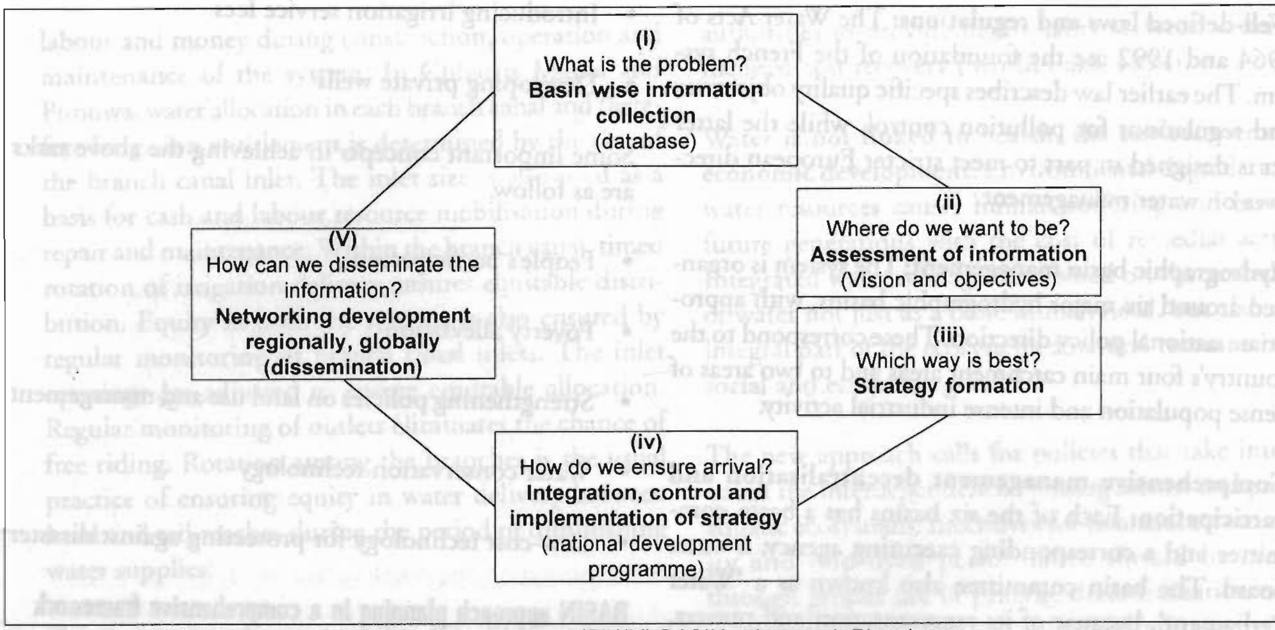

Figure 5: *Participatory integrated watershed management (PIWM) BASIN – Approach Planning*

for co-ordinating intersectoral water resources management, designing and administering fee structures, and monitoring project performance.

- Poverty relief should be a project goal at the design stage.
- Water users should be given more responsibilities for managing water. In addition, where feasible, emphasis should be given to private pumping and small-scale systems managed by users.
- To protect the environment, drainage networks should be an integral part of the basic design of all irrigation systems, the water table should be continuously monitored for operating irrigation projects, and erosion control and reforestation programmes should be an integral part of the project design for reservoir catchment areas.
- The following recommendations are relevant in promoting participatory irrigation management (PIM).
- Commitment at the political and management level
- Improved policy and legal frameworks to support the programme to fit the local conditions
- Improved management environment in the agency with a clear vision and commitment
- Sufficient training programmes to be developed to further orient and train agency staff and WUAs to cope with emergency situations in the field
- Adequate provision for financial support for institutional development should be part and parcel of the programme.
- To reap the long-term, full benefits of increasing agricultural production, PIM should be accompanied by support activities, input supply, credit, marketing, land reform, etc.
- Users' participation is to be encouraged, making programmes, budget and outcomes transparent.
- WUAs must be administratively, technologically and financially capable before their irrigation systems are completely turned over.
- Guidelines for implementation issued by the centre should have uniformity in approach.

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MODULE 3

New Methods, Skills and Tools in Participatory Integrated Watershed Management

Methods of Preparing Verifiable Environmental Impact Statements (EIS)

M. Ghimire and B. Upreti

Objectives

- To describe an environmental assessment process for watershed programmes with emphasis on how to conduct assessment and prepare an EIS or an assessment report with a participatory approach
- To outline the steps for environmental assessment where local people have an opportunity to participate from the planning stage to its implementation and monitoring
- To consider the role of local people in developing and implementing the EIS to manage and utilise their watershed resources on a sustainable basis and to highlight the benefits of preparing an EIA through a participatory approach

Definitions

The environmental impact statement (EIS) is a document written in a format prescribed by law or terms of reference (TOR). It contains a summary of the environmental inventory and the findings of the environmental assessment and is presented to decision-makers. It may also be opened to the public.

The EIS is also called an environmental statement, impact statement or environmental impact assessment. The environmental impact assessment (EIA) is to identify, predict, interpret and communicate information about the environmental impact of an action. Information and findings of the EIA are put into the EIS report. As in many other reports, the EIS report is prepared in two stages as a draft statement and final statement. The draft statements after review by the competent authority and the public, as applicable, are made final.

Why is EIA needed?

Watersheds experience increasing environmental degradation because of development activities. Such degradation is a major concern for the people both in the mountains and the plains. Mountain people experience the problems of increased soil loss and landslides while the people living in the plains are affected by deposition of unproductive soil on productive farmland. The source of the problem, by and large, is human activity in the watersheds.

Preparation of the EIS for a (watershed) development project largely facilitates the concerned organization to design actions holistically. A good EIS is prepared through a participatory process. People's participation has contributed to selecting and implementing programmes with intensive interaction among stakeholders. To this end, preparation and implementation of the EIS contributes to resource management and improves the quality of life of local people living in the watersheds. In this process, all the stakeholders are actively involved: the stakeholders' concerns are adequately accommodated, and the stakeholders implement the EIS. In sum, an EIS is prepared to ensure that watershed management activities address environmental concerns adequately and that the local people are fully involved in the management.

The EIS must integrate environment and development; but this integration is not that simple. A sectoral outlook that attempts to accomplish the targets generally guides the development process. However, the environment is a multi-disciplinary and multi-sectoral subject. Significant environmental effects of development actions are both direct and indirect.

What are the important dimensions of EIA?

A systematic procedure for the EIA should be introduced into the project cycle before implementation (Figure 1).

The EIA deals with methodologies and techniques of planning, environmental analysis and management of project proposals. The EIA provides the relevant

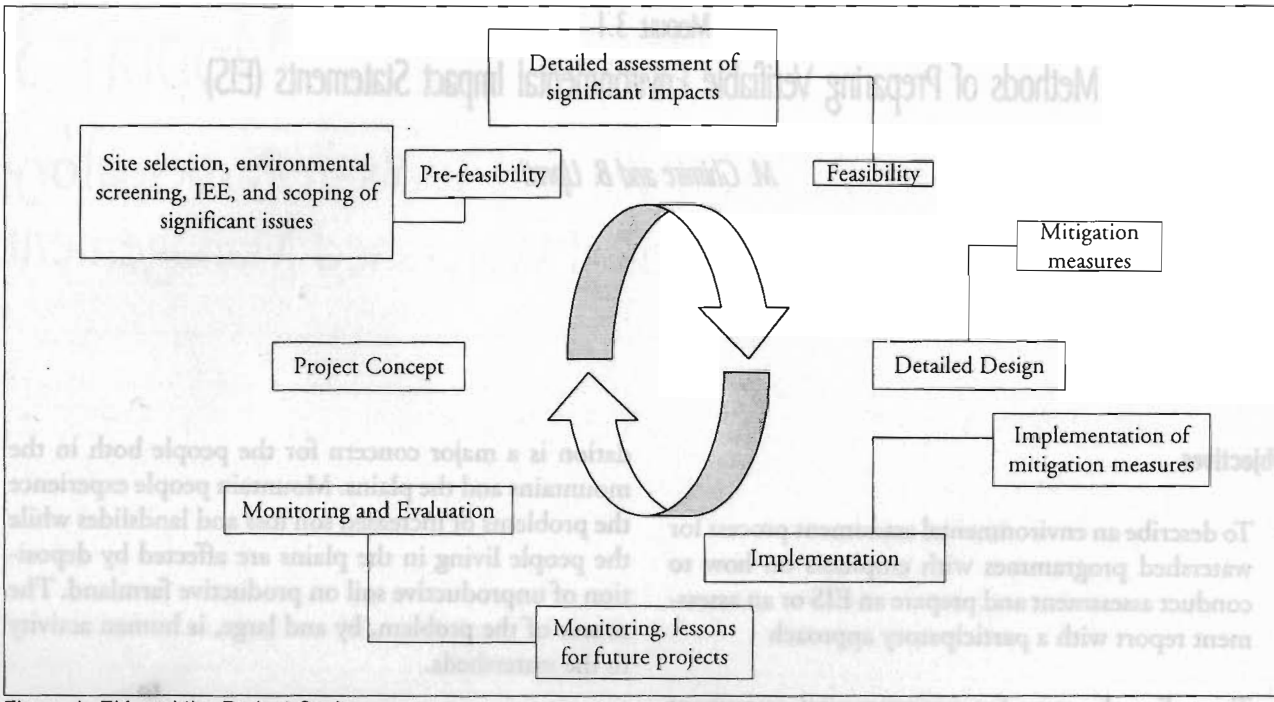

Figure 1: *EIA and the Project Cycle*

stakeholders with details about assessing and mitigating the environmental impacts of actions proposed. The EIA (and the EIS) influences the decision-making process at various levels. It is used to

- identify likely impacts of the proposed action on the environment,
- analyse, predict and evaluate the significance of the impacts and present options for decision-makers,
- provide corrective and preventive measures to each adverse impact,
- provide measures to augment beneficial impacts,
- recommend a monitoring and evaluation system including indicators, methods and responsible agencies during project implementation,
- provide information on the framework of environmental auditing, and
- recommend whether the proposed action should be implemented and in what form.

Types and topics of assessment reports

Different types of impact analyses are carried out at different levels. At the project level, detailed impact analysis is done through an EIA; at the regional level, a regional environmental assessment (REA) is carried out to assess cumulative impacts; and at the programme and policy levels, a strategic environmental assessment (SEA) is done as a new generation of the EIA.

The environmental analysis contains a description of the environmental impacts of the proposed action. The EIS should also contain a list of, primarily, negative impacts that cannot be avoided during the project implementation. It should recommend whether the project should be implemented even if the impacts are unavoidable.

The EIS should focus on the possible alternatives and the likely environmental impacts of each alternative. It should also focus on short-term needs and enhancement of long-term productivity. Adequate attention should be given to future options if there is a possibility of removal of resources.

If these issues are addressed, then the EIS will be considered as reasonably pragmatic.

Environmental Impact Analysis: Process and Decision-Making

The proponent or the approving agency should screen the proposal to understand the level of environmental assessment required. The screening activity helps divide the actions proposed into the following categories

- project clearly requiring an EIA,

• project not requiring an EIA, and

• need for an EIA is not clear.

In Nepal, for example, according to the Environment Protection Rules 1997, an initial environmental examination is required for a watershed management plan. However, there could be many more sectoral projects implemented in, and/or passed through, the watershed area. These projects should also undergo screening for impact assessment. If it is unclear, it is appropriate to screen the project as in Figure 2.

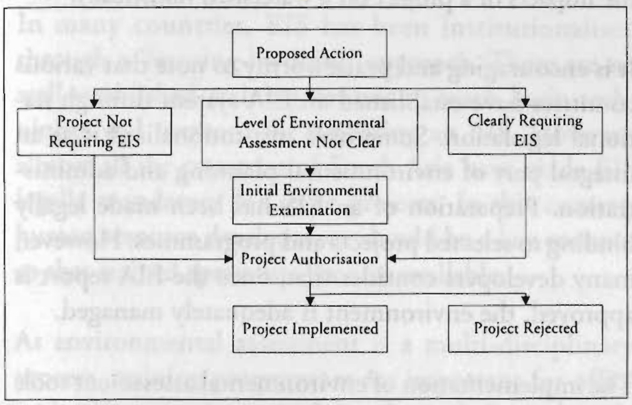

Figure 2: *Project screening for EIA*

The second step of the environmental assessment is to appreciate the scope of the study: often called scoping. This step helps identify issues and areas to be covered by the study. A plan for public involvement is made, relevant information collected, and a public notice for the attention of people likely to be affected by the proposed action is issued. Scoping identifies major issues of public concern, evaluates the seriousness of issues raised, sets a priority on the issues, and develops a strategy for addressing the priority issues. The scoping report leads to the development of the terms of reference (TOR) to guide the preparation of the EIA or the EIS. The EIA should also contain a framework for environmental audit. The detailed process of EIA report preparation is given in Figure 3.

The environmental assessment exercise requires a multidisciplinary team of experts. As set out in the TOR, various impacts—biophysical and socioeconomic—should be identified. The impacts should be rated as direct, indirect or cumulative, and as of a reversible or irreversible nature. Various methods, such as checklists, matrices, networks, overlays, etc, can be employed. Mathematical models (cause-effect relationship), statistical models (data-hypothesis relationship), geographic models (possible effect of project on resources), field experiments, and expert judgement are also used to assess the impacts and prepare the EIS (IUCN 1997).

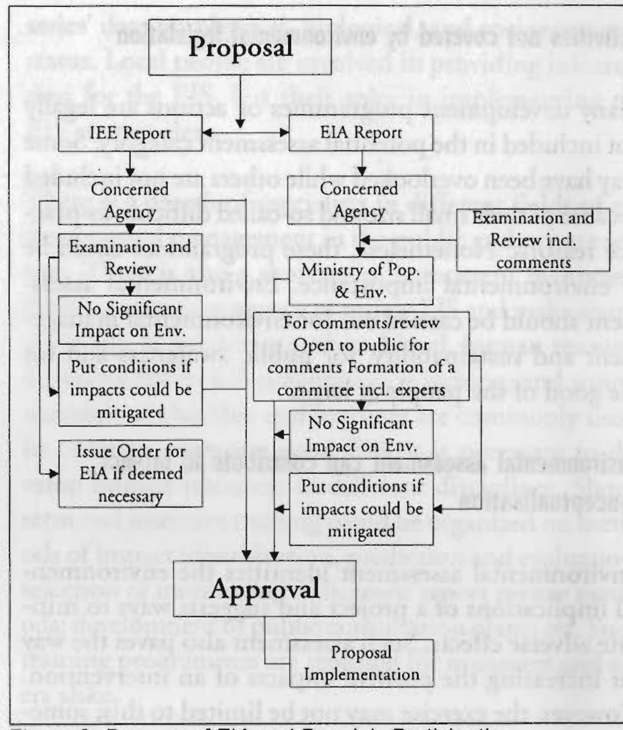

Figure 3: *Process of EIA and People's Participation*

During the assessment process, local people are directly or indirectly involved in furnishing information to the reporting team. Once the report is prepared it should be made public to encourage people's advice, suggestions and comments.

Nepalese Legislation

In Nepal, the Environment Protection Act 1996 (EPR) and Environment Protection Rules 1997 (EPR) require a scoping report by the proponent for all proposals as mentioned in the legislation (HMG 1997). The proponent is required to issue a 30-day public notice regarding the nature of the proposed action for a particular area. The people may submit their concerns or issues to be included in the terms of reference and addressed during the study. All such issues should be well documented in the scoping report.

The legislation also has provision for penalties. A maximum penalty of NRs 100,000 (approx. US$ 1,500; US$ 1 = NRs 67.35, Dec 1998) may be imposed on anyone who implements a project requiring environmental assessment without approval of its environmental report. In this case, the Designated Officer may also issue an order to stop the project activity immediately. The legislation has also a provision for Environmental Inspectors to inspect and report on proposal implementation.

Activities not covered by environmental legislation

Many development programmes or actions are legally not included in the potential assessment category. Some may have been overlooked while others are not included because of their small size and so-called difficult-in-practice reasons. Nonetheless, these programmes could be of environmental importance. Environmental assessment should be carried out for environmental management and sustainability, for public awareness and for the good of the people at large.

Environmental assessment can contribute to project conceptualisation

Environmental assessment identifies the environmental implications of a project and suggests ways to mitigate adverse effects. Such assessment also paves the way for increasing the positive impacts of an intervention. However, the exercise may not be limited to this; sometimes it creates a situation that allows for the development of a new project concept. An example in Nepal is presented in Box 1.

Main lessons

A number of countries prepare EIS prior to the approval of proposed actions in order to inform decision-makers and the public on likely environmental impacts. Environmental assessment studies help in the preparation of EIS. Generally, they overlook the impacts of macro-level policy, plans and programmes. An assessment of cumulative impacts is usually outside the scope of the project-level EIAs; these EIAs focus on project-specific impacts. However, a higher level of environmental assessment, such as an EIS, opens opportunities for integration of environmental aspects in development proposals, assesses cumulative impacts, focusses on maintaining a chosen level of environmental quality, and creates a framework for measuring impacts and benefits of environmental improvement activities (IUCN 1997). It is important to see the impacts of a project on a watershed holistically.

