ICIMOD

Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayan Region

Proceedings of an International Workshop
Held in Baoshan, China
December 19-22, 1994

Edited by
Pei Shengji

assisted by
Sameer Karki

Organised by
International Centre for Integrated Mountain Development
in Collaboration with the Kunming Institute of Botany, the Chinese Academy of Sciences (CAS), and
the Baoshan City Government

Cover Photograph: Workshop participants visiting the ICIMOD Rehabilitation Site in Baoshan, Yunnan Province, China
Foreground: Legume shrubs (*Tephrosia candida*) two years after planting on degraded land
Background: Rehabilitated water reservoir at the site village

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Foreword

The degradation of the environment in the Hindu Kush-Himalayas (HKH) is not a recent phenomenon. What is new is the scale and speed of land degradation during the last 20 to 30 years, in particular the degradation of natural resources on common land, which are frequently affected by changes of land-tenure systems in many countries of the region. One of the strategies to cope with declining fertility or productivity, in part, has been to move to other sites within traditional village boundaries or to migrate to other uninhabited parts of the region. However, the people: land ratio is now exceeding the natural carrying capacity of the land in many parts of the HKH region. The carrying capacity of the land is to a large extent determined by the ratio of cultivated land to the lands that support and maintain the fertility of agricultural lands. These "support lands" consist of forests and pastures, and it is these lands that have deteriorated rapidly over the last 30-40 years due to increasing population pressure and overgrazing.

ICIMOD's project on `Rehabilitation of Degraded Lands in Mountain Ecosystems' has been developed to look into the issues of resource degradation in the HKH region through a multidiciplanary approach and through community participatory, action-oriented research. The programme is being implemented and participated in by the ICIMOD member countries of China, India, Nepal, and Pakistan. The project has encouraged an integrated approach and a wide range of activities; these include biomass development, water harvesting, soil-water erosion control, and planting of useful indigenous and exotic grasses, shrubs, and trees which are mostly fast growing and nitrogen-fixing species, and planting in contour hedgerows and in pits on the heavily-eroded slopes of degraded lands. As such the project activities differ considerably from afforestation programmes that have been used in the past for rehabilitation of degraded lands.

The research undertaken so far provides not only technologies for biomass development , water-soil erosion control, and water harvesting methods for similar mountain areas in the region, but also provides experience in institutional strengthening and peoples' participation at local village level. Examples are social fencing and stall-feeding of animals which are successfully implemented in the project site villages.

The workshop provided a forum for experts and development workers from the region and other countries to meet and exchange research findings from field studies and discuss subjects concerned with the restoration of degraded ecosystems for mountain development. First-hand information and data were generated from field-based case-study sites in collaboration with ICIMOD member country institutions and were presented and assessed at the workshop.

I would like to take this opportunity to thank the International Development Research Centre (IDRC), Canada for their generous support to the programme and workshop, the Chinese Academy of Sciences, the Kunming Institute of Botany, and the Boashan government for their hospitality and support to the success of the workshop. Thanks are also due to Professor Pei Shengji, Head of ICIMOD's Mountain Natural Resources' (MNR) Programme and Coordinator for the Project as well as to other staff members from the MNR Programme of ICIMOD .

Egbert Pelinck
Director General
ICIMOD

Preface

This workshop report presents the highlights of an International Workshop on Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayan (HKH) Region held from December 19-22, 1994, in Baoshan of Yunnan Province, China. The workshop was jointly organised by the International Centre for Integrated Mountain Development (ICIMOD) and the Chinese Academy of Sciences (CAS) and attended by 35 participants from research institutions, universities, government agencies, and NGOs in Canada, China, India, Pakistan, Nepal, and Hongkong. The participants were mainly from collaborating institutions involved in the ongoing research project on Rehabilitation of Degraded Lands in Mountain Ecosystems of the HKH Region and scientists from other institutions working in the area.