It is encouraging and praiseworthy to note that various countries have established an EIA system through national legislation. Some have institutionalised it as an integral part of environmental planning and administration. Preparation of an EIS has been made legally binding to selected projects and programmes. However, many developers consider that, once the EIA report is approved, the environment is adequately managed.

The implementation of environmental assessment tools has been limited due to the weak institutional capacity for enforcement. This includes inadequately trained human resources, a lack of information dissemination and database systems, and a lack of procedures and criteria for reviewing assessment reports and for integrating rec-

Box 1

EIA study that changed the project concept

In the mid-1980s, a scheme was designed to irrigate about 5,300 ha of the northern part of Tandi and Bhandara, Chitwan District, in the central Terai. The southern part of the project area had a well-established farmer-managed irrigation scheme. The plan was to divert water from the East Rapti River. This river runs through the Royal Chitwan National Park located south of the proposed site. The National Park was established in 1973 and is home to a number of protected wild animals. In 1984 it was included in the UNESCO World Heritage List. The river provides an aquatic habitat for 44 species of fish and is a perennial water source for grassland mammals.

The highest average discharge rate of the Rapti River was estimated to be 180 m^3/sec in August during the monsoon with a dry-season average flow of 17.4 m^3/sec and a mean annual flow of 62 m^3/sec. The project was designed to provide a 400m–long diversion weir across the Rapti River to divert a maximum flow of 14.3 m^3/sec. An under sluice, guide banks and a 3.7m–wide fish ladder was proposed for construction. Similarly a self-flushing *de-sander*, 21.9 km of canal networks and 24.6 km of drainage networks were also designed to protect the river bank and distribute the water.

After the project design was completed, the National Park authority and NGOs raised the question of environmental impact. The proponent then conducted an EIA study. The study identified, predicted and evaluated the likely environmental impacts of the diversion of water for irrigation during the dry season. The project was likely to affect flora and fauna including rare and endangered animals, income generation from eco-tourism in the park, and cause possible contamination downstream from chemical fertilizers and pesticides.

The EIA study concluded that the project should not be implemented as envisaged and that the farmer-managed irrigation scheme should be strengthened. The study further concluded that the recharge of the river downstream should be monitored for at least two years. The EIA changed the project concept and reformulated the project.

ommendations into project design and contract documents. Also, mechanisms for public consultation and for monitoring and evaluation are grossly inadequate. The responsibilities of non-governmental and private organizations, affected people, business communities, academicians, professionals, and politicians should be counted on to strengthen this system. Other ingredients such as education, research, professional development, etc are equally important for preparing an EIS and implementing it more effectively.

Future directions

In many countries, EIS has been institutionalised through a 'learning-by-doing' approach. There are no well-established training centres to teach basic techniques and methods for preparing an EIS. However, almost all the countries of South Asia have made EIS legally mandatory for some projects. In this context, human resource development should be a key concern so that trained specialists become available.

As environmental assessment is a multi-disciplinary process, training programmes are important for officers in the approving agencies and people from the private and public sectors. Since environmental management is a rapidly growing area, the people concerned must be exposed to recent research and development on environmental assessment. Furthermore, education, training and extension programmes for local people are important if the assessment is to be realistic, implementable, far reaching, and effective.

Conclusion and recommendations

Watershed management activities are generally environment-friendly. The impacts of other sectoral projects and programmes implemented in the watershed areas are generally overlooked in such activities. The watershed area should be considered as a development unit, and an EIS should be prepared with people's participation prior to the implementation of any development programmes. This process will provide a basis for identifying the cumulative impacts of programmes and ensuring intersectoral co-ordination during programme implementation. This will also help to assign the responsibilities of each development partner involved in watershed management.

Preparation of an EIS is a legal requirement in many countries. EIA reports are generally prepared at project level, and cumulative impacts of the proposed action are, in most cases, overlooked. EIA reports are prepared on a value-judgement basis because of the lack of time-series' data on physical, biological, and socioeconomic status. Local people are involved in providing information for the EIS, but their roles in implementing the EIS are not clear.

There is a dearth of specialists in different fields of environmental management in the public and private sectors. There is also a shortage of competent manpower in the government agency to review EIS and make sound decisions. In countries such as Nepal, human resource development in EIS preparation is lacking, and simple methods of checklist and matrices are commonly used. In order to prepare a good EIS, it is necessary to develop human resources in different disciplines. Short-term and intensive training could be organized on methods of impact identification, prediction and evaluation; selection of monitoring indicators; report review methods; development of public consultation plans; etc. Such training programmes are required for managers and users alike.

Environmental effects of small but collectively significant programmes are generally not assessed. Such assessments should be made for environmental and sustainability reasons, if not for legal obligations. Simple guidelines for conducting such studies are needed. Mass awareness about environmental effects of development programmes on watersheds is needed.

A myth prevails that the environment is managed once the EIS is prepared. There are weak or no institutionalised monitoring and evaluation systems, and use of monitored information in programme design and future planning is also lacking.

The EIS provides a basis for linking different development programmes within a watershed area. The statement helps to manage the resources and deal with the environmental impacts of development. The EIS should be integrated into watershed development planning not only in its preparation but also in its implementation and evaluation. A good EIS report ensures local people's participation and the involvement of all stakeholders.

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Application of Strategic Environmental Assessment (SEA) in Watershed Management

R. B. Khadka

Objectives

- To provide some insight and describe briefly the significance of strategic environmental assessment (SEA) in terms of its concept, methodology and the processes being used globally

Why is Strategic Environmental Assessment (SEA) needed?

In order to bring environmental balance and sustainability, there is a need for developing a new perspective that combines social, economic, and environmental concerns in watershed management where optimal utilisation of natural resources and urban parcels are treated in an integrated manner. Development of such a new perspective in watershed management with appropriate integration of strategic environmental assessment (SEA) is required, in order to ensure a sustainable balance of ecological, economical and sociological parameters.

In most conventional watershed management, the integration of environmental assessment in order to address the causes of unsustainability emanating from the implementation of development proposals is ignored. Watershed management is considered as environmentally benign and conservation-oriented. However, watershed management activities can be complex, ranging from simple rehabilitation measures to the construction of large irrigation channels, feeder roads, bridges and other infrastructure, most of which have significant environmental effects. The application of project-level EIAs on a project-by-project basis is cumbersome, time-consuming, expensive, and ineffective. Therefore, the integration of SEA at the planning stage for evaluating the management plan from an environmental point-of-view could be beneficial and effective. It could minimise most of the anticipated adverse environmental impacts that are likely to emanate from plan implementation.

SEA: general concept, process and method

What are the inefficiencies, inadequacies and limitations of EIA?

Integration of environmental impact assessment (EIA) in development projects was initiated almost 30 years ago with the enactment of the Natural Environment Protection Act in the USA. The primary objective of integrating EIA in development proposals was to make economic development projects environmentally sound and sustainable. EIA proved useful in ensuring a balance between environmental conservation and economic development objectives. Consequently the adoption of this tool spread to most countries of the developed world during the 1970s and 1980s. More recently, developing countries have also adopted this tool as one of their national instruments in order to protect and conserve the environment from the harmful effects of development project implementation. Most have enacted EIA laws and regulations, establishing appropriate institutions and administration procedures and developing human resources. However the implementation of EIA has not yielded the expected output in terms of combining the aims of conservation and development. Experience from developed countries indicates that the implementation of EIA at the project level is constrained by a number of deficiencies such as the following.

- EIA is a self-limiting process (reactive) and is not able to tackle the current scale of the global ecological deterioration.
- It is not an effective tool to analyse and assess the cumulative impact.
- It does not go beyond the process of impact fixation.
- It is often applied to assess the downstream impacts of a decision-making cycle and therefore does not influence upstream decision-making in which the

real cause of environmental unsustainability is believed to be rooted.

- It does not consider project alternatives.
- It is not able to assess the impact of non-project actions.
- EIA is of limited value when it is considered only as a mechanism for obtaining government clearance for the execution of a project—a situation common in most developing countries.

Is SEA a second generation EIA process? Where is it applied? Whom does it address?

Realising the ineffectiveness of project-level EIA, a second generation EIA process called strategic environment assessment (SEA) has been adopted recently. SEA is applied at the upper level of decision-making, particularly at the policy, plan and programme levels. The effectiveness of SEA goes beyond the process of impact fixation and is effective in reducing the causes of unsustainability that usually lie at the upstream level of decision-making. SEA, if applied at the upper level of decision-making, addresses all major environmental issues resulting from activities proposed and contained within a plan.

Definition of SEA, similarity and differences with EIA

SEA is defined as a systematic process for evaluating the environmental consequences of proposed policy plan and programmes initiatives in order to ensure they are fully included and suitably addressed at the earliest appropriate stage of decision-making. In other words, SEA is an EIA of policy, plan and programmes. The procedural aspects of SEA are similar to EIA, but SEA at the strategic level addresses issues at the upper level of decision-making, whereas EIA addresses project-level activities. Therefore, SEA differs from EIA in its scope and the dimension of issues to be covered.

A policy is defined as an inspiration and guidance for actions, a plan represents a set of co-ordinated and timed objectives for the implementation of policy, and a programme is a set of projects to be implemented in particular areas. SEA can be applied to all these actions and in their associated decision-making cycle. Policy, plan and programme (PPP) may be sector-specific such as transport, mineral extraction, forestry, etc. It can also be spatial such as national, local and regional. PPPs are tiered, in the sense that a policy provides the framework for the establishment of a plan, a plan provides a framework for a programme, and a programme leads to projects. However in practice these tiers are fluid and have no clear-cut divisions. When SEA is applied to different tiers of PPP the major environmental issues are often addressed and those which are apparent in project implementation are resolved by the application of project-level EIA. Therefore, if the major impacts have been addressed at the upper level of decision-making through the application of SEA, then minimum attention needs to be given to environmental issues at the project level.

What are the merits of SEA?

The application of SEA at PPP level has the following merits.

- SEA applied at the upper level of the decision-making cycle influences downstream decision-making and implementation.
- SEA provides an opportunity at the upstream level for considering alternatives that may make the process more sustainable environmentally.
- SEA strengthens project-level EIAs, making them more sequential, and reduces time and effort involved in their preparation.
- SEA is effective in tackling the environmental effects of large-scale programmes (regional, transboundary, watershed and global) and their cumulative effects.

How many types of SEA are there? What are their specialties?

Types of SEA

Several important activities, including project and non-project development actions which can not be addressed easily by project-specific EIAs, are usually subjected to SEA. They include the following.

<u>Sector-specific SEA</u>

Sector-specific SEA is the process of examining environmental and social implications of all or most project proposed in the same sector. Sector-specific SEA can influence project selection more easily than project-level EIA. It provides environmental ranking of all projects proposed before pre-feasibility and helps in project selection (for example, in the power sector, coal vs. hydro vs. thermal; or in the transport sector, road vs. railway vs. airport). Initially SEA sets a development objective and then evaluates a number of possibilities for achieving the set objective. For example, if there is need for 2,000 MW of power for a certain location, SEA evaluates a number of viable project options: this is not possible through project-specific EIA.

A sector-specific SEA can

- provide an environmentally and economically sound strategy to achieve objectives,
- introduce non-traditional options into the planning process at an early stage,
- help in ranking potential alternatives in sequence of environmental soundness,
- start gathering existing data and identify data gaps,
- make project-specific EIA cheaper, quicker and robust,
- make things transparent so that the project selected is acceptable to taxpayers and people affected, and
- help minimise political pressure in project selection.

Regional SEA

A regional SEA analyses cumulative impacts resulting from the implementation of environmental, social, economic and multi-sectoral developments within a defined geographical area over a certain period of time. If an area, such as a watershed, is likely to be subjected to intense development pressure then there is a need to analyse the effects of the likely impacts and proposed mitigation measures. This can be performed in two ways. The project proponent can undertake individual project-specific EIAs (such as for irrigation, hydropower, road construction, town development, etc). In such cases, impacts from all activities should be summed up through cumulative impact assessment. Alternatively SEA can be applied at the planning stage for all activities in order to reduce the anticipated impacts. The former method is cumbersome, ineffective, expensive, and time-consuming. However the application of SEA is more effective, quicker and cost-effective.

Cumulative SEA

The cumulative SEA focusses on assessing the impact of currently proposed projects added to the impact from existing development projects and the impact of foreseeable future projects to be implemented in the same area. The distinctions between cumulative and regional SEA are not sharp and, in some cases, they overlap in concepts and application. However, a cumulative SEA deals with the synergy of the impacts of past, present and future development projects whereas a regional SEA deals with the future consequences of implementation of plans and programmes in a defined watershed area. Box 1 illustrates the application of SEA in a forestry sector management plan.

An example of sectoral SEA of Bara District Forest Management Plan

Background

Forty-two percent of Nepal's natural forest is protected by law. However, extraction of timber, fuelwood and fodder, and deforestation for acquiring agricultural land are still common practice. As a result, the forest area of Nepal is degrading at an alarming rate, if this continues the remaining forest area will be degraded within the next 20-25 years. The Forestry Sector Master Plan (1988) realised that current practices of protection-oriented forest management are not enough to maintain and conserve forest resources. Production-oriented forest management planning is necessary for sustainable use of forest resources. With these objectives in mind, the Department of Forests in collaboration with the Forest Management and Utilisation Project (FMUDP) developed a strategy for the production-oriented forest management planning that relies on the natural regenerative potential of sal *(Shorea robusta)* trees.

Project description

The operational forest management plan (OFMP) proposed covered 26,000 ha of forest in Bara District. Harvesting was to be carried out initially on 14,000 ha for the first five years. However, the implementation of the OFMP included activities geared towards shifting from protection–oriented to production-oriented forest management and encompassed an array of adverse and beneficial impacts associated with biophysical, social and economic conditions. Government-endorsed national and forestry sector guidelines require EIA for such a large project that changes the management regime from one type to another. Therefore, an EIA was carried out for the OFMP, and two alternatives were analysed: the 'do-nothing' alternative that evaluated the impacts if the existing situation continued and implementation of the proposed management plan.

Impact analysis

Based on background reports and scoping exercises, 19 environmental impacts were identified. Each impact was evaluated and its magnitude, extent and duration were predicted. The following critical environmental impacts were identified.

- Fuelwood gathering for domestic use
- Forest clearing
- Grazing
- Wood-cutting
- Wildlife poaching
- Uncontrolled forest fires
- Loss of habitat and biodiversity
- Soil erosion
- Silvicultural practices
- Timber harvesting methods
- People's participation
- Tenure rights
- Economic activities
- Employment
- Awareness and education
- Health
- Legal and institutional arrangements
- Transportation
- Marketing strategies

Conclusion

The production-oriented forest management plan examined during the EIA did not include most of the issues listed above. It contained only timber management. Therefore, the EIA recommended their inclusion and appropriate measures to overcome the adverse impacts identified. Ranking of each impact indicated that most of the adverse impacts identified in the 'do-nothing' alternative would be lessened by implementing the OFMP. Therefore, the EIA study recommended implementing the OFMP and incorporating consideration of the impacts identified. The final version of the OFMP incorporated all the impacts identified and was modified according to the conditions given in the EIA recommendations. The government of Nepal recently approved the OFMP and authorised the proponent to implement the plan which, with the use of SEA, now fulfils the strategy of production-oriented forest management laid out in the Forestry Sector Master Plan.

SEA and sustainable development

It is now well recognised that SEA is a keystone in achieving sustainable economic development. There are two approaches to the application of SEA. They are (a) expanding the existing EIA framework incrementally to reach the sustainable objective, and (b) adopting a trickle-down strategy in achieving the sustainability objective. The incremental type of system goes on expanding its policy towards sustainable development, whereas the trickle-down strategy adopts sustainable development as a central aim. For example, the Natural Environment Protection Act of the USA was originally enacted to implement EIA at the project level; however, the same act was expanded to cover the application of SEA. Similarly EC directives on SEA are the expansion of directives on project-specific EIA. The Dutch system of SEA is an example of the trickle-down approach in which policy sets targets for sustainability and efforts are made to achieve the targets.

Relevance of SEA in Watershed Management Plans

Watershed management plans include an array of activities and often have different kinds of projects within a plan. Some of these are environmentally benign and will improve environmental conditions; for example, protection and plantation of forest trees enhance forest cover which ultimately leads to the protection of soil and the provision of habitat for wildlife. However, there can be activities within a plan that are necessary but that may generate significant cumulative environmental impacts. These need to be addressed propertly. Such activities include construction of access roads, irrigation channels, farming, and other infrastructural developments. It is usually not possible to assess the environmental impacts of such activities for every project and try to mitigate them individually. However when considered in totality at the planning stage through the application of SEA, the majority of anticipated impacts can be assessed and almost 90 per cent will be resolved at the implementation stage of individual projects if prescriptions made in SEA are implemented.

SEA procedures and methods

Most of the steps in SEA are similar to EIA except that the dimension and scope differ to some extent. The issues addressed at the strategic level tend to be more generic and at the project level more specific. Therefore, there are some variations in methodology. The following are the steps that are generally used for making an SEA.

Screening

Screening triggers the SEA process. The screening procedure usually determines whether the plan in question needs to undergo SEA. In most countries where EIA is legally mandatory, guidelines indicate the type of project that needs screening or list projects that need to be considered and those that do not (exclusion/inclusion lists). Screening lists are often given as an appendix in the legislation, and the screening process is legally binding. Although in most cases screening lists are prepared for project-level EIA only in some cases, lists also indicate types of plan and policy to be examined for environmental soundness. For example, the Nepalese Forestry Sector EIA guidelines contain a provision for environmental assessment of watershed management plans and any type of forest management plan. Similarly, in other sectors there are provisions for plans and programmes requiring environmental assessment. Such cases are examples of the incremental system for consideration of SEA.

In most cases, strengthening of screening procedures could bring key process benefits. It would allow practitioners to decide on

- whether SEA is necessary for a particular plan,
- at what stage the assessment should take place,
- the extent and type of involvement of people from outside in the light of planning, and
- the requirements.

Scoping

Scoping is an important step in the process of SEA. It determines the coverage or the scope of SEA of a plan or programme. Scoping helps to develop and select alternatives to the proposed action and to identify the issues to be considered. It is also a procedure for designing the terms of reference (TOR). The scoping exercise involves various steps as follow.

Collection of existing information. Information about the plan and the area in which the plan is to be implemented is collected. It is supported by maps, drawings and other aids. The information is presented in a way that is easy for readers and interested groups to understand and should be accessible to all people concerned.

Information distribution. Compiled and processed information is assembled in a package and distributed to individuals and institutions for their review and comments. An open scoping process can be organized to facilitate interaction on issues related to the proposed plan. Alternatively, closed scoping, such as sending letters and conducting interviews or discussions in small groups, can be organized in order to obtain opinions about the plan proposed and its environmental consequences.

Identification of issues of public concern. Opinions expressed by the people are assembled, processed and categorised. Such information is compiled into a comprehensive list and concerns without any significance are usually rejected. Only significant issues directly related to the proposed plan are usually considered for further analysis.

Analysis and comparison of alternatives

Another important step in SEA is the consideration of alternatives and their comparison in terms of environmental soundness. The alternatives should include the case for continuing the existing situation (the no-action option) and the need for modification. If feasible, a series of options should be compared. However, the minimum should be at least two options in order to provide reference for decision-making. Alternatives are developed by using optimisation techniques. However, in some cases, multi-criteria and sensitivity analysis are also used to determine the preference and robustness of policy options.

Identification of environmental impacts

Implementation of any economic development plan will have some environmental implication whether beneficial or adverse. Therefore, it is essential to identify changes that will affect the existing environment. The process of identifying environmental impacts for all viable options identified is one of the key steps in carrying out SEA. The impacts are identified in three key areas as follow.

- **Socioeconomic impact.** Impacts, both adverse and beneficial, generated in socioeconomic areas.
- **Biophysical impacts.** Impacts on biophysical resources such as vegetation, wildlife, crops, and aquatic life, also includes air, water and soil quality.
- **Cultural impact.** Impacts on cultural and heritage sites, religious sites and traditional practices likely to be affected by the plan.

Impacts may be direct, such as deforestation due to project implementation, or indirect such as impacts on river fish due to the siltation affecting the production of plankton.

Methods for impact analysis

Techniques and procedures for SEA vary from plan to plan. Some plans may cause greater impact on the environment than others. Similarly, some impacts are beneficial while others are detrimental. The following methodology may be used for identifying impacts associated with plan implementation.

- **Use of matrices.** Interaction matrices are used for displaying an area of impacts. Activities to be implemented are presented in the horizontal column and resources likely to be affected are presented in the vertical column of an impact sheet. The area likely to be significantly affected by an action is displayed in a square box. There is a variety of matrices used for various situations.

- **Computer modelling.** Computer models are used in analysing impacts. Calyx Expert System contains a set of impact rules that describes the condition under which environmental impact will occur based on general principles.

- **Geographic information systems (GIS).** GIS are especially useful in land-use planning and in assessing the cumulative impacts of several projects in the same area.

- **Cost-benefit analysis (CBA).** This technique is applied in many cases because impacts can be expressed in comparable terms: the cost:benefit ratio is used as a basis for choice between options.

- **Multi-criteria analysis (MCA).** This is an advanced form of CBA. MCA uses mathematical operations leading to weighting and ranking of options. Unlike CBA, MCA allows for joint analysis of environmental and financial costs.

In addition to these, there are many other techniques used to evaluate policy, plans and programmes from an environmental point of view for SEA. Examples include life-cycle analysis, aggravation methods and several consultative tools.

Impact prediction, evaluation and comparison of alternatives

Once impacts have been identified, it is essential to predict their magnitude, extent and duration. The prediction made should be based on the following factors.

- Determine the initial reference or baseline condition
- Estimate the future state with the proposed action
- Estimate the future state without the proposed action
- Impact predictions are made in the following way
- **Magnitude of impact.** An impact is assessed in terms of its severity. It is classified as reversible or irreversible and ranked as high (H) if it cannot be mitigated, medium (M) if it can be mitigated with an appropriate measure and low (Lo), if it does not make a difference whether it is mitigated.

- **Extent of impact.** An impact can be classified on the level of its spatial influence. It can be site-specific (SP), occurring locally (L), regionally (R), nationally (N) and internationally (I).

- **Duration of impact.** An impact can be classified on a temporal basis: short duration (S), medium term (10-20 years) (M) and longer periods of time (L).

There are several methods available for predicting impacts. No prediction method is perfect, and additional methods are being devised. Most methods are extrapolative, and a few of them are normative. For details of such methodologies please see *EIA Training Manual for Professionals and Managers* (Khadka et al. 1996).

There are several methods for comparing alternatives. Some of the methods are listed below, however, for details of the methodology refer to Khadka et al. 1996.

- Quantitative approach
- Qualitative approach
- Ranking, rating and scaling approach
- Weighting approach
- Nominal group process technique
- Delphi methods
- Environmental evaluation system

Should the public be involved in SEA and how?

Public involvement in SEA

Public involvement is an integral part of SEA. It ensures procedural integrity and provides relevant information and input to policy development. Public involvement brings together stakeholders, affected interest groups, NGOs and other relevant organizations. There are several ways to involve the public either by workshops, meetings and seminars (open) or letters, interviews and discussions (closed), etc. There are two approaches as follow.

- When policy, plan and programme are to be evaluated, the first public involvement is organized during scoping. People will be asked for comments on the main objectives of the plan, policy or programme and on environmental issues likely to arise due to plan implementation.
- The second public involvement can also be organized after the SEA is completed. The report is opened to the public at the strategic level, and suggestions for improvement are obtained.

Documentation and SEA report

The length of report can be as short as one page to several pages, depending upon the issues addressed. If the report is long then there should be a short executive summary that should include a precise non-technical description of the significant results and recommended actions. The report should also include a clear description of

- the proposed policy/planning concept,
- the environmental consequences of policy option and how these alternatives compare,
- the difficulties encountered in the assessment and the resulting uncertainty in SEA results,
- recommendations in terms of approval and implementation of proposals, and
- arrangements for monitoring and post-decision analysis

The report should also be accompanied by supporting documents, graphs, charts, relevant baseline information, study team personnel, a list of people contacted and reference materials. A glossary of terms should also be provided to make the report understandable to decision-makers and the public at large.

Summary of SEA procedure

- Initiation: screening mechanism, identify whether SEA is needed.
- Scoping: identify the significant issues to be addressed.
- Impact identification: identify the main impacts on the key resources.
- Prediction of impacts: predict and evaluate the impact and identify the significance.
- Mitigation measures: propose mitigation measures for each impact.
- Public participation: involve the public in the SEA process.
- Preparation of the SEA report.
- Decision-making: take the SEA conclusions and recommendations into account.
- Post-decision: identify follow-up measures for overall impact of projects and measures resulting from policy, plan and programme.

Conclusion

SEA has become one of the most direct and effective ways to ensure that human activities are carried out in an environmentally sustainable manner over a period of time. Many countries have now adopted this method of analysing environmental impacts arising from the implementation of development proposals. In future, this strategic method, particularly the trickle-down approach, is likely to become more popular for achieving sustainable development objectives.

References and further reading (not necessarily cited in the text)

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Resource Dynamics: Complex Problems, Complex Solutions

Hans Schreier, R. A. Allen and P. B. Shah

Objectives

- To describe and discuss the methodology used by ICIMOD in its natural resource management projects
- To share the experiences gained and lessons learned in identifying the problems and the various efforts made for solving them

What are the major findings of the project?

A multi-media CD-ROM entitled *Complex problems-complex options: preservation, degradation and rehabilitation in a Nepalese watershed* was produced as part of the 1997 Annual Report. The People and Resources' Dynamics Project (PARDYP) grew out of the Mountain Natural Resources' Management Project (formerly Jhikhu *Khola* Watershed Project).

The main goal of the Jhikhu *Khola* Watershed Project was to quantify the status and changes in the water, soil, agricultural and forest resources in the watershed over the past 20 years and to determine the socioeconomic conditions and dynamics that shape the lives of the inhabitants. The integration of socioeconomic conditions with biophysical conditions was of key importance and a special effort was made to link soil fertility and degradation with gender and socioeconomic conditions.

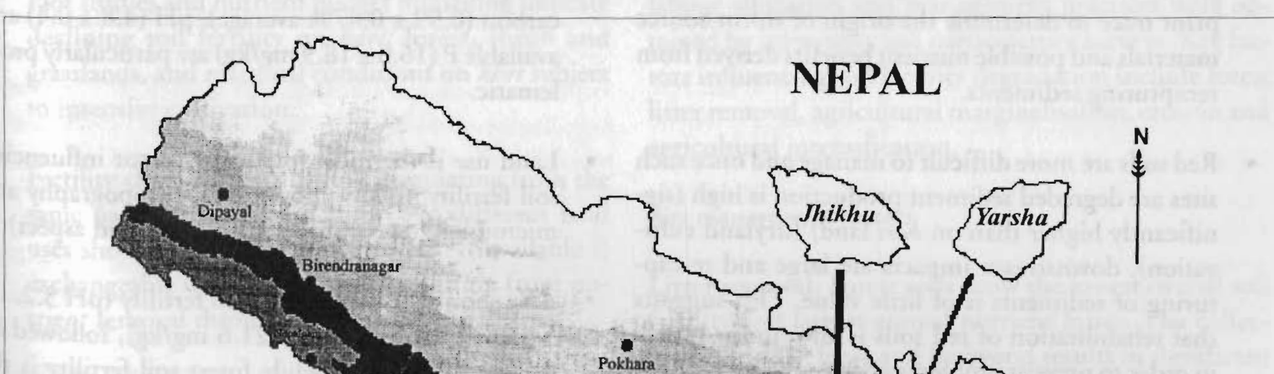
The main findings in the Jhikhu *Khola* Watershed covered research activities between 1989 and 1997 and are summarised below.

How is rainfall, erosion and sediment transport affected?

Rainfall, erosion and sediment transport are key issues to consider when determining resource management and sustainable farming in mountain environments. The research findings over the past years are as given in the following passages.

Rainfall

- There are on average 77 storms annually, of which 3.5 per cent have a peak 10-min rainfall intensity of



Locations of Jhikhu and Yarsha Khola Watersheds

>50 mm, a critical level for erosivity. About one third of all storms occur during the pre-monsoon season.

- Total rainfall during the monsoon represents about 70 per cent of the annual total.

- Most of the rainfall delivery is highly variable and local rather than regional-pattern dominated.

Erosion

- Annual losses were highly variable ranging between 0.1 and 40 t/ha/yr on rainfed agricultural sites.

- Pre-monsoon losses were over one order of magnitude greater than monsoon losses and were attributed to a lack of vegetative cover during the pre-monsoon period. Unfortunate timing of cultivation during the pre-monsoon results in the greatest losses, and farmers have little warning or predictive power to prevent such events. Planting a cover crop that can survive the dry season is one of the options considered to reduce the erosion risk during this period.

Sediment properties and behavior

- Silt and clay is dominant in sediment yield during the premonsoon season, and silt and fine sand are dominant during the monsoon season.

- Because of differences in parent materials, soil age and weathering intensity, red soils produce sediments with significantly lower nutrient content than non-red soils (particularly phosphorus and calcium). Since red soils only occur below 1,700m, sediment colour and associated P content can be used as a fingerprint trace to determine the origin of storm-source materials and possible nutrient benefits derived from recapturing sediments.

- Red soils are more difficult to manage and once such sites are degraded sediment production is high (significantly higher than on *bari* land) (dryland cultivation), downstream impacts are large and re-capturing of sediments is of little value. This suggests that rehabilitation of red soils is an important task in order to prevent problems affecting more productive land downstream.

- Farmers have a profound effect on sediment dynamics. Management practices are designed to prevent soil loss and sediment production. Agricultural intensification increases erosion risk and presents more challenges to farmers.

- Sediment yield is highly dependent on season, scale and land use. Of the total annual sediment production, 30 per cent is recaptured on *bari* and *khet* (irrigated rice field) fields. In larger watersheds, up to 60 per cent of sediment is put into long-term storage within the basin.

- Average annual sediment yield was found to be in the range of 10-20 t/ha/yr at all basin scales investigated (75-11,000 ha), and degraded land produces sediments in direct proportion to the total event rainfall independent of season and scale.

- Individual events were most damaging on the field or terrace scale and declined rapidly as scale increased.

What are the soil fertility status and dynamics?

Overall soil fertility conditions were examined over the past five years using four different survey methods: soil mapping evaluation covering the entire watershed; soil comparison between forest and upland agriculture in the headwater area; detailed soil fertility analysis in the subwatershed to identify the key factors that affect soil fertility declines; and selective soil analysis in long-term forestry monitoring plots (11 forests). Farmers were consulted in all surveys, but a special effort was made to relate farmers' inputs and experiences to soil fertility (200 sites were analysed), and information on inputs, yields, and constraints was obtained through farm interviews. The findings of these surveys are summarised in the following passages.

Soil fertility status

- The overall soil fertility conditions are poor. Soil carbon (0.99 ± 0.47% average), pH (4.8 ± 0.4) and available P (16.6 ± 18.9 mg/kg) are particularly problematic.

- Land use is the most important factor influencing soil fertility, followed by soil type, topography and micro-climatic conditions (elevation and aspect).

- *Khet* shows the best overall soil fertility (pH 5.2, Ca 5.3 cmol/kg, available P 21.6 mg/kg), followed by *bari* and rangeland, while forest soil fertility is the poorest (pH 4.2, Ca 0.9 cmol/kg, available P 0.7 mg/kg).

- Red soils are the oldest soils in the study area and have a greater clay content, higher CEC, and higher acidity, but lower available P than non-red soils (9.8 versus 22.1 mg/kg).

- A site-factor approach based on relationships between soil fertility and site characteristics facilitated extrapolation from point data to a spatial coverage and was useful for assessing the extent of soil fertility problems. The composite soil fertility map produced with GIS overlay techniques indicates that only 14 per cent of the classified regions have adequate pH, available P and exchangeable Ca.

- Phosphorus sorption studies indicate the high P-fixation capacity of red soils. Sorption ranged from 2-4 g P_2O_5/kg soil for the 16 red-soil sites. Phosphate sorption calculated using Borggaard's model, which includes AAC extractable Fe and Al and CBD extractable Fe, showed good agreement (.. =0.85) with measured P sorption and was used to calculate P sorption under different land uses.

- The P sorption capacity on red soils is nearly one order of magnitude greater than calculated values for non-red soils, and forest sites sorbed significantly greater P than agricultural sites.

- A phosphorus sorption map was developed using GIS techniques and a site-factor approach. The results indicate that 29 per cent of the area has very high P-fixation capacity (>1.5 g/kg) and 61 per cent has a P fixation capacity >0.5 kg. The high P-fixation capacity of these soils has important implications for phosphorus management as fertilizer P will quickly be converted to insoluble or complex forms.

Soil fertility dynamics

- The direction and rate of change of soil fertility influence both current and future biomass production. Plot studies and nutrient budget modelling indicate declining soil fertility on *bari*, forest, shrub and grasslands, and marginal conditions on *khet* subject to intensive cultivation.

- Fertility characteristics of soils originating from the same parent material but subject to different land uses show that sites have the lowest N, available P, exchangeable Ca and pH values resulting from nutrient removal through biomass collection.

- *Bari* sites, which receive the highest organic matter inputs, have the highest C and N levels, and *khet* enriched by irrigation water and suspended sediments have the highest available P, Ca and Mg.

- Rates of soil fertility depletion estimated from differences in soil fertility between land uses indicates substantial N and Ca losses from forest land (94 and 57 kg/ha furrow slice respectively). Annual losses from *bari* are small due to additional inputs from organic sources suggesting that losses from agriculture are strong and are influenced by management.