Degradation of mountains ecosystems is a global malaise, and the Himalayas constitute a threatened ecosystem. More than ninety per cent of the people in the Himalayan region have to cultivate land for a living. Rural people rely on natural resources such as soil, water, forests, and pastures to meet their daily needs. Heavy rains erode fertile mountain slopes during the monsoon, population pressure on mountain lands increase year by year; overgrazing, deforestation, transformation from traditional to modern systems, and cultivation of marginal land and steep slopes evoke further damage; biomass cover is extensively destroyed, soil fertility declines, and water cycles are affected. It is clearly understood that natural resources, in particular land-soil, water, and biomass and the entire biosystems of the HKH region are drastically depleted and unstable. Sustainable management of natural resources in the degraded mountain ecosystems is seen, therefore, as a major challenge for all mountain societies and governments in the region.

The objective of the workshop to bring together all the participating institutions involved in the ICIMOD project and individuals working in the areas of land rehabilitation to meet and discuss: (1) the major outputs so far from the past two years of the project; (2) important findings from field-based studies of the project and relevant studies from the region; (3) the type of training materials that could be prepared by collaborating institutions, and (4) to discuss and identify priority activities for future follow-up programmes.

It is believed that the four-day workshop itself and the field trip to Damay village site in Baoshan have achieved the objective through the sharing of knowledge and interaction amongst all participants. The outputs generated from the workshop, which are presented here in this report, will be most useful for guiding collaborative institutions taking part in the project as well as other institutions in the region.

On behalf of the workshop organisers, I would like to take this opportunity to thank all the participants for their valuable contributions. I would also like to thank the Baoshan city government, the Kunming Institute of Botany, CAS, and the Damay villagers for their hospitality. We extend, here again, our gratitude to the International Development Research Centre (IDRC), Canada for its financial support to the workshop and contribution to the success of the project.

Pei Shengji
Head, Mountain Natural Resources
Division and Coordinator of the Project

Acknowledgements

ICIMOD gratefully acknowledges the financial support of the International Development Research Centre (IDRC, Canada) and the support from the Chinese Academy of Sciences which co-hosted the workshop. The hospitality of the local government of Baoshan City of Yunnan Province made it possible for the workshop to be held successfully.

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Part I

Proceedings of the Progress and Prospects for the Project "Rehabilitation of Degraded Lands in Mountain Ecosystems of the HKH Region"

Chapter 1

Introduction to the Workshop

The International Workshop on the 'Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayas' was held in Baoshan City, Yunnan, China from 19 to 22 December, 1994.

ICIMOD's project on 'Rehabilitation of Degraded Lands in Mountain Ecosystems' has been developed to look into the issues of resource degradation in the Hindu Kush-Himalayan Region through participatory action-oriented research. Under this programme, which is funded by the International Development Research Programme (IDRC), Canada, rehabilitation of degraded lands is being carried out at the community level in the ICIMOD member countries of China, India, Nepal, and Pakistan. The project has encouraged a wide range of activities such as water harvesting; building of checkdams; water diversion ditches; and plantation of economically useful indigenous and exotic grass, shrubs, and tree species in hedgerows and in pits. Thus the activities of the project differ from conventional afforestation programmes.

The project has successfully broken the myth that open grazing of domestic animals in the Himalayas cannot be stopped and that plantations cannot be protected without fencing. The project sites do not have any fences but the forest user groups have ensured protection through social fencing and the domestic animals are stall fed. The project has also established soil erosion monitoring plots and has carried out studies on natural regeneration.

Under the project activities on Nepal Site II, for example, rehabilitation of two very degraded forest patches at Bajrapare and Dhaireni, which have been handed over to respective forest user groups, has been carried out since 1993. Forest lands were selected as they represent some of the most degraded sites in the country. The two sites were selected because they differ considerably in size, relative accessibility, and the number and ethnic composition of the households in forest user groups but are located on similar soils and in agro-ecological zones.

The use of contour hedgerows to reduce soil erosion by the project represents the use of the technology on such a scale in community forestry for the first time in Nepal. The project also organises various training programmes and visits for forest user group members to other successful rehabilitation programmes at the community level in Nepal. By working through the forest user groups the project has ensured that decisions on activities are taken by the user groups and are of relevance and importance to them so that the benefits are direct and immediate, e.g., fulfilling their need for fodder.

The project has thus demonstrated that with conducive legislation for community forestry of a country, and by recognising people as a positive source in the rehabilitation of degraded lands, the participation of people in such activities can be improved.

The inaugural session of the workshop was chaired by Mr. Egbert Pelinck, Director General of ICIMOD. In his opening address, Mr. Pelinck emphasised the gravity of the issue of environmental degradation in the Hindu Kush-Himalayan Region. He expressed the hope that this workshop would be able to harness the wealth of experience of the participants from four ICIMOD member countries and the institutions they represented for the well-being of the people and the environment of the Hindu Kush-Himalayas.

Mr. Zhao Yong Ren, representative of the Chinese Academy of Sciences (CAS), and Mr. Steven Tyler, representative of the International Development Research Centre (IDRC), Canada, also spoke on the occasion. Following this, Mr. Zhang Bai-Ying, the Deputy Governor of Baoshan City, welcomed the participants of the workshop to the city, which is known to be a resting place along the famous Southern Silk Route in the Hindu Kush-Himalayas.

Session One

The first half of the first session was chaired by Mr. Steven Tyler of IDRC and the second half was chaired by Mr. Egbert Pelinck of ICIMOD. Professor Pei Shengji, ICIMOD project coordinator, gave a brief report on the eco-regional approach to rehabilitating degraded lands in the Hindu Kush-Himalayan ecosystems. Country reports of the participating ICIMOD member countries were presented specifying the five sites of the project for 'Rehabilitation of Ecologically Degraded Lands'. The five sites were the Baoshan site in China; the Godavari and Kavrepalanchok sites in Nepal; the Almora site in India; and the Mansehra site in Pakistan.

The papers presented during Session One included

Eco-regional Approaches to Rehabilitation of Degraded Land in Mountain Ecosystems of the Hindu Kush-Himalayas	- Professor Pei Shengji ICIMOD
Country Report from India	- B.P. Kothyari G.B. Pant Institute of Himalayan Environment and Development
Country Report from Pakistan	- B.H. Shah Pakistan Forest Institute, Pakistan
Country Report from Nepal - Site I	- B.R. Bhatta ICIMOD
Country Report from Nepal - Site II	- S.R. Chalise ICIMOD
Country Report from China	- Xu Jian-chu Kunming Institute of Botany, CAS

Session Two

The second session of the workshop was chaired by Dr. B.A. Wani, Deputy Inspector General of Forests, Pakistan, D. P. Parajuli, Director General of Forests, Nepal, Professor Pei Shengji, ICIMOD, and Dr. Ronald Hill, University of Hongkong, respectively. The session focussed on Technology and Socioeconomic Aspects of Rehabiliation of Degraded Lands in Mountain Ecosystems. The papers presented addressed species, technologies, and systems of management of degraded land, often government owned but considered common property by local inhabitants. Issues, such as understanding degradation processes, soil fertility, soil erosion, use of slopes and watersheds, use of native plant species and indigenous knowledge, water harvesting technology, and alternative approaches for rehabilitating degraded lands were covered.

Papers presented during *Session Two* were as follow.

Understanding Degradation Processes in the Middle Mountains of Nepal	- Hans Schreier and P.B. Shah
Soil Fertility Issues under Irrigated and Upland Agriculture in the Middle Mountains of Nepal	- P.B. Shah and Hans Schreier
Alternative Approaches to Rehabilitating Degraded Lands in Mountain Ecosystems of Nepal and the Hindu Kush-Himalayas	- D.P. Parajuli
SWEET Package for Regeneration of Degraded Lands in the Indian Himalayas	- B.P. Dhyani
Living Terrace Edge: An Effective Method of Slope Utilisation in the Upper Reaches of the Yangtze River	- Li Xiu-Bin