- Nutrient budget modelling of N, P and Ca levels for the dominant crops and cropping patterns was used to estimate nutrient depletion from the soil pool and identify management practices contributing to soil fertility degradation. Practices related to maize production result in large deficits in N, P_2O_5 and Ca (118, 38 and 32 kg/ha furrow slice respectively). Rice and rice-wheat cultivation on irrigated land appear to have limited impact on the soil nutrient pool, but the addition of pre-monsoon maize in the rotation results in deficits of 106 kg N and 12 kg P_2O_5 /ha furrow slice.

- The collection of forest biomass results in annual nutrient losses of 56 kg N/ha, 16 kg P_2O_5/ha and 34 kg Ca/ha, which are comparable to nutrient depletion determined from plot studies. Biomass removal from rangelands results in nutrient losses roughly estimated at 60 kg N/ha, 20 kg P_2O_5/ha, and 20 kg Ca/ha while soil erosion on degraded range and shrublands results in comparable losses (34 kg N and 23 kg Ca /ha furrow slice).

What are the key management factors and options?

Land-use change and soil-nutrient budget modelling are useful for assessing the impact of management factors on soil fertility and identifying management options that may reduce nutrient deficits. Data on soil inputs, yields, labour allocation and management practices were obtained by interviews and participatory surveys. Key factors influencing soil fertility degradation include forest litter removal, agricultural marginalisation, erosion and agricultural intensification.

Key management factors

Litter removal: Forest soils show the lowest overall soil fertility and largest annual nutrient losses. The collection of fodder, litter and fuelwood results in significant nutrient removal (56 kg N, 7 kg P and 72 kg total bases/ha) and disrupts natural nutrient cycling. Historical forest cover data suggest a cyclical decline in forest cover with at least two cycles of deforestation followed by efforts at rehabilitation. Biomass removal contributes to a low soil organic matter content and soil acidification through the removal of bases from forest land, and pine litter inputs to agricultural fields are likely to be acidifying cultivated land.

Marginalisation: The nutrient status on *bari* is generally poor and nutrient modelling indicates that N, P and Ca inputs are insufficient to maintain the soil nutrient pool under maize-wheat production. *Bari* soils are acidic with pH values ranging from 4.1 to 4.9, acidification from chemical fertilizer use is a concern and P availability is limited on red soils due to their high P-fixation capacity. Rainfed agriculture has expanded on to former range-, shrub- and abandoned lands located on steep slopes and at high elevations. These marginal lands have inherently lower soil fertility and are less favourable for intensive nutrient management.

Erosion: Erosion from upland *bari* and degraded lands result in substantial nutrient transfer to lowland agricultural fields. Erosion on *bari* removes an average of 25 kg N and 13 kg Ca /ha furrow slice, and marginal upland agricultural sites are prone to higher erosion rates. Nutrient losses through erosion on forest land are small when understorey vegetation is maintained, but litter removal leaves the forest floor unprotected from monsoon rains. Degraded shrub and rangelands (>50% soil exposure) cover 5 per cent of the study area and are a significant source of sediments, removing an estimated 34 kg Ca /ha furrow slice.

Intensification: *Khet* fields act as a nutrient sink receiving inputs from compost, fertilizer, sediment, water and biological fixation. Soil fertility conditions on *khet* are adequate and nutrient modelling suggests that inputs are sufficient to maintain a rice-wheat cropping system. The amount of irrigated land has remained relatively constant over the last 25 years, but cropping has intensified and shifted toward cash-crop production. Nutrient budgets under triple cropping are causing N and P_2O_5 depletion (106 kg N and 12 kg P_2O_5 /ha furrow slice), and cash crops such as tomatoes and potatoes require higher N and P_2O_5 levels than staple grain crops. Vegetable production and the use of high-yielding varieties have resulted in an increased dependence on agrochemicals, and water quality problems are associate with heavy fertilizer and pesticide use.

Excess use of pesticides: The introduction of high-yielding varieties of tomatoes and potatoes has resulted in the increased use of pesticides. The lack of extension services and appropriate education programmes are key reasons for the misuse of agrochemicals. The long-term health implications are severe and urgent action is needed to address the proper handling and use of these chemicals.

Management options

Potential options for reducing nutrient deficits include organic matter management, water management, lime, integrated nutrient management, *Azolla* and on-farm fodder production.

Organic matter management: Organic matter inputs have many beneficial effects on soil chemical, physical and biological properties, providing macro- and micro-nutrients, reducing acidification, maintaining soil structure and enhancing micro-activity. Best management-practice and deficit-elimination scenarios identified improved composting as a practical option for improving nutrient budgets on *bari*. Pit composting nearly doubles the N and P_2O_5 content of compost, and improved composting reduced estimated N deficits on *bari* fields by 17 per cent.

Water management: The diversion of stream floodwater through the irrigation system carries suspended sediments and nutrients on to *khet* fields. Sediments are enriched in Ca, P and C, and an average accumulation of 4 mm/yr supplies an additional 11 kg N and 28 kg Ca /ha furrow slice in addition to nutrient enrichment from sediment accumulation.

Lime: *Bari*, forest, shrub- and rangelands all have median pH values <5.0 and further acidification is a concern with the increasing use of chemical fertilizers on *bari* and biomass removal from forest, shrub- and rangelands. Calcium- and magnesium-based rocks provide a source of liming materials that are locally available in limestone and marble deposits. Rehabilitation studies with lime and manure have shown increased fodder production and a slight increase in soil pH.

Integrated nutrient management: Nutrient-deficit elimination scenarios suggest chemical fertilizer use would need to be quadrupled to meet crop N requirements under a triple crop rotation. The high cost of fertilizer constrains application rates and the associated soil acidification would be detrimental to crop productivity. Many farmers already report that soils are becoming hard due to continued chemical fertilizer use. Integrated nutrient management combining chemical fertilizers and compost is critical to maintaining soil fertility. Compost alone will be insufficient to meet crop nutrient demands with increasing cropping intensities and vegetable production, but organic matter additions improve soil structure, provide available nutrients gradually, and are less prone to nutrient losses through leaching.

Azolla: N-fixation by blue-green algae and *Azolla* may provide sufficient N to meet the requirements of rice grown on *khet* fields.

On-farm fodder production: Eighty-five per cent of the households surveyed report fodder trees on their private land, but fodder shortages are common during the dry season. Additional fodder may be produced by planting species such as Napier grass on terrace risers and waste lands. Regular cutting would minimise rodent problems, provide a source of fodder close to the house and reduce pressure on forest resources. Nitrogen-fixing fodder trees planted as hedgerows are able to grow on N-deficit sites, and litter adds organic matter to the soil. Regular cutting would provide fodder and fuelwood and minimise the shading effect on agriculture.

Extension service for fertilizer and pesticide use: There is an urgent need for improved agricultural extension services. With the introduction of cash crops, new management techniques are needed and, without professional advice from agricultural staff, the indiscriminate use of fertilizers and pesticides is leading to water-quality problems (eutrophication and toxicity) that have long-term health consequences.

What are the key socioeconomic factors and options?

Population growth, land tenure, culture and poverty are key socioeconomic factors influencing nutrient management and driving soil fertility degradation. Potential options that may counter the negative impact of socioeconomic influences on soil fertility include off-farm employment, community forestry, cash cropping and population stabilisation.

Population growth: Up to 1995, population growth rates were estimated at about 2.6 per cent. However, recent analysis (1996 surveys based on aerial photo work) indicates that the rate is significantly higher in part due to immigration and natural growth. This is placing additional pressure on soil resources. The per capita availability of land had decreased to 0.17 ha, and double and triple crop rotations are applied in an attempt to meet the increased demand for food. Agricultural marginalisation in response to population pressure has brought steep slopes under cultivation and is indicative of continuing pressure on forest resources. Population growth is a dominant factor driving land-use dynamics and the increased demand for food, animal feed and fuelwood results in increased nutrient removal.

Land tenure: Land ownership varies dramatically with 15 per cent of the surveyed households owning 36 per cent of the agricultural land and 53 per cent of the households owning only 25 per cent with total holdings <1 ha per household. Share cropping is practised by approximately one third of the households, and 47 per cent of households report that the land they farm does not generate enough food and income to meet their family's basic needs. The poorest soil fertility conditions within the study region are found on forest and rangelands, which are primarily under government ownership. Agricultural land holdings are positively correlated with total fertilizer and compost applications, and significant differences in nutrient budgets and soil fertility are noted with farm size. Share-cropped land receives significantly lower compost fertilizer and pesticide inputs, and rangelands are largely unmanaged.

Culture: Ethnic distribution, the role of livestock, and women as resource users and managers are three components of Nepali culture related to soil fertility in the study region. Rich farmers typically own the most *khet* and apply more fertilizer and pesticides to their land. Livestock are important in Nepali culture, particularly cows and goats, and impact soil fertility through manure inputs. Female buffaloes are obtaining economic importance with increased commercial milk production. Women are central in soil fertility management due to their responsibilities for livestock care, litter collection, and compost application, and the commercialisation of milk production is dramatically increasing the workloads of women farmers.

Poverty: Agricultural assets (land and livestock), farm gross margins (total returns less variable costs) and sources of cash income (crop sales, milk production and off-farm employment) are used as indicators of household economic well-being. Access to land and land quality assessed by local land values are highly skewed. Livestock values are highly variable between households, and some 50 per cent of household livestock assets are accounted for by female buffaloes. Vegetable crops involve higher levels of resources (labour, pesticides, fertilizer, compost and water), but farmers have an economic incentive to adopt vegetable crops. Total returns and household gross margins are greatest for households growing vegetable crops as part of their rotation, but 47 per cent of households have gross margins <US$ 70 /yr. Farmers sell a variety of crops, but only a small minority systematically produce for the market. Households with higher agricultural assets and gross returns apply more compost and fertilizer to both *khet* and *bari* and households with higher returns and milk sales appear to farm sites with better soil fertility conditions.

Socioeconomic options

Potential options for reducing socioeconomic pressure on resources include off-farm income, community forestry, cash cropping, and out-migration and population stabilisation.

Off-farm income: Off-farm activities provide cash income that may be used to purchase chemical fertilizer, thereby reducing nutrient deficiencies associated with intensive cultivation. However, male out-migration in pursuit of wage employment negatively impacts the household by increasing the workloads of women farmers and increasing their responsibility for farm decision-making. The workload placed on women farmers is particularly problematic given parallel increases in demand for their labour associated with agricultural intensification, vegetable-crop production and commercial milk production.

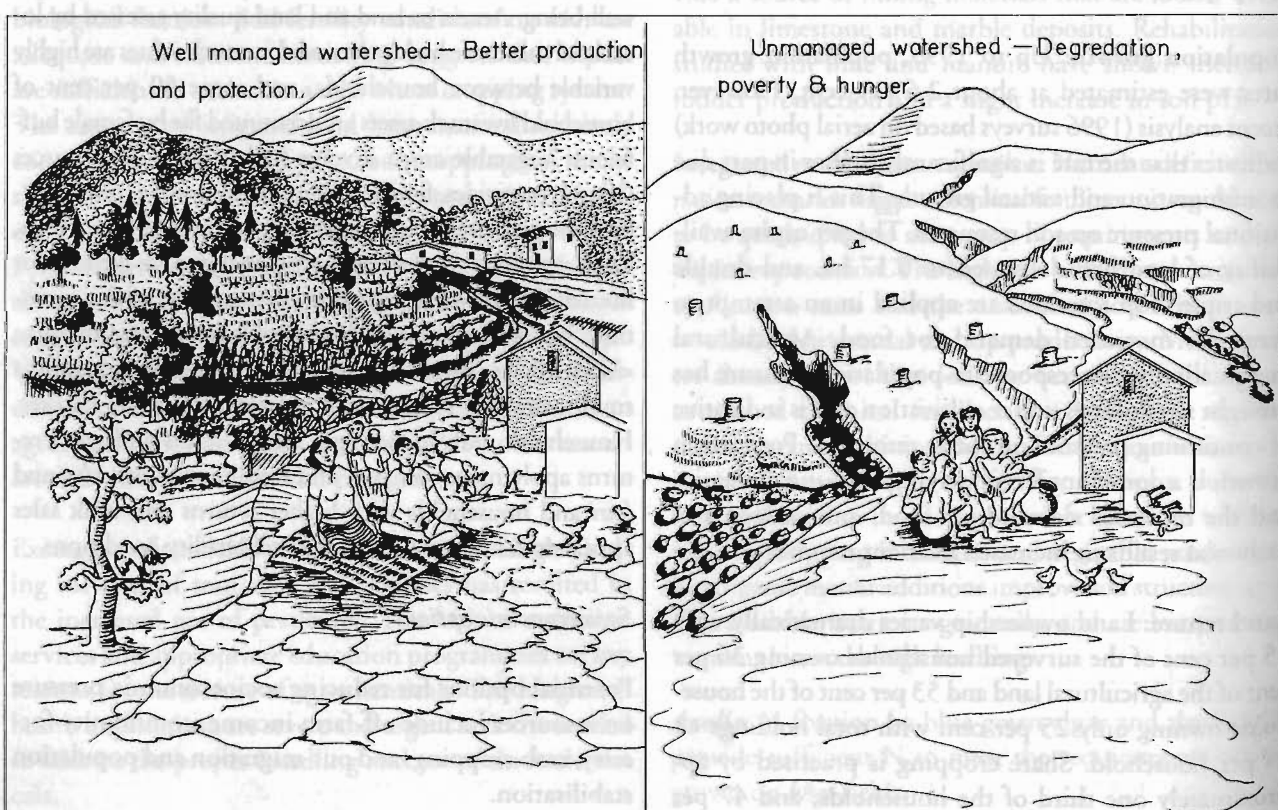
Community forestry: Community forestry initiatives have been successful in increasing biomass through restocking and restricted access, but long-term investments are required. Local farmers now have incentives to manage common forest land, but the necessary capital resources to initiate community forestry projects require outside subsidies.

Cash cropping: Market-oriented production provides a source of income that may be used to purchase commercial inputs. Vegetable production, however, increases water and pesticide requirements, and increased chemical fertilizer use is associated with soil acidification and water-quality problems. Integrated nutrient management is required to minimise the negative effects of agrochemical use, and water-use efficiency issues need to be addressed.

Are traditional farming systems sustainable? What are the implications for future research?

Farms in Nepal need to be viewed as systems that integrate forest, livestock and cultivation activities. Biomass collected from forest, shrub- and rangelands provide nutrients to the agricultural system with livestock, through manure, playing a central role in nutrient redistribution. Erosion is an important natural process, but water and sediment regimes are modified through complex irrigation systems. Off-farm employment, cash-crop production and milk sales provide income to farm households that is partially used to purchase agrochemicals impacting on agriculture. Nutrient flows must be evaluated within and between components as nutrient fluxes are interlinked. Pressure on one component will impact on the entire system and alter the transfer of nutrients.

The traditional farming system appears to have been sustainable. Despite high rates of erosion, nutrients were recaptured on *khet*, and compost was used to replace nutrients lost from *bari*. However, triple cropping and increased vegetable production are now threatening sustainability. Both require more fertilizer, pesticides, water and labour. As a result nutrients on *khet* are being depleted and *bari* receives less compost. Cultivation of low soil-fertility sites leads to low productivity, low returns to human and capital inputs, and the inefficient use of scarce nutrient resources. Forests are cleared of



understorey vegetation, short circuiting the natural nutrient cycle and more erosion results. Social sustainability is also being threatened: given the increased demands, particularly on female buffalo numbers to provide more manure, milk production increases labour demands for fodder collection, feeding and milking, which are tasks mostly fulfilled by women. Increasing off-farm employment and schooling remove male and child labour from the system. Some 25 per cent of the farmers cannot provide for their families. They will have no choice but to take a short-term view and use the capital stock of soil nutrients rather than investing in soil fertility.

Implications for future research

Understanding how resources are changing, and why, requires the integration of biological, physical and socioeconomic factors. Farmers' perceptions of soil fertility are useful in identifying past trends. However, given the nonlinear charactersitics of relationships between soil parameters (e.g., pH and P fixation), farmer perceptions do not indicate the proximity to threshold values. Long-term research on soil fertility and nutrient dynamics are necessary to understand the physical processes. While soil fertility research provides an index of soil resilience and an understanding of the agronomic processes, it does not indicate the underlying socioeconomic factors driving nutrient management. Household, farm and off-farm activities need to be viewed in terms of their interactions with natural and socioeconomic environments. More interdisciplinary efforts that seek to integrate our understanding of these subsystems are needed to fully comprehend resource issues in the Middle Mountains in Nepal.

For more information consult the CD-ROM.

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Population Dynamics and Land-Use Changes: A Case Study of Jhikhu *Khola* Watershed, Nepal

B. Shrestha

Objective

- To assess and study the interrelationships between population, natural resources and land-use changes in mountain watersheds for developing a better understanding of these relationships and formulating better policies and intervention mechanisms

How to assess the population dynamics in Jhikhu *Khola* watershed?

Population information for each village development committee (VDC) is available over time, but in most cases the VDC boundaries cross the Jhikhu *Khola* watershed (JKW) boundary. Only two are totally within the JKW; the remaining VDC boundaries extend outside the watershed. Selective aerial photographs on a scale of 1:20,000 were enlarged to 1:5,000 and used for counting all houses. The number of houses was multiplied by the average family size determined for each VDC through surveys and interviews. This methodology seems appropri :te and reliable for the study of population dynamics. The 1947 numbers were obtained from 1:50,000 scale topographical maps and the average family size was obtained from historic census data. To check for manual errors, 10 per cent of the households were selected from the total of each VDC. The family size of these households was compared to the estimated average.