Land Degradation and Rehabilitation of a Hot and Dry Valley in Yen-Mu of Yunnan - Yang Zhong

Mapping of Watershed Afforestation by Means of the Global Positioning System (GPS): Land Ownership, Tenancy Systems, Ethnic Composition, and Problems in the Tarbela Watershed Project Area - B.P. Wani

A Matter of Relativity: Design for the Low-cost Monitoring of Soil Erosion under Differing Land-use Regimes - Ronald Hill

Use of Native Plant Species and Indigenous Knowledge for the Rehabilitation of Degraded Lands in Mountain Ecosystems - Tong Shaoquan, Yang Qui-xiu, and Xu Jian-chu

Preliminary Study on the Key Techniques for Restoration and Rehabilitation of Degraded Mountain Ecosystems Qui Xue-zhong and Tang Jian Wei

A Study of Species' Screening and Techniques for Afforestation in the Hot and Dry Valley of the Jinsha River - Shi Pei-Li, Diao Yangguang, Wei Taichang, Cheng Keming, and Xi Yourong

Rehabilitation of Degraded Lands in Mountain Ecosystems: A Technical Report of Plantation Establishment in Nepal - Lu Rongsen

Water Harvesting Technology and Its Impact on Development of the Central Himalayas - B.P. Kothyari and P.P. Dhyani

Site Visit

The workshop participants visited Damay Village, the Baoshan site of the ICIMOD project on Rehabilitation of Degraded Lands in Mountain Ecosystems, on 21st December. The field visit was aimed at getting first hand experience of the approaches undertaken on the Chinese site.

Session Three

The field visit was followed by group discussions in the third session. Professor Pei Shengji was the chairperson. First priority was given to completing the current phase of the project and consolidating the achievements of the remaining four months. The papers presented during the workshop were discussed. Other topics discussed were programme activities for the next phase of the project and follow-up activities, types of training materials that could be developed by collaborating institutions for the rehabilitation of degraded mountain ecosystems, and a detailed work plan for project implementation in 1995.

Session Four

The fourth session of the workshop was also chaired by Professor Pei Shengji. Based on the discussions, common issues, problems, and opportunities for rehabilitating ecologically degraded lands were identified and consolidated.

Concluding Session

The workshop's concluding session was held on December 22nd. Mr. Zhao Yong Ren of CAS was the chairperson. Dr. B.P. Wani, Mr. D.P. Parajuli, and Professor Pei Shengji gave the concluding remarks. The workshop provided a forum for discussing the common issues and problems regarding resource degradation in mountain ecosystems in the Hindu Kush-Himalayas and finding short and long-term solutions that would contribute to poverty alleviation, environmental protection and regeneration, and equity among beneficiaries of rehabilitation activities.

Opening Address by Mr. Egbert Pelinck, Director General, ICIMOD

Mr. Deputy Governor, Prefecture – Mr. Wang
Mr. Deputy Governor, City – Mr. Zhang
Mr. Zhao Yong Ren – Bureau of International Cooperation, CAS
Prof. Tong Shaoquan, KIB of CIS
Mr. Tyler, IDRC
Participants
Colleagues
Ladies and Gentlemen

It is a pleasure to be back in Yunnan Province and meet again with several staff of the KIB, who made my first trip to Yunnan earlier this year both successful and pleasant. One of the results of that visit is this workshop for which the KIB is the host organisation on behalf of the CAS. It is also a pleasure to meet old friends from Pakistan, India, Nepal, and Canada and have the opportunity to get to know other experts in the field of rehabilitation of degraded lands.

The degradation of the environment in the Hindu Kush-Himalayas is not a recent phenomenon. Here in Baoshan, an important resting place along the traditional souther Silk Route, we know that lands were eroded already many centuries ago. also elsewhere in the HKH we know from oral and written history that there have always been pockets of degraded lands in the HKH. What is new is the scale and speed of land degradation over the last 20 -30 years. One of the strategies to cope with declining fertility or productivity in the past has been to move to other sites within traditional village boundaries or to migrate to other uninhabited parts of the HKH. However, although population densities in the mountains have not reached the levels of the plains, the people: land ratio is now exceeding the natural carrying capacity of the land ion many parts of the HKH. This carrying capacity of the land is to a large extent determined by the ration of cultivated land to the lands that support and maintain the fertility of the agricultural lands. These "support lands" consist mainly of forest and pasture, and it is these lands that have deteriorated fasted over the last 30-40 years due to increasing population pressure and overgrazing.