How is land use in JKW estimated?

Land use was determined from aerial photographs (1:20,000 to 1:25,000 scale) and field surveys for 1972, 1990 and 1996. General land-use categories such as irrigated land, rainfed terraces, forest, grassland, shrubland and others were delineated on each photograph. Additional details were collected during field work.

Geographical information systems (GIS)

All land-use information was digitised into a GIS using Terrasoft in order to create a detailed land-use inventory for the watershed. Total areas and units in the various land-use categories were determined from the digital database, and land-use changes over different time periods were examined by GIS.

Table 1: Population Distribution of Jhikhu Khola Watershed

VDC	1947			1990			1996		
	House-hold #	Family size	Population	House-hold #	Family size	Population	House-hold #	Family size	Population
Anaikot	124	4.7	583	445	5.6	2492	619	5.6	3466
Baluwa	148	5.8	858	568	6.7	3806	1066	6.7	7142
Banepa	6	5.8	35	18	5.6	101	18	5.6	101
Devitar	99	5.8	574	343	6.3	2161	406	6.3	2558
Dhulikhel	128	7.8	998	304	6.0	1824	557	6.0	3342
Hokse	70	5.8	406	338	5.2	1758	468	5.2	2434
Kabhre	75	5.3	398	462	5.4	2495	538	5.4	2905
Kharelthok	102	5.8	592	353	4.9	1730	375	4.9	1838
Maithinkot	51	5.8	296	220	5.4	1188	266	5.4	1436
Panchkhal	250	5.8	1450	1117	6.5	7261	1638	6.5	10647
Patlekhet	246	5.8	1427	477	6.2	2957	807	6.2	5003
Phoolbari	52	5.3	276	179	5.6	1002	214	5.6	1198
Rabi Opi	104	5.8	603	422	7.1	2996	685	7.1	4864
Sathighar	82	5.8	476	228	5.2	1186	345	5.2	1794
Total	1537	5.8	8971	5474	5.8	32956	8002	5.8	48728

Population status of the JKW in 1947, 1990 and 1996

The population status of the watershed in 1947, 1990 and 1996 is provided in Table 1. The data show that the overall population has increased from 8,971 in 1947, through 32,956 in 1990, to 48,728 in 1996.

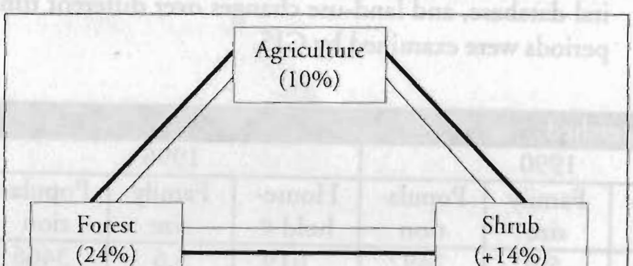
Population growth from 1947 to 1990 averaged 3.0 per cent. From 1990 to 1996 the number of houses has increased by 5.7 per cent.

Land-Use dynamics in the JKW between 1947, 1972, 1981, 1990 and 1996

From 1980 to 1994, the average cropping intensity in the watershed increased from 1.3 to 2.3. To understand and quantify the trends of land-use dynamics, historic land use (1947, 1972, 1981, 1990) and recent land use (1996) have been compared. Quantification and analysis of land-use changes between these various periods were carried out by applying GIS technology.

Broad land-use changes between 1947 and 1981

In 1947, general land use was mapped delineating forest, shrubland and agriculture. The spatial distribution of land use for 1947 and 1981 is presented in Map 1. This assessment shows an overall gain of 10 per cent in agriculture and 14 per cent in shrubland. It indicates substantial forest deterioration over this period. A significant net conversion of forest into agricultural land of about 1,164 ha and forest deterioration into shrubland of some 1,551 ha is absent.



Map 1: *Land use in 1947 and 1981*

Land use 1972 - 1990

The land-use changes over the period of 18 years were examined using GIS. There were substantial increases in forest of 10 per cent, and *bari* (dry land cultivation) of 5 per cent while *khet* (irrigated fields) increased by only 1 per cent, shrubland decreased by 9 per cent and grassland by 5 per cent (Table 2).

GIS results show that forest has increased over this 18-year period: 738 ha from shrubland and 317 ha from grassland. *Bari* has also increased: 250 ha from shrubland and 224 ha from grassland.

There has also been a change in forest species' distribution. The increase in forest cover due to pine plantations is 63 per cent. Sixty-five per cent of all pine plantations are on slopes of less than 35 per cent with the largest area in the 20-35 per cent slope range. Eighty-four per cent of the plantations are below 1,200m. During the 1972-1990 period, significant agricultural changes occurred in two directions: expansion on to marginal land and crop intensification. *Bari* increased by 5 per cent from 1972 to 1990. Sixty-six per cent of all sites converted into *bari* occurred on slopes greater than 20 per cent. The highest land conversion occurred in the 36-49 per cent slope class. This clearly suggests that a critical limit was being reached in dry land cultivation during the period from 1972 to 1990. Lowland irrigated agriculture intensified over this period with the introduction of high-yielding crop varieties and application of mineral fertilizer.

Land use 1990 - 1996

The six major land-use categories were compared by superimposing the land use of 1990 and 1996 using GIS. The GIS analysis shows that between 1990 and 1996 there has been an expansion of grassland and *khet* by 1 per cent balancing a similar loss of shrubland and *bari* (Table 3). There were significant increases in forest cover from 1972 to 1990 but almost no changes from

Table 2: Land Use in 1972 and 1990

Landuse Types	1972		1990		
	Area (ha)	Area (%)	Area (ha)	Area (%)	% Change
Khet	1653	15	1719	16	+1
Bari	3844	34	4354	39	+5
Forest	2181	20	3359	30	+10
Grassland	1184	11	466	4	-7
Shrub	1857	16	937	8	-8
Others	422	4	306	3	-1
	11141	100.0	11141	100.0	0.0

Source: Land-use maps of ISS, Topographical Survey Branch, Department of Survey Scale 1:20,000

Table 3: Land use 1990 and 1996

Landuse Types	1972		1990		
	Area (ha)	Area (%)	Area (ha)	Area (%)	% Change
Khet	1719	16	1838	17	+1
Bari	4354	39	4264	38	-1
Forest	3395	30	3319	30	+<10
Grassland	446	4	613	5	+1
Shrub	937	8	781	7	-1
Others	306	3	326	3	+<2
	11141	100.0	11141	100.0	0.0

Source: Land-use map of PARDYP/ICIMOD. Scale 1:20,000.

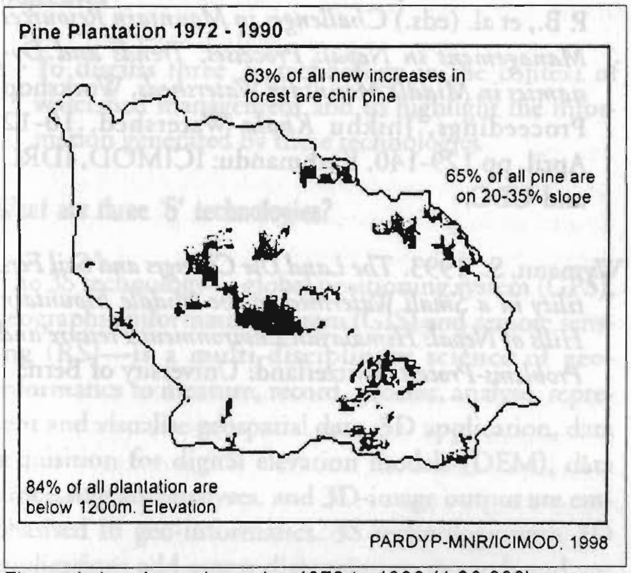


Figure 1: *Land use dynamics 1972 to 1990 (1:20,000)*

1990 to 1996. The expansion of *khet* was mainly from *bari* during this period, with about 119 ha of land converted from *bari* to *khet*.

Population and land-use dynamics in JKW

There is a close relationship between population growth and land-use dynamics in the JKW. During the last fifty years the population has increased significantly influencing land use and cropping systems. Population growth has resulted in a dramatic decrease of per capita agricultural land from 0.62 ha/capita in 1947 to 0.18 ha/capita in 1990 and 0.11 ha/capita in 1996. To meet the increasing demand for food, agriculture has intensified and expanded on to marginal upland slopes. The pressure on forest resources also appears to be increasing as illustrated by recent losses of sal *(Shorea robusta)* forest.

Summary and conclusions

Aerial photography and GIS are useful tools for documenting and quantifying trends and processes of population and land-use dynamics. This methodology can be used in any watershed study of mountain regions and can provide information that is generally not available from government sources.

Population growth increases the demand for food and places an additional pressure on limited resources; this has quickly affected land-use practices in the Jhikhu *Khola* watershed. From 1990 to 1996 farmers practised more commercial farming systems, and *khet* expanded by one per cent. Between the 1970s and 1990s the cropping patterns were mainly dominated by rice, wheat and some potatoes on the *khet*, and maize, mustard, wheat or millet on the *bari*. From 1990 to 1996 the cropping system has changed to include more diversified crops dominated mainly by rice, potato, tomato, wheat and early maize on *khet* and maize, wheat, mustard, tomato, potato and some millet on *bari*. More and more farmers are practising commercial cultivation of potatoes, tomatoes, radishes, onions, and garlic. The change from largely subsistence to more commercial farming systems in the JKW over the last six years is due to the development of market centres and the extension of motorable secondary roads; during the last six years more than six secondary roads have been constructed. Milk-chilling centres, telephone facilities, rice mills, a college, etc. were also established.

The three sets of assessments record deforestation from 1950 to 1970, significant plantation from 1972 to 1990, and almost no change from 1990 to 1996. GIS analysis shows that about 47 per cent of all increases in forest are pine below 1200 m elevation, and 65 per cent of all pine plantations are on slopes of less than 35 per cent.

At the same time, annual crop rotation intensified from an average 1.3 in 1980 to 2.3-2.7 in 1994, and this was accompanied by expansion of agriculture into marginal environments. Agricultural intensification may indirectly be helping to protect the forest: limited time is available for fuelwood, fodder and litter collection. Farmers are applying more and more chemical fertilizer and pesticides. Maintenance of soil fertility (organic matter, nutrients, and soil pH) may become a serious issue in the future.

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Three 'S' Technologies for Watershed Management

Moe Myint

Objectives

- To discuss three 'S' technology in the context of watershed management and to highlight the information generated by these technologies

What are three 'S' technologies?

The 3S technology— global positioning system (GPS), geographic information system (GIS) and remote sensing (RS)—is a multi-disciplinary science of geo-informatics to measure, record, process, analyse, represent and visualise geospatial data. 3D application, data acquisition for digital elevation models (DEM), data processing and analyses, and 3D-image output are emphasised in geo-informatics. 3S technology with 3D applications add a new dimension to research and applications in watershed management.

What is the global positioning system (GPS)?

The global positioning system (GPS) is a world-wide radio-navigation system formed from a constellation of 24 satellites and their ground stations in Hawaii, Ascension Island, Diego Garcia, Kwajalein and Colorado Springs. GPS satellites are called NAVSTAR. The altitude of the satellites is 10,900 nautical miles. The orbital period is 12 hours. The orbital plane is 55 degrees to other equatorial plane. The GPS provides three dimensional positioning, velocity and time information. The first and most obvious application of GPS is the simple determination of a basic position or location. GPS is the first positioning system to determine highly precise location data for any point on the earth in any weather.

How does GPS work?

The position is calculated from distance measurements (ranges) to at least four satellites to determine the exact position of the antenna of the GPS receiver. It is called triangulation. The distance to the satellite is determined by measuring how long a radio signal takes to reach the receiver from the satellite. In order to make the measurement, both the satellite and the receiver are generating the same pseudo-random codes at exactly the same time. By comparing how late the satellite's pseudo-random code appears compared to the receiver's code, determines how long the signal took to reach the receiver. This time is then multiplied by the speed of light to determine the distance. Therefore, accurate perfect timing is the key to measuring distance to satellites. Receiver clocks do not have to be too accurate because an extra satellite range measurement can remove errors.

There are a wide variety of possible errors. For example, as the GPS signal passes through the ionosphere and troposphere, it slows down and creates an atmosphere-induced error. One way to counteract this error is to compare the relative speeds of two different signals. The dual frequency measurement is sophisticated and is only possible with advanced receivers. When the signal reaches the ground, it may bounce off various obstructions before it reaches the receiver. This is called multipath error. Good receivers use sophisticated signal rejection techniques to minimise multipath error. Atomic clocks are very precise but they are not perfect. Miniscule discrepancies can occur in travel time measurements, so slight position errors can appear. The configuration of satellites in space can magnify these errors. This is called geometric dilution of precision (GDOP). There are more satellites available than the receiver needs to fix the position, the receivers pick a few and ignore others. If the receiver picks satellites close together in space, the intersection circles that define the position will close at very shallow angles. This increases the error margins around a position and GDOP is high. If the receiver picks satellites that are widely separated, the circles intersect at almost right angles and minimise the error regions: GDOP is low. Good receivers can select satellites that will give the lowest GDOP. Alternatively GDOP is also referred to as PDOP (positional dilution of precision). The position should be measured when the PDOP value is less than 6.

The accuracy range of position is from 100m to better than one cm depending on the design of the GPS and method of measurement. Use of a single GPS is called autonomous GPS. The positional accuracy of an autonomous GPS is 100 m and the speed accuracy of autonomous GPS is about 3 mph. Mapping applications use GPS receivers with sub-metre accuracy. In order to obtain better than a 100-m accuracy, differential GPS (DGPS) must be used. Differential GPS can eliminate almost all the errors. It can provide a position accuracy of about 10 m to 1 cm and speed accuracy of better than 0.1 mph. DGPS corrections are available for both real time and post-processing. DGPS requires the co-operation of two receivers. One receiver is a stationary or reference station and another receiver is moving around to mesa positions—the rover receiver. If two receivers are within a few hundred kilometres, the signal that reaches both of them will have travelled through virtually the same slice of atmosphere, and so will have virtually the same error. The reference station is placed at a point that has been accurately surveyed. The reference station calculates the timing using its known position instead of calculating the position using timing. So it calculates backwards. Since the reference station knows where the satellites are supposed to be in space, and it knows exactly its location, the theoretical distance between itself and each satellite can be calculated. Dividing the theoretical distance by the speed of light determines the time. The reference station compares the theoretical time and the time actually taken. Any difference is the error or delay in the satellite signal. The reference station uses all visible satellites and computes their instantaneous errors. It encodes this information into a standard format and transmits it to the roving receivers through a radio link. The roving receivers receive the complete list of errors and apply corrections for the particular satellites they are using. In the early days of GPS, reference stations were established privately. Now there are enough public agencies and commercial firms transmitting corrections. One service provider for DGPS is Omnistar. The home page is http://www.omnistar.com/

Deriving high-accuracy data in real time uses real-time kinematics' (RTK) techniques, while post-processing techniques require phase data to be collected. Radio links are required for real-time DGPS. A number of different types of radio transmitters are used. The main types are radio navigation beacons, commercial FM transmitters, and geostationary satellites. Many GPS receivers are designed to accept corrections, and some are even equipped with built-in radio receivers. FM stations can be used to transmit correction data cost-effectively, especially in the HKH region. Some DGPS applications do not need radio links because they do not need immediate precise positioning. Rover receivers record all measured positions and the exact time each measurement is made. Then the data can be corrected at a reference receiver. This is called post-processing DGPS. Internet can also be a good source of corrected data because some academic institutions are experimenting with the Internet as a way of distributing corrections.

Post-processing DGPS will be an excellent tools for positioning and mapping in the watershed areas. GPS can pinpoint the position of a gauging station, a meteorological station, a drain, a trail or a particular patch of forest or sample plots in a watershed. Moreover the position of soil samples, elevations points, endangered animals, sources of pollution and villages can be recorded for inclusion in a spatial database of a GIS. Moreover ground control points in a watershed can be precisely measured by DGPS and used for rectification of digital image data in remote sensing.

What is a geographic information system (GIS)?

A geographic information system (GIS) is a computer-based geospatial database tool on which location information (where) and attribute information (what) of spatial objects such as houses, rivers, and forests can be recorded and stored. This information can be represented as points, lines and polygons. In a watershed, gauging and meteorological stations, pollution sources and villages are the point features, trails and drainage are line features, and land use and watershed boundaries are the polygon features. GIS generate new information based on the spatial relationship of individual objects for particular spatial decision support and problem-solving. For example, by examining the spatial relationship and connectivity of pollution sources, drainage and villages, GIS can derive new information on 'villages that stand a high risk of toxic pollution'. GIS can visualise and present results cartographically. The capability carry out to spatial analyses distinguish GIS from other information systems and make it valuable to a wide range of applications such as urban planning, telecommunication network monitoring, transportation planning, environmental planning, watershed classification and natural resources' applications, etc.