Within this overall context of environmental degradation ICIMOD was established in 1983 with the dual mandate of environmental management and poverty alleviation. From the very beginning, ICIMOD has tried to address the problems of the HKH ion an integrated way. It tries to do so by identifying and promoting linkage between

- disciplines, e.g., between agriculturists and foresters, agriculturists and economists, natural resources managers and social scientists
- policies and technologies
- research and development
- countries

The present workshop reflects very well several of the linkages and activities ICIMOD is promoting. I am glad that we have been able to bring together representatives of 4 of ICIMOD's member countries with their wealth of experience, not only from the sites for which they are responsible, but also from the institutions they represent.

We are in a unique position to harness that knowledge and apply if for the wellbeing of the people and environment of the HKH. We can do so ion different ways over the next 4 days.

Firstly, we will listen to each other and discuss critical issues affecting rehabilitation of degraded lands at 5 sites ion the HKH. This will hopefully be not only a discussion on species and technologies for rehabilitation, important as they are, but also address the important issue of systems of management of degraded lands, often owned by governments but considered common property resources by the people living nearby. Based on these discussions we will identify common issue, problems and opportunities for rehabilitating ecologically degraded lands.

Secondly, we will visit the Chinese field site here in Baoshan and get first hand experience with the approaches undertaken here. I expect this to be a visit of mutual benefit to our Chinese colleagues and the visitors from abroad.

Thirdly, we will look at the future of the project that brings us together "Rehabilitation of ecologically degraded lands." What to do to complete the present phase and consolidate what is achieved in the remaining period of 4 months is the first priority. But also to identify the need for and scope for follow up activities.

May I recommend that you look both in the short term and in the long term for solutions that contribute to poverty alleviation, environmental sustainability and equity among beneficiaries form rehabilitation work. With only men participating in this workshop the Chairmen of the Sessions should ensure that in each session the issue of gender balanced development is being raised.

Ladies and Gentlemen, ICIMOD is grateful to the Chinese Academy of Sciences, and in particular the Kunming Institute of Botany for hosting this workshop. I am also very grateful to the Deputy Governor of Baoshan Prefecture and the Deputy Governor of Baoshan municipality for their keen interest in co-hosting the workshop and all the facilities and hospitality provided.

I am particularly pleased that a representative of the Canadian International Development Research Centre participates in the workshop. We are grateful for IDRC s support to ICIMOD which has made it possible to implement this project and bring you all together.

I hope that the results of this workshop will also be useful for other IDRC to continue it s support to ICIMOD in the fields we are discussing this week.

To conclude, I wish you all a successful meeting, a pleasant stay and friendship among colleagues, committed to the cause of rehabilitating ecologically degraded lands.

Thank you

Chapter 2

Reports by Working Groups on Issues of Themes on Rehabilitation of Degraded Lands

1. **Group I:** *Priority Activities for the Future Implementation of Rehabilitation Activities*

Methodologies

The activities in each case study were based on the guidelines laid down by the methodological workshop held in Kathmandu in 1992. The Kathmandu methodologies' workshop defined technologies and socioeconomic components that were deemed to be of importance and also recognised that every site did not follow all approaches as site situations differed considerably. It was agreed that, for the next phase, the project activities would build on methodologies already established.

It was suggested that each soil erosion plot should not be smaller than 100 square metres (and not 10 square metres), and this was agreed up on. For the study of socioeconomic impact, it was suggested that a control community with similar socioeconomic conditions to those of the community in which the project had been implemented might give a better idea of the effect of intervention, and this would remain an option to be followed if adequate resources were available.