Components of a GIS

Hardware is the computer on which a GIS operates. The digitiser, scanner, printer, and plotter are also hardware components. GIS software runs on a wide range of hardware types — stand-alone or network computers in client server environments.

Software allows a GIS to input, correct, store, analyse and display geographic information. Major components of GIS software are

- inputting, cleaning and manipulation of location and attribute information,
- database management system,
- spatial query, spatial analyses, database query, spatial modelling and visualisation of geographic data,
- graphical user interface for easy access by users, and
- application programming language to customise applications.

Data are the most important component of a GIS. A database of spatial data and attributes can be created in-house or by sharing or by purchase from a commercial data provider. Creating the data is time consuming. By sharing existing data from different agencies and organizations, the capability of a GIS can be increased by reducing the time and effort spent in creating duplicate data. Data quality and data standard are important, and data requirement analyses should be performed in the watershed. The data in the GIS, especially location data, contain explicit geographic references such as latitude and longitude or national grid co-ordinates. The attribute data contain nominal variables that are described by name (such as park, pine forest) , ordinal variables such as lists of discrete classes with an inherent order (classes of stream: first order, second order and so forth), interval variables that have a natural sequence within addition (such as temperature 10-20 °C , 20-30 °C), ratio variables that have the same characteristics as the interval variables but in addition have a natural zero or starting point, and implicit references such as an address range, postal code and census tract name. The attribute information is stored in the attribute table of a particular spatial object. GPS technology provide the basic location information of x,y co-ordinates to GIS. However, by using the data dictionary facility of a GPS data collector, attribute information can be recorded. Location and attribute information can be downloaded from GPS to GIS by using the utility software of the GPS.

GIS users range from technical specialists, who design and maintain the system and manage the data; application specialists from different disciplines, who apply GIS to a particular field; and policy-makers who use the GIS as a support tool for decision-making. GIS integrate not only different data layers but also professional knowledge from different disciplines in order to solve a particular spatial planning problem. GIS are of limited value without the knowledge of people who develop plans for the real world. In a watershed, the knowledge of the hydrologist, agriculturist, agronomist, soil scientist, ecologist, forester, economist, GIS specialist and land-use planner is essential for sustainable management and planning.

GIS Models

Geographic information systems are based on two fundamentally different types of spatial data models—the vector model and the raster model. In the vector model, the position of points, lines and polygons are precisely specified. Location of a point feature, such as a gauging station, is described by a single x,y geographic co-ordinate and its attributes are described by its identifier number and name or label and other attribute information defined by the user. The location of a line feature, such as drainage, is described by a series of x,y geographic co-ordinate pairs, and its attributes are described by its identifier number and name or label and other related attribute information defined by the user. The location of a polygon feature, such as a lake, is described by the close loop of x,y geographic co-ordinates and its attributes are described by its identifier number, name or label and other related attribute information defined by the user. Vector data are efficient at recording and describing discrete features, but less useful for describing continuously varying features such as soil types, temperature and rainfall.

The raster model represents point, line and polygon spatial features as a collection of grid cells. Each cell is assumed to be a homogeneous unit. Each grid cell is only assigned one value. In a soil pH map, each cell is assigned the pH value of that particular location. In a soil texture map, each cell is assigned the soil texture value of that particular location. The raster model is efficient at recording and describing continuously varying features such as temperature, soil and rainfall and transition zones.

Modern GIS, so-called hybrid GIS, are able to handle both models.

How can GIS be used for a watershed management?

In a watershed, line features and their attributers; such as trails, drainage, and contour lines; point features and their attributes; such as rainfall stations, gauging stations, water origins, villages, pollution sources and ground water wells; and polygon features and their attributes such as land use/land cover, watershed boundary, catchment boundary can be recorded in a vector GIS.

A digital elevation model (DEM) of a watershed can be generated with a triangular irregular network (TIN) model in a vector GIS by using a network of irregularly spaced, randomly selected elevation points. More sample elevation points are selected in the areas of rough terrain and fewer in smooth terrain. Alternatively, in a raster GIS a DEM can be generated based on digitised elevation points by using interpolation algorithms. Using stereo aerial photographs and stereo space images, automated DEM can be generated by stereo-image matching algorithms. This will be discussed in more detail in the section on remote sensing. Topographic features such as slope, aspect, drainage network and elevation contours can be generated in vector or raster GIS based on the digital elevation model. A rainfall map or temperature map can be generated by using thiessen polygons and by interpolation based on the location and temperature and rainfall data of meteorological stations.

What can GIS do?

GIS performs the five tasks: input, manipulation, management, query and analyses and visualisation.

The location and attribute data of a paper map can be input to a GIS by scanning or digitising. Tabular data can be imported from a database management system or spreadsheet or directly input to the DBMS. Many types of geographic data already exist in GIS-compatible formats. These data can be obtained by data sharing or from data suppliers. Departments of Agriculture, Forest, Geology, Mining, Meteorology, Statistics and Hydrology are useful sources of data for the watershed.

The data may have to be transformed from one geographic co-ordinate system to another (for example, the latitude-longitude geographic co-ordinate system to the UTM [Universal Transverse Mercator] co-ordinate system). The data format may have to be manipulated to be compatible to a particular GIS (for example, the MapInfo MIF file format to the ArcView Shape File format). Data may have to be merged to obtain complete coverage of a watershed or it may have to be clipped out for an area within a watershed. Data may have to be cleaned and the dangle errors (overshoots and undershoots of arcs) and attributes of spatial objects corrected. Changes have to be updated. GIS technology offers tools for manipulation, transformation, map joining, clipping, reclassification, updating and cleaning of spatial and non-spatial attributes.

A database management system (DBMS), especially a relational DBMS (RDBMS), is best for storing, organizing and managing data. In the relational database design, data are stored as a collection of tables. Common fields in different tables are linked to one another. Therefore, to normalise the database, tables can be split into smaller tables based on common fields.

GIS provide simple point-and-click spatial query and attribute query systems. In a simple point-and-click spatial query, click on a spatial object (point or line or polygon) and the GIS provides attribute information. In a simple point-and-click attribute query, click a particular record in an attribute table or enter a query (such as land use=forest and elevation >500 m) and the GIS highlights spatial objects (such as all the forest above 500 m). GIS also provide sophisticated tools for analysis to look for suitability, patterns, trends and to model 'what if' scenarios. Proximity or buffer analyses are a useful tool for answering spatial queries such as 'derive forest types and areas within 200m of first order drainage'. Overlay analyses are another powerful tool used to integrate data layers of spatial objects according to criteria derived from the integration of knowledge from application specialists. The overlay or spatial join can integrate data on soils, slope, vegetation and elevation in order to derive 'an area suitable for reforestation with soil types of sandy loam or loam, slope <30°, eastern aspect, deforested and elevation <500 m'. Land-use dynamics and change maps can be derived by simply overlaying time series' land-use maps.

The end results of GIS operations are maps, graphs and tables. Maps are efficient at storing, communicating and presenting geographic information. GIS and automated cartography will provide new and exciting tools such as integrated image output with DEM , birds eye views, and image animation.

What is remote sensing (RS)?

Remote sensing is defined as the use of electromagnetic radiation reflected, emitted or backscattered from an object, area, or phenomenon in order to acquire, identify, measure and analyse the characteristics (spectral, spatial, temporal) of the object, area and phenomenon without direct contact. It is recognised as an essential data source, especially when there is no map available or existing maps are out of date. It provides multi-spectral, multi-resolution, multi-temporal and multi-sensor imagery of the latest conditions of an area.

Passive remote sensing makes use of sensors that detect the reflected (visible, near infrared) or emitted (thermal infrared) electro-magnetic radiation from object, area and phenomenon. Active remote sensing makes use of sensors that detect the backscatter energy from an object, area or phenomenon through artificially generated energy sources such as synthetic aperture radar (SAR).

The electro-magnetic radiation characteristics used in remote sensing are listed in Box 1.

In general, resolution is defined as the ability of an entire remote-sensing system, including lens, antenna, display, exposure, processing and other factors, to render a sharply defined image. Resolution of a remote-sensing system is of different types. Spectral resolution is the number of spectral bands of the remote-sensing satellite. More spectral channels means higher spectral resolution. For example, Landsat TM has seven spectral bands and the SPOT multispectral mode has three spectral bands, so the Landsat TM has a higher spectral reso-

Box 1

EMR	*Wavelength*	*Remote Sensing*
Visible	0.4 - 0.7 ?m	Visible and Infrared Remote Sensing (VIR)
Near infrared	0.7 - 1.3 ?m	Visible and Infrared Remote Sensing (VIR)
Short wave infrared	1.3 - 3.0 ?m	Visible and Infrared Remote Sensing (VIR)
Intermediate infrared	3.0 - 8.0 ?m	Visible and Infrared Remote Sensing (VIR)
Thermal infrared	8.0-14.0 ?m	Visible and Infrared Remote Sensing (VIR)
Microwave	1 mm - 1 m	Microwave Remote Sensing

Characteristics of microwave and VIR

	VIR	Microwave (active)
General		
Detection	Reflected sunlight	Radar backscatter emission
Interaction	Chemical	Geometric/dielectric
Resolution	2 - 1,000 m	9-100 m
Swath width	36 - 2,700 km	45 - 510 km
Geometry	Vertical looking	Side looking
Interaction with earth surface		
Penetration		
Soil	None	Yes (variable)
Vegetation	None	Yes (variable)
Water	Yes (variable)	None
Information	Surface	Volume
Interaction with atmosphere		
Independence		
Cloud cover	No	Yes
Haze	No	Yes
Rainfall	No	Yes
Sunlight	No	Yes
	Yes (Thermal Infrared)	
Data presentation capability		
Stereo	Yes	Yes
Interferometry	No	Yes
Multispectral	Yes	Yes* (VV, HH, VH, HV Polarisation)
Multitemporal	Yes	Yes
Available since	70's	90's
Difficulties between VIR and microwave		
Interpretation	Relatively Intuitive	Relatively not intuitive
Illumination	Variable	Constant
Distortion	Limited	Topographic layover Foreshortening and shadow
Noise	limited	Highly speckled

lution than SPOT. Radiometric resolution is determined by the number of discrete levels into which signals may be divided. For example, the NOAA AVHRR sensor has 10 bit (2^{10} = 1024) and Landsat TM has 8 bit (2^8 = 254) digital levels. Therefore, the NOAA AVHRR has higher radiometric resolution than the Landsat TM. Spatial resolution describes the representation of each pixel size to the ground distance. For example, spatial resolution of the SPOT Multispectral sensor is 20 m and that of Landsat TM is 30 m. Therefore the SPOT Multispectral sensor has higher spatial resolution than the Landsat TM. Spatial resolutions related to accuracy for map production are provided in Box 2.

Temporal resolution is the revisit capability of a remote-sensing satellite to the same location. the Landsat TM revisits every 16 days and SPOT revisits every 20 days. Therefore the Landsat TM has higher temporal resolution.

Some visible and infrared sensor system characteristics of earth resource satellites used in natural resource studies are illustrated in Table 1. The SAR instrument characteristics for Radarsat, ERS-1, ERS-2 and JERS-1 are illustrated in Table 2.

Land cover/land-use mapping is an important application of remote sensing. Land cover corresponds to the physical condition of the ground surface, such as forests, grasslands ,etc, while land use reflects human activities such as industrial zones, residential zones and agricultural fields, etc. Land cover/land-use change mapping is another application for updating land cover maps and the management of natural resources. Change vector analyses of remote-sensing data can be applied at the watershed level for multispectral monitoring of land cover and condition. Remote-sensing data can be use for forest-type mapping and biodiversity inventory. Coarse resolution data, such as NOAA AVHRR, can be used to monitor land cover. Temperature can be derived by using the thermal infrared channel of Landsat TM or MOS-1 (Marine Observation Satellite) VTIR (Visible and Thermal Infrared Radiometer). Water-quality monitoring is a typical application, especially in offshore areas. The visible bands are useful for monitoring clear water and suspended turbid water near offshore areas.

Digital elevation models (DEM) can be generated from a stereo pair of satellite images. The height accuracy Dh depends on the base:height ratio and the accuracy of parallax, which can be approximated by ground resolution, DG.

$$\Delta h = H/B\ ?G$$

Satellite	Satellite height (H)	Orbital interval (B)	Spatial resolution (DG)
Landsat MSS	705,000 m	145,000 m	80 m
Landsat TM	705,000 m	145,000 m	30 m
SPOT Pan	830,000 m	840,000 m	10 m

Δh of Landsat MSS is approximately 400 m.
Δh of Landsat TM is approximately 145 m.
Δh of SPOT Pan is approximately 10 m.

Level 1A SPOT stereo pair with base:height approximate to 1 is suitable for DEM generation of a watershed. Based on the DEM, drainage network and watershed, slope and aspect can be extracted. In addition to the SPOT satellite, the IRS1-C, IRS1-D, JERS and Radarsat satellites have the capability of acquiring the stereo-image data.

Box 2

Scale	Pixel Size Spatial Resolution	Height Accuracy	Contour interval	Position Accuracy	Application
1:250,000	25.0 m	33 m	100 m	33.3 m	Natural Resources
1:100,000	10.0m	17 m	50 m	50 m	RegionalPlanning
1:50,000	5.0 m	7 m, 13 m	20 m, 40 m	25 m	Base topo map
1:25,000	2.5 m	3 m, 7 m	10 m, 20 m	12.5 m	Base topo map
1:10,000	1.0 m	3 m	10 m	5.0 m	City map

Remarks:
1. Height accuracy is one third of the contour interval
2. Pixel size is taken as 0.1 mm on maps
3. Position accuracy is taken as 0.5 mm on maps

Conclusions

3S technologies of GPS, GIS and remote sensing can be integrated to create a powerful complementary tool for real-time mapping, data collection, feature extraction, data modelling, data analyses and data visualisation for watershed, environmental and natural resource management. The ability of GPS technology to define the geographical features to a high degree of positional accuracy has greatly enhanced the value of data for GIS application. Moreover, high-resolution remote-sensing data, such as Quick Bird from Earth Watch, Orb View-1 from Orbital Sciences and CRSS from Space Imaging, 1-m spatial resolution data with stereo-image matching technology, 1:25,000 scale topographic maps with 10-m contour intervals, can be produced. These high-resolution remote-sensing data will enhance the value of data for GIS application. At the same time, visualisation and spatial analyses functions of GIS and three-dimensional information processing technology such as image orientation, image matching, and automated cartography are much improved. In recognising 3S technologies as powerful tools, conventional systems will have to be modified or replaced by these new technologies in order to use geo-informatics effectively in watershed and natural resource management.

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Module 3.6

Remote Sensing (RS) and Geographical Information System (GIS) Applications at Watershed, National, Regional and Global Levels

A. K. Myint

Objectives

- To present the application of RS/GIS at a micro-watershed level
- To describe applications of RS/GIS at national, regional and global levels
- To discuss the advantages and limitations with some recommendations

How can remote sensing (RS) and geographical information systems (GIS) be used for PIWM?

Remote sensing (RS) and geographical information systems (GIS) can be applied at all levels of area coverage and presentation. Application at the watershed level is most common, but RS and GIS applications at national, regional and global levels are also possible.

Although GIS methodologies are highly technical, communities can participate in preparatory work when information is gathered and when the results of the analysis are used for decision-making. In India, the Indian Remote Sensing (IRS) satellite data have been applied through an integrated approach in the National Natural Resources Management System (NNRMS) and Integrated Mission for Sustainable Development (IMSD). These applications involved integration of various central and state agencies/departments. The Indian National Satellite (INSAT) facilitates communication applications that include radio and television networking, weather forecasting and education services. Through the INSAT satellite, it is possible for remote farmers to be educated and even for TV interaction between farmers and professionals in towns. GIS maps have assisted farmers in planning agroforestry activities and developing village forest management plans. With these approaches community participation can be achieved.

What types of application are possible using RS and GIS?

- Land-use and land cover analysis
- Land-use changes over time
- Town planning applications
- Forestry planning applications
- Hazards and landslide analysis
- Environmental impact analysis
- Disaster warning and remedy operations

GIS applications at the watershed level (Shivapuri Watershed, Kathmandu, Nepal)

GIS has been used in the Shivapuri watershed for

- preparation of maps of land-use change between 1981 and 1993,
- assessment of major land-use categories,
- estimation of the extent of land-use changes in agriculture, forestry and non-forest lands, and
- establishment of land capability criteria for proposing the land capability map and land-use adjustment map.

For carrying out the above tasks, base maps of the Shivapuri Watershed were first prepared. A topographic map from the Indian Survey of 1950 with 1' to 1 mile scale and the maps prepared by E. Schneider with 1971 aerial photographs on a scale of 1:10,000 scale were used for preparing the base maps. Aerial photographs from 1981, 1989 and 1991 were used for interpretation of land use. After field checks, the land-use information was put on to base maps. 1981 and 1993 land-use maps were prepared. These land-use maps were digitised to ente them into the GIS computer for analysis and mapping.

Land-use changes in the watershed have been analysed and tabulated (Table 1). Changes are given as reduc-

Land Use	1981		1993		Changes	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Agriculture	7668.8	36.16	7477.0	35.26	-191.8	-0.90
Forest	7771.4	36.65	8638.3	40.74	+866.9	+4.09
Shrubs	3412.2	16.09	3148.2	14.85	-264.0	-1.24
Grassland	1032.3	4.87	618.9	2.92	-413.4	-1.95
Grassland with shrubs	850.8	4.01	555.6	2.62	-295.2	-1.39
Landslides	87.3	0.41	102.3	0.48	+15.0	+0.07
Settlements	166.6	0.79	187.6	0.88	+21.0	+0.09
Riverine features	22.9	0.11	45.7	0.22	+22.8	+0.11
Abandoned lands	191.9	0.91	430.6	2.03	+238.7	+1.12
Total	21204.2	100	21204.2	100		

Table 1: Land use in Shivapuri Watershed for 1981 and 1993 and changes

Source : Karim and Tamrakar 1994

tions in agricultural land and increases in forest. These changes are also shown on the map.

More detailed analysis of land-use categories can be carried out. The change in various forest types and shrubland in 1981 and 1993 indicated the actual changes observed (Table 2).There was an increase of 700 ha of hardwood and 180 ha of conifers.

Once the database is in the GIS, further analyses can be made. One example is analysing slope to determine land capability for agriculture, forestry or fodder and grazing lands.

Applications of GIS at the national level

GIS applications for flood control in Bangladesh

Flood control is important in Bangladesh as frequent floods occur and have devastating effects on human life, agriculture, industry and infrastructure. Entire flood control which is impracticable, but systems can be built for flood damage reduction. Rainfall in Bangladesh is high and flooding is serious. International assistance was requested to develop a flood action plan (FAP) to identify and prepare structural and non-structural flood control and water management plans. Mathematical models are used to predict the hydraulic behavior of the river systems. Models using one dimension are used for predicting river flow and two dimensions are used for flood-plain flow predictions. The main objective of the FAP is 'to protect people's lives, houses, commercial and industrial centres' (Paudyal and Syme 1994). To achieve the objective of the FAP, computer-based mathematical models of the Brahmaputra, Ganges and Meghna rivers were developed. MIKE11 software (a one-dimensional hydraulic model) provides simulation for flows, water quality, and sediment transport in rivers as well as irrigation systems, channels and other water bodies but it has no capability for spatial presentation of data. It was necessary to link the hydraulic model with a GIS to build a spatial decision support system (SDSS). A PC/ARCINFO workstation software was linked with MIKE11 software and the simulation results for hydraulic characteristics were spatially presented and analysed in GIS. This was the basis for developing the Flood Plain Management Model. GIS outputs were used to estimate the flooded area duration, depth, and extent and for frequency mapping of floods. In combination with other data, such as crop-planting data, land-use data, soil-association map data and return-period data, it was possible to assess flood damage. The indirect costs could also be calculated. Thus environmental and social impacts were also assessed.

Land Use	1981		1993	
	Area (ha)	%	Area (ha)	%
Mixed Forest	94.0	0.84	45.1	0.38
Hardwood Forest	7207.4	64.45	7934.1	67.32
Coniferous Forest	470.0	4.20	659.1	5.59
Shrubs/ Scrub	3412.2	30.51	3148.2	26.71
Total Forest Area	11183.6	100	11786.5	100

Table 2 : Changes in various forest types between 1981 and 1993

Source : Karim and Tamrakar 1994

Data associated with the GIS are flood data, such as flood depth, area, and duration; socioeconomic data, such as demography, employment, social status, and education; environmental data on fisheries, wetlands, habitats, forestry (mangrove), ecology, pollution, surface water, a groundwater, forests, and fuelwood use; data on infrastructure agriculture and livestock. During floods ground survey may not be possible so remotely sensed data may be applied and digitised for GIS (Paudyal and Syme 1994).

Constraints include

- need for MIKE11 and other systems including hardware and software,
- need to link different systems,
- collection of data for analysis during flood period needs a lot of effort,
- financial necessities, and
- manpower required.

Opportunities include

- can assist flood control,
- flood damage can be reduced,
- planning for the after-flood period can be facilitated,
- the database will be useful for studies and future analyses, and
- cost and speed are reasonable.

RS/GIS applications to construct a land-use map for Myanmar

A land-use map for Myanmar was prepared using Landsat TM imagery for 1989 (Tint et al. 1991). (Table 3).

In the analysis the following land-use categories were identified

- closed forests,
- closed forests affected by shifting cultivation,
- degraded forests,
- degraded forests affected by shifting cultivation,
- non-forest areas including agricultural land, settlements, etc, and
- water bodies.

In identifying the various land-use types existing, aerial photographs were also used. The resulting land-use map was used to determine forest cover changes by comparing them with the land-use map of 1979 (Tint and Hla 1991).

Constraints include

- Landsat TM satellite data are expensive,
- gathering digitising data of state and division boundaries is time consuming, and
- the absence of digital imagery of Landsat data and software for analysing imagery, such as ERDAS (Earth Resources' Data Analysis Systems)

Table 3: Land-use table by states and divisions of Myanmar (sq. km.)

State / Division	Closed forest	Degraded forest	Forest with shifting cultivation	Non-forest	Water body	Total
Kachin	72718	2292	8119	5147	763	89039
Kayah	3536	1606	4165	2345	79	11731
Kayin	12155	1068	11080	5897	182	30382
Chin	17640	882	17062	419	14	36017
Sagaing	56950	7157	5163	24201	1150	94621
Tanintharyi	33755	1083	5637	2112	756	43343
Bago	14473	1274	5594	16914	1148	39403
Magway	4864	6884	15433	16205	1433	44819
Mandalay	6630	4303	6611	18710	768	37022
Mon	2739	1130	2804	5032	591	12296
Rakhine	20059	1881	3482	8980	2375	36777
Yangon	1164	145	478	7998	386	10171
Shan	41679	18335	66896	27991	895	155796
Ayeyarwady	4907	2928	1865	22649	2787	35136
Myanmar	293269	50968	154389	164600	13327	676553

makes manual interpretation unavoidable; transferring data into the system is time consuming.

Opportunities include

- state or division analysis is possible,
- the Himalayan region of Myanmar can be easily separated for different studies,
- the land-use map of Myanmar can be published, and
- comparison with previous land-use data is possible for forest degradation rates.

Application of RS/GIS at the regional level

An application has been designed for studying the forest cover of key Asian watersheds; these include the following river basins: Indus, Ganges, Brahmaputra, Mekong, Yangtze, and Yellow river. Estimating forest cover in a few months is not possible by any means other than remote sensing. In this study, NOAA AVHRR satellite imagery for 1992-93 (Loveland et al. 1997) was applied. Satellite data were available for the whole Asia and Pacific region and the study watersheds need to be separated by GIS. The following activities were carried out.

- Key Asian watersheds were identified by differentiating drainage on the world digital chart on a scale of 1:1,000,000.
- Land-use data for each key Asian watersheds with GIS were generated (Table 4).
- Elevation data for each key Asian watersheds were generated (Table 5).

Constraints include

- need for NOAA AVHRR data,
- need for a digital chart of the world,
- need for field checking: the land-use data had to be cross checked with the land-use map of Myanmar

Table 4: Land cover for six key watersheds in Asia and the Pacific

Sr. No.	Land cover type	River Basin (Area in percentages) Yangtze	Yellow	Indus	Ganges	Brahmaputra	Mekong	Total
1	Evergreen needleleaved forest	0.05	0.01	0.03		0.02	0.01	0.02
2	Evergreen broadleaved forest	0.22	0.24	0.02	0.57	2.09	18.42	2.86
3	Deciduous needleleaved forest	0.19	1.82					0.30
4	Deciduous broadleaved forest	6.49		0.37	7.63	11.64	14.36	6.41
5	Mixed forest	1.46	0.88	0.12	0.17	0.76	11.23	2.18
6	Closed shrublands	2.38	0.02	2.24	1.93	0.12	3.03	1.83
7	Open shrublands	0.99	20.08	27.22	1.63	8.90	0.84	8.54
8	Woody savannah	0.94	0.16	0.23	0.01	0.66	4.17	0.96
9	Grasslands	20.80	41.92	16.24	6.59	44.00	10.38	21.25
10	Permanent wetlands	0.17	0.01	0.11		0.05	0.02	0.08
11	Croplands (agricultural lands)	41.04	15.51	35.20	67.61	13.72	31.60	37.48
12	Urban built-up areas	0.11	0.11	0.12	0.18	0.02	0.04	0.11
13	Croplands/natural vegetation mosaic	23.05	12.36	2.31	9.92	12.86	4.32	12.56
14	Snow and ice			3.24	0.88	1.09		0.77
15	Barren/ sparsely vegetated	0.26	5.73	11.36	1.58	2.27	0.03	3.14
16	Water bodies	1.84	1.17	1.17	1.30	1.79	1.55	1.51
	Total	100	100	100	100	100	100	100

Source : Myint and Hofer 1998

Table 5: Elevation zones for six key watersheds in Asia and the Pacific

Sr. No	Elevation Zone (m)	River Basin (Area in thousand sq. km.) Yangtze		Yellow		Indus		Ganges		Brahmaputra		Mekong		Total	
		Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
1	0 – 300	603.8	33.39	56.0	7.06	330.3	34.97	510.0	48.58	108.92	18.7	250.1	31.47	1,859	31.14
2	300 - 1,000	418.1	23.12	61.5	7.75	95.9	10.16	113.5	10.81	34.22	5.90	290.8	36.58	1,014	16.98
3	1,000 - 2,300	290.2	16.05	467.0	58.8	135.5	14.35	70.88	6.75	43.15	7.44	136.4	17.16	1,143	19.14
4	2,300 - 3.600	119.7	6.62	77.1	9.71	85.30	9.03	33.81	3.22	30.86	5.32	20.43	2.57	367	6.15
5	Above 3,600	338.9	18.74	132.2	16.6	263.3	27.88	82.74	7.88	315.23	54.3	93.65	11.78	1,226	20.53
6	No data	37.4	2.07	0.00		34.10	3.61	238.9	22.76	47.68	8.22	0.32	0.04	358	6.00
	Total	1,809	100	794	100	945	100	1,050	100	580	100	795	100	5,972	100

Source : Myint and Hofer 1998

(comparison indicates the reliability of the land-use interpretation).

Opportunities include;

- forest cover estimates are available within the time permitted,
- regional as well as watershed level analysis is possible, and
- representative maps are produced.

RS/GIS applications at the global level

RS and GIS applications at the global level can also be formulated. For a good example of global applications refer to the training material on RS/GIS applications entitled, *Remote Sensing for Environmental Impact Assessment,* by S. Murai (1994). The NOAA AVHRR satellite data and other global data sets including temperature, precipitation, soil, and elevation are applied for assessing global forest cover and potential areas for forest cover. With the analysis, global planning is proposed. For this exercise the following tasks are involved.

Preparation of actual vegetation maps with a global vegetation index of eight types.

- Tropical forests
- Evergreen forests
- Deciduous forests
- Tundra
- Agriculture and grassland
- Semi-desert
- Alpine-desert
- Desert

Preparation of potential vegetation against global data sets of the following.

- Arid or moisture index
- Temperature
- Precipitation
- Elevation

Assessment of changes in vegetation cover (Table 6).

- GIS was applied using global data for predicting the suitability of forest conservation and reforestation.
- The global map for forest conservation was prepared indicating the 'very high' and 'high' land suitability of forested areas.
- The global map for reforestation was also prepared showing the 'high' and 'low' land suitability for reforestation in non-forest areas.
- The exercise demonstrated that RS/GIS applications are powerful tools for global environment monitoring as well as global planning.
- Use of RS/GIS is helpful for planning the sustainable use of the earth's resources.

Constraints include

- need for global data sets, and
- need for technical know-how
- Applications needs global collaboration cannot be at the watershed level.

Opportunities include

- global analysis of environmental monitoring is possible,
- analysis can be done in a short time,
- the cost is reasonable, and low for global coverage, and
- policy-level strategic planning can be exercised.

Advantages in and limitations to using GIS

GIS are efficient because spatial data once stored in the computer system can be retrieved and used for analysis.

Table 6: Change in vegetation cover due to human interference (unit %)

	Tropical forests	Other forests	Grassland	Semi-desert	Desert	Total
Potential vegetation	13.4	35.9	28.7	10.6	11.4	100.0
Actual vegetation	5.9	28.1	33.9	14.9	17.2	100.0
Difference	-7.5	-7.8	+5.2	+4.3	+5.8	0.0
	-15.3	Deforestation	+5.2	+10.1	Desertification	0.0

Source : Murai (1994), Shunji Murai, Global Engineering Project for Sustainable Use of the Earth, Technical Report to the UN COPUOS, June 1993

Information is easy to update and the whole process does not need repeating, unlike in manual systems. Comparison of changes is possible for a series of data. GIS applications are fast and accurate. Maps can be produced for many alternatives and repeated with great accuracy. Presentations of GIS maps are of major value and the scale of the maps becomes flexible.

Advantages can be summarised as

- speed,
- accuracy,
- efficiency,
- repetition and duplication is possible,
- complicate analysis is possible,
- better presentations, and
- flexibility in mapping.

Limitations of GIS applications are the need for special hardware and software, technical know-how, and skills for operating the system. Some investment in these has to be considered. Remote-sensing data are costly and sometimes interpretation is difficult. Participation of the community in implementing GIS is not easy; it is only possible in data gathering and use of the results. Proper maintenance of the system and a regular supply of stationery can also become limitations in some circumstances.

Limitations are

- need for special hardware and software,
- need for trained persons for operation and analysis,
- involvement of some investment,
- community participation is difficult,
- satellite data or remote-sensing data can be expensive, and
- poverty being the root of most problems and development being the main solution, this high-tech application may not be in the interests of the community.

Conclusion and recommendations

It is important that the community is aware of the environment and the impacts of development. Rapid and accurate results using modern technologies can be helpful. RS/GIS data can yield strategic information, such as forest cover and land-use changes, within a reasonably short period of time. RS/GIS application can be used for community-based and global planning. It involves the following main activities.

- Setting of clear objectives for using RS/GIS
- Design of the application
- Collection of material
- Preparation of data
- Analysis
- Interpretation of the results
- Reporting

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MODULE 3.7

Extending an Integrated GIS-based Watershed Modelling Approach to Participatory Watershed Management

S. H. Achet

Objectives

- To present the state of the art in integrated GIS-based hydrologic modelling.
- To outline how a participatory watershed management dimension could be added to such a model.

Why is watershed modelling important?

- Rainfall-runoff processes affect people, land use, vegetation, channels and geomorphic processes in a complex way in a watershed.
- Developing a model can significantly improve our understanding of the landscape-level response.
- It helps to refocus watershed management towards a systems' approach.
- In view of the shift from traditional watershed management to participatory integrated watershed management, watershed modelling can integrate science and participatory mechanisms.

Many studies in the USA have addressed the interrelationships between timber harvesting and runoff using different modelling and research approaches. Reviewing several modelling and research approaches, Achet (1997) concluded that, in general, the impact of timber harvest on streamflow is blurred and contradictory, and that the appropriate approach to addressing the integrated modelling problem is to use a physically based distributed approach.

What is the approach for hydrologic modelling?

The present know-how on watershed modelling is focused on

- using geographic information systems (GIS), remote sensing (RS), visualisation techniques and computer programming combined with watershed modelling to produce a physically based distributed watershed modelling approach;
- GIS providing spatial reference, programming keeping track of changes in different components of the hydrologic process, and visualisation helping to display and communicate results; and
- borrowing techniques from other relevant disciplines.

What are the models and modelling?

There are no universally ideal models, they have to be developed for specific purposes (Daniels 1992). A model can be used to challenge conventional wisdom, explore complex systems, identify gaps in knowledge (Daniels 1992) and as an aid to resource management decision-making. Hydrologic modelling is also an alternative approach to comparison of treated watersheds with untreated control watersheds. By using a hydrologic model, the cost of data acquisition can be reduced and research can be extended into areas where control watersheds may be impractical (Troendle and King, 1985). Many scenarios can be generated within minutes.

Irrespective of the classification approach, reliable hydrologic models should not only work well, but work well for the right reasons (Kelmes 1986). They must reflect, even in simplified form, the essential features of the system. However, practical considerations can result in a model being accepted as accurate without being a valid representation of the prototype (Beven and Kirkby 1979). Uncertainty or confidence interval of predictions must be an integral part of the modelling (Kelmes 1986). Although models seldom provide unambiguous answers, good models are not only simple but also complete and focus attention on what matters most (Brooks 1992; Daniels 1992). In practice, preference is always given to models with a transparent structure and easy handling, especially if, at the same time, they provide reliable results (Turcan 1990). Since hydrologic models can be used as submodels of complex systems, hydrologists doing simulations need to interact with others to help incorporate new concepts in hydrology into ecosystem-level models (Federer 1982).

How is remote sensing used in modelling?