Rehabilitation Activities and Their Impact

Socioeconomic processes that affect the participation of the local community in rehabilitation activities need to be looked into more carefully, as well as the cost: benefit ratios of such activities. The need to look at interventions and their impact on women was also felt. The need to identify methodologies that looked at off-site impacts of rehabilitation efforts was also felt by the group.

The Rehabilitation Project as a Replicable Model

For the activities of the project to be replicable, it was suggested that monitoring techniques should be such that they could also be replicated by other researchers and by the communities themselves.

Government Policy and Rehabilitation

The group recognised that various government policies impacted directly on how resources were used in a community. One of the most important issues was that of ownership of land or land tenure. It was felt that, as well as these, other policies also needed to be examined and their impact assessed on degradation or rehabilitation of mountain ecosystems.

Workplan for 1995

A meeting of all country coordinators of the project on **'Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayan Region'** took place in the presence of the ICIMOD Director General, Mr. Pelinck and Dr S. Tyler (IDRC). The desirability and possibility of the next phase of the project were discussed as the first phase of the project was to conclude on January 15, 1995.

It was unanimously agreed that, after the end of the current phase of the project, ICIMOD would submit a proposal for the continuation of the project for the next three years. The regional project coordinator, Professor Pei Shengji, proposed that, since project implementation had been delayed by a few months initially, an extension until June 30, 1995, should be requested from IDRC, and this, too, was agreed upon unanimously.

It was decided that, for 1995, the stress would be on consolidation of the present work on site development and research and some extension. The nature and extent of the work was to depend on the amount of funds made available by the donor agency. The components of 1995 activities for the project were to include the following.

- Monitoring of water, soil, biomass, and socioeconomic changes in the participating rural communities
- Maintenance of plantations, trails, erosion plots, checkdams, water harvesting ponds, biogas facilities, and other on-site developments by the project
- Additional work on site development and management
- Preparation of training material
- Conduction of training and dissemination

In addition, the country project coordinators were requested by the project coordinator, Professor Pei Shengji, to complete and send a short report for the IDRC on the completion of the first phase of the project by mid-April 1995.

2. **Group II:** *Types of Training Materials Needed for Future Follow up Activities*

Training on Rehabilitation of Degraded Community Land

In its first phase, the project established five case study sites and selected suitable plant species and technologies for rehabilitation of fragile mountain lands. Monitoring systems for soil erosion studies were also established. The project coordinators felt that sufficient work had been carried out at each site for these to be useful as training on different approaches and methods of rehabilitation of similar degraded lands.

It was reported that the sites were already being used as training sites by various organisations. In Pakistan, for example, the forestry students, who often used a field station situated close to the case study site, had started using the site as a training site. In Nepal, the site at Godavari had attracted local visitors and visitors from many different countries, and the site at Kavrepalanchok was already being used as a demonstration site by the District Forest Office for other forest users' groups. However, for the sites to play a more important role nationally, the need for a more concerted effort was felt.

Training: The Focus Group

The 'clients' for training were identified as government officials, non-government organisations, students, and farmers.

Training components should include technological components, such as biophysical monitoring, as well as socioeconomic components. The need to stress the training of so-called professionals by farmers was also stressed, and Professor Pei made a strong case for learning about and incorporating indigenous knowledge in project activities. It was also felt that farmer-to-farmer exchanges should be the main component of such training. The need to involve more women in training was also highlighted.

It was decided that training would be for professionals and for farmers. The specific components of the training would be as follow.

<u>For Professionals</u>

a) Tools and methods: analytical data processing, GIS methods
b) Technology for plantation establishment, plant propagation, and plant nursery establishment
c) Improved technology for soil-water conservation
d) Indigenous knowledge for soil-water conservation
e) Extension/communication skills
f) Suitable management of plant resources

It was felt that exchanges of professionals between countries would facilitate exchange of ideas and experiences.