Remote sensing (RS) provides a means of rapid assessment of various parameters related to a hydrologic model in a convenient, repeatable and objective way. RS as data input to a GIS enhances the possibility of data integration, synthesis and analysis. In the recent past, there have been several applications of RS and GIS in hydrologic modelling. The advantage of using RS is that data with high resolution in space can be obtained for areas for which no measurements exist (Schultz 1986). Increasingly, not only are simulation models and GIS being combined to provide improved means of managing and displaying data, but RS data are also being integrated into GIS as a part of the hydrologic modelling approach. In addition, RS techniques, oriented to aerial rather than point events, have an inherent potential for fertilization of hydrologic thinking (Kelmes 1983). Thus, a GIS-based modelling system with RS data as inputs continue to be the focus of hydrologic modelling.

Expressing hydrologic parameters as a function of current land use makes it possible to predict rationally the impact that future land-use change will have on runoff response (Rango et al. 1983). In any hydrologic model, land cover plays an important role in determining the streamflow response (Duchon et al. 1992). Researchers assert that Landsat-based information gives similar or better results than traditional methods.

Land-use classification techniques commonly integrated in a GIS framework for relating hydrological parameter change are supervised and unsupervised. Supervised classification is used most commonly because it permits greater refinement. Although accuracy associated with the practical use of RS data is variable, applicability of remotely sensed data is not limited by the degree of accuracy.

What are the limitations of GIS and how can they be overcome?

Current GIS represent a static view of the world from a temporal perspective. To analyse spatiotemporal information digitally, current cartographic theory and methods are inadequate (Langran and Chrisman 1988). The GIS have not reached a stage of representing temporal phenomena effectively. Efforts to enhance temporal capabilities of GIS have revealed several problems at the fundamental and conceptual levels (Langran 1989; Peuquet 1994). In cartography, three approaches are used for representing time and depicting change: sequence of discrete displays (snapshots or oscillating colours) at various speeds; dynamic display using interactive control; and a static map with supplemental graphics (Peuquet 1994). However, the primary basis of cartographic approaches to representation is spatial. Temporal representation of time as a way of organizing a database is so complex and challenging that experts have suggested interdisciplinary research involving concepts from perceptual psychology, artificial intelligence, and other fields (Peuquet 1994). The state of the art in modelling the temporal dynamics of a process in a GIS framework comes down to integration with computer-based programming.

What are the model types?

A simulation model can be event-based (storm runoff) or continuous. Some commonly used event-based models are: the flood hydrograph package (HEC-1) of the US Army Corps of Engineers (1981), TR-20 (SCS, 1969), TR-55 (SCS, 1975), SEDIMOT-II (University of Kentucky 1985) and Hydrograph-2. Most of these models are based on unit hydrograph theory implying that the relationship between rainfall and runoff is linear and constant. Commonly used continuous models are: the Stanford Watershed Model, National Weather Service River Forecast System (Curtis and Smith 1976), Sacramento Watershed Model, Precipitation-Runoff Modelling System (Leavesley et al. 1983), SSARR and Simulation of Urban Runoff Process (Australian Water Resources' Council 1977) and the Peatland Hydrologic Model (Guertin et al. 1987).

What are the issues surrounding the accuracy of models and modelling?

Accuracy of any hydrologic model depends on the accuracy of the parameter inputs. Precipitation distribution is an important factor affecting streamflow response. Another factor is evapotranspiration. Since research on evapotranspiration is limited (Nakama and Risley 1993), leaf area index is used as a principal independent variable for ecosystem modelling - including estimation of transpiration (Running and Coughlan 1988). In the absence of evaporation data, water body evaporation rates are taken as close approximations (Nakama and Risley 1993). Representation of the antecedent soil-water condition is one of the most difficult aspects of parameter estimation in hydrologic modelling. A uniform antecedent soil-water content throughout the catchment is often assumed, but this simplification undermines the physical basis of subsequent modelling. Uniform conditions rarely exist under wet conditions. The best approach to defining antecedent conditions is to use the model to establish them.

Model complexity is another issue. A number of studies has compared simple and complex models. Results generally show that simple models are almost as accurate as complex ones. Results of comparative studies as well as development application and evaluation of complex distributed models continue to be areas of active research. Michaud and Sorooshian (1994) concluded that a simple model performed as accurately as a complex distributed model provided that calibration was performed. In another study, comparing four models in South Africa, differences in simulation results could be explained either by differences in complexity of the modelling approach or resolution of input data (Hughes 1994). Many factors affect the accuracy of runoff models: input data, initial conditions, assumptions, parameter values, runoff dynamics and model resolution. These factors are difficult to examine properly (Michaud and Sorooshian 1994). Thus, simple models may be as good as complex ones (Federer 1982 and Dickenson 1982).

In view of the complexity of the model and the practicality of applying it, the use of a compromise approach—in which the model is kept simple but lumping occurs at the land-cover level—emerges as a practical approach to modelling at the watershed level. Process modelling needs to evolve and experimental research needs to develop parameter values. New research should include experimentation on flow representation, expansion and contraction of source areas at the micro- and macro-levels.

How is flow routing important?

Flow routing is another important factor in determining streamflow response. Usually, prior to flow routing, hydrologic analysis is performed by subdividing the catchment into subwatersheds. Runoff hydrographs are obtained for each subwatershed, routed through interconnected channels and combined to develop a design flood hydrograph at approximate locations. Flow routing may be done by using kinematic wave approximation, Muskigum method or dynamic wave formation (Prakash 1986). In recent years, digital elevation models (DEM) have been used in hydrologic modelling for representing terrain and its attributes. Approaches to terrain representations can be grouped as continuous and discrete. Continuous approaches include surface elevation contours, triangulated irregular networks (TIN) and grids. The grid-based approach is applied most widely because of the low cost of computer memory. In the gridded approach, the steepest downslope gradient between the cell and its adjacent neighbour is used to determine the flow path; the drainage network is identified based on a channel threshold value. There are basically two variations of this approach: treating sinks as artifacts and accepting DEMs as accurate.

The approach of flow representation in only one direction fails to represent divergent flows on convex slopes and can lead to bias in flow path orientation. So, approaches for divergent flow have been proposed. The divergent flow approach requires six to seven times more computer execution time than the one-dimensional steepest gradient representation. The quality of information that can be automatically derived from DEM as well as the quality of slope information are functions of both horizontal and vertical resolution of the DEM (Jenson 1991). In fact, the one-dimensional steepest gradient approach is sufficient for channel representation and overland flow routing in a large mountain watershed. More recently, multiple flow direction approaches have also been proposed. The application of current physically based models might be carried out in conjunction with a programme of field measurements to ensure consistency between model predictions and real-world processes (Beven 1992; Grayson et al. 1992).

How are results displayed and communicated?

Display and communication of model results are receiving attention in watershed modelling research. Several three-dimensional visualisation models (e.g., Utools, Vantage Point, Grass) and computer graphic techniques are used to display and communicate results. Combining watershed modelling, computer programming, GIS, RS and visualisation is the present state of the art in integrated watershed process modelling.

An example of an integrated approach to GIS-based watershed modelling

The approach is illustrated by using a study developed for the US Man and the Biosphere Programme. The main features of the approach are presented in Figure 1.

- Use of RS for land-use/land-cover information for generating different management scenarios
- Use of existing model for precipitation distribution in mountain areas
- Use of C programming to generate initial conditions and characterise hydrologic conditions based on antecedent conditions and event magnitude

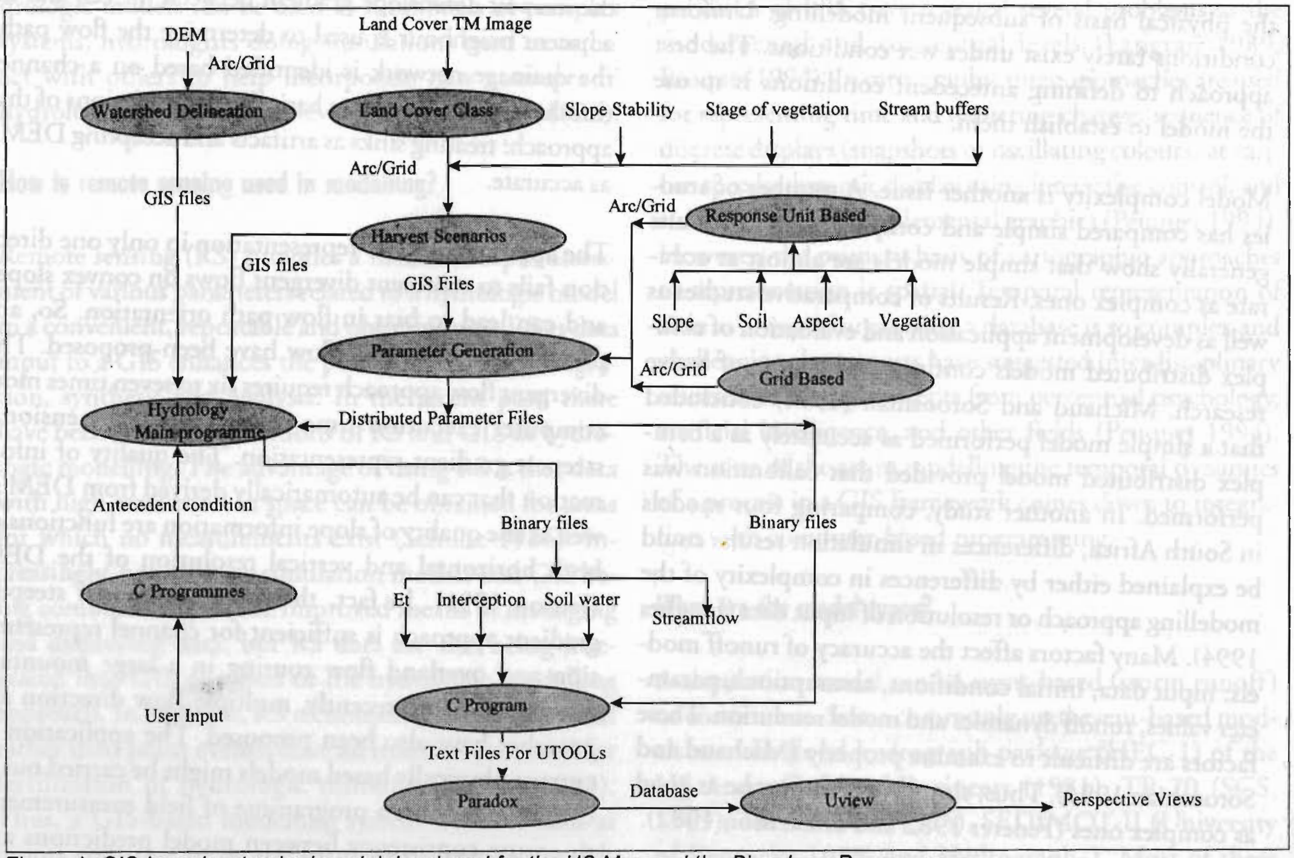

Figure 1: *GIS-based watershed model developed for the US Man and the Biosphere Programme*

- Use of C programming to keep complex accounting of each component of the hydrologic process
- Use of watershed, sub-basin and basin scales for modelling
- Use of an event-based approach to assess impact on streamflow peak, timing to peak and mean daily flow
- Hypothesis testing using 4 management scenarios, 2 modelling approaches, and 3 hydrologic conditions for three watershed scales to confirm model predictions
- Use of two modelling approaches: distributed and response-unit-based to predict hydrologic response
- Use of readily available meteorological information
- Use of GIS-based parameterisation techniques
- Use of ASCE standards for model calibration and validation
- Use of model to arrive at new management criteria
- Outlining of ways to link hydrologic science and natural resource management
- Use of user 3-D perspective views to communicate model results

What are the main activities in formulating and testing hypotheses?

The main activities in formulating and testing hypotheses are

- reviewing and drawing inferences from previous work,
- linking hypotheses to public issues and management concerns,
- formulating clear-cut research questions, and
- designing experiments or approaches to address the question(s) or hypothesis or hypotheses.

How can GIS-based hydrologic modelling be extended to participatory watershed management?

The entry points in embracing participatory watershed management could be as follow.

- Public consensus building before setting objectives.

- Involving the public in accuracy, details and error concerns
- People's participation in defining scenarios, modelling approaches and sizes of watershed scales
- Specifying and changing of model input and output
- Ascertaining 3-D perspective views
- Using the model to evaluate post-development environmental impacts

Conclusions

Adapting an integrated GIS-based hydrologic model to the Asian context involves the following.

- Defining a working hypothesis embracing participatory issues
- Using participation analysis before model building
- Developing management scenarios that reflect people's actions
- Using readily available information
- Providing refresher training in hydrologic modelling
- Using remotely sensed data and data from secondary sources
- Building a modelling database and sharing digital data
- Using PC-based modelling
- Focussing on priority issues needing quantitative predictions
- Making models flexible in order to address gender and equity concerns.

The future of an integrated approach to watershed modelling that encompasses participatory watershed management can be briefly outlined as follows.

- Integration of socioeconomic and ecological processes as a one-step procedure
- Use of models to address sustainability of human-dominated landscapes
- Use of interdisciplinary planning and model building
- Use of transdisciplinary techniques
- Use of a comparative modelling approach

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PWMTA

The Participatory Watershed Management Training in Asia (PWMTA) Programme (GCP/RAS/161/NET, FAO/Netherlands) is designed for human resource development in participatory watershed management. It will contribute to sustainable use and management of forest, soil, water, and other natural resources by improving skills and national capabilities to plan, implement, evaluate, and monitor participatory watershed rehabilitation programmes. This will be achieved by regional training, workshops, seminars, and national and regional watershed management networking. Many of the Asian Countries are seriously investing in WM today. However, few are providing training in holistic approaches to participatory watershed management. PWMTA is to assist the member countries in filling this gap.

ASIAN WATMANET
(Asian Watershed Management Network)

This is a regional network for people's participatory watershed management founded in Nov. 1994 by the national coordinators of the RAS/93/063, WMTUH/FARM Programme. It is now sponsored by the PWMTA, GCP/RAS/161/NET Programme of the FAO/Netherlands since January 1996. Its member countries are the participating countries in the PWMTA programme. The network is to facilitate people's participation in watershed management at small watershed, village, and district and national levels; exchange of experiences at farmer, extensionist, technical, professional, educator, and policy-maker levels; exchange of information among member countries; and the strengthening of a movement of GO/NGO/PO/FO for sustainable natural resources' management of fragile watersheds in the Asian region. It also publishes a quarterly ASIAN WATMANET newsletter.

Participating Countries

Afghanistan
Bangladesh
Bhutan
China
India
Myanmar
Nepal
Pakistan
Sri Lanka
Thailand

Publications of PWMTA – ASIAN WATMANET

I. ASIAN WATMANET Newsletters

Issue No. 1, theme:	WMTUH and FARM Introduction
Issue No. 2, theme:	Status of Watershed Management in Asia
Issue No. 3, theme:	Farmers' Organizations
Issue No. 4, theme:	Policy Issues in Watershed Management
Issue No. 5, theme:	Gender Framework for Resource Management
Issue No. 6, theme:	Participatory Watershed Management Training
Issue No. 7, theme:	Gaps in Participatory WM Training and Education in Asia
Issue No. 8, theme:	Envisioning of WM professionals
Issue No. 9, theme:	Elements of Participatory Processes in WM
Issue No.10, theme:	Land Use Titles - A Key to People's Participation
Issue No.11, theme:	Sustainability of Participatory WM
Issue No.12, theme:	Participatory Watershed PME
Issue No.13, theme:	Indigenous Technology Knowledge for WM
Issue No.14, theme:	Sustaining Success and Learning from Failure
Issue No.15, theme:	People's Movements in Watershed Management
Issue No.16, theme:	Farmers' technical Associations (FTAs) in China
Special issue:	Membership Directory

II. Field Documents

No. 1 Status of watershed management in Asia

No. 2 A rapid review of the NWDPRA in India

No. 3 Case study of people's participation in WM in Nepal (BTRT area), (in Nepalese language, out of press)

No. 4 Case studies of people's participation in WM in Asia: Part 1: Nepal, China and India

No. 5 Case studies of people's participation in WM in Asia: Part 2: Sri Lanka, Thailand and Vietnam.

No. 6 Recent developments, status and gaps in participatory watershed management training and education in Asia

No. 7 Participatory processes in integrated WM

No. 8 Farmer led integrated WM- A trainers' resource book

No. 9 APEX and SWAT models for rapid impact assessment (in draft)

No.10 Participatory upland watershed planning, monitoring and evaluation -A training resource pack

No.11 Indigenous technology knowledge for upland WM in Bangladesh

No.12 A glimpse of local technology knowledge for comprehensive WM in China

No.13 Building farmers' organizations for integrated WM in India- A trainers' manual

No.14 Ripples of the society – Peoples' movements in watershed development in India

No.15 A glimpse of indigenous technology knowledge for watershed management in Upper North-West Himalayas of India

No. 16 An introductory training manual on village organizations for IWM in Pakistan

No. 17 Recent concepts, knowledge, practices and new skills in participatory integrated watershed management – A trainers' resource book