<u>For Farmers</u>

a) Appropriate technology for plantation establishment, plant propagation, and plant nursery establishment
b) Improved technology for soil-water conservation
c) Indigenous knowledge of soil-water conservation
d) Extension/communication skills
e) Management of plant resources
f) Alternative rural energy sources and devices
g) Water harvesting technologies

Training will be carried out by participating institutions in the concerned countries, apart from GIS which will be carried out by ICIMOD.

Production of Training Materials and Dissemination

It was agreed that each site should identify its priority for training and develop methods accordingly. It was suggested that documentation of other successful community-based rehabilitation efforts within each country would provide a much more balanced approach to training.

The role of the media in training and disseminating was also discussed in the meeting. Again, the need for a country-specific approach was highlighted. For example, in China, since television reaches about 70 per cent of the population it was suggested that this could be a very useful medium for dissemination, whereas in Nepal the radio was considered more suitable.

Production of video films on project activities in national and other common languages was identified as one method of disseminating the results of project activities, and for most sites recording of site activities had already commenced.

For the production of materials for training and dissemination, collaboration with national institutions is essential. ICIMOD will standardise and compile training materials for dissemination within the region as well as outside the region.

Institutional Strengthening

Training on institutional strengthening at the local level was identified as a crucial step towards achieving sustainable rehabilitation of degraded community lands. Since all case studies were being carried out with local communities, the need to strengthen their capacity to carry on the work initiated by the project was felt by the group.

The meeting concluded with agreement on the following issues.

Build on Methodologies

For the next phase of project activities, consolidation and continuation of the achievements of the first phase of the project would be the biggest priorities. For the next phase, it was agreed that the projects would build on the guidelines laid down by the methodological workshop held in Kathmandu in 1992. It was decided that the choices in biophysical and socioeconomic monitoring would be according to the site-specific requirements.

A Holistic Approach

Rehabilitation of degraded common lands must be looked into as a part of overall natural ecosystems and farming systems in the mountain areas as they are the vital support areas for agriculture, forestry, and other life-support activities. Gender concerns need to be incorporated in all project activities.

Institutional Strengthening

The meeting overwhelmingly recommended that the project should stress strengthening of local institutions, such as users' groups and local NGOs, for social, economic, and ecological sustainability and replicability.

Training/Awareness

It was decided that training, demonstration, awareness-raising, and farmer-to-farmer exchange of technological innovations would be emphasised. Many felt that, for rehabilitation of degraded lands, the constraints were not technical but socioeconomic in nature, and it was suggested that such outreach programmes with appropriate policies would be of great benefit at both the local and national levels.

Chapter 3

Eco-Regional Approach to Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayas

Pei Shengji

Introduction

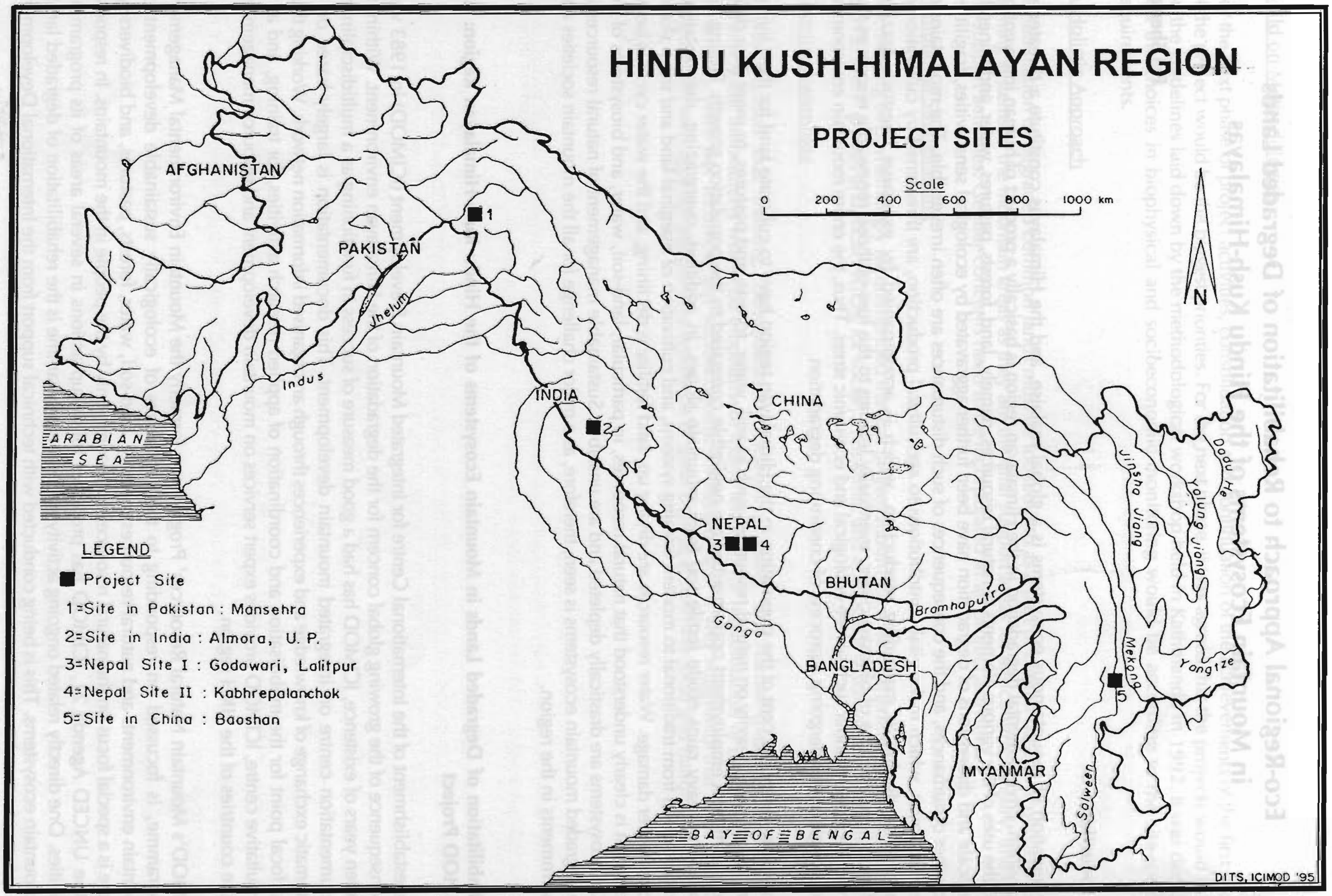
Degradation of mountainous ecosystems is a global malaise, and the Himalayas constitute a threatened ecosystem. Environmental degradation in the Himalayan region is basically a product of human intervention into the uses of the various elements of natural resources, namely, land, forests, pastures, water, and minerals. The scale and dimensions of degradation have been further aggravated by ecological sensitivities, fragilities, and other disturbances, and the consequences of such disturbances are often irreversible. The mountains of the Himalayas, which make vital contributions to agricultural production, are threatened by cultivation of marginal lands due to expanding production, which is accompanied by excessive livestock grazing, deforestation, and loss of biomass cover, eventually leading to the loss of those renewable resources that cannot be revived under such severe ecological and economic stress. Thus, the entire mountain environment in our region is undergoing a process of continuing degradation.

More than ninety per cent of the population in the Himalayan region have to cultivate land for their living. Rural people rely heavily on natural resources, such as soil, water, forests, and pastures, to meet their daily needs. Off-farm employment opportunities are negligible compared to the population growth. During the monsoon, heavy rains erode fertile soil from mountain slopes. In addition, overgrazing, deforestation, transformation from traditional to modern farming systems, and cultivation of marginal land and steep slopes evoke further damage. Water resources are drying up, land fertility is declining, and the water cycle is being affected. It is clearly understood that natural resources, in particular, land-soil, water, and biosystems of the HKH ecosystems are drastically depleted and are unstable. Sustainable management of natural resources in the degraded mountain ecosystems is seen, therefore, as a major challenge for all the mountain societies and governments in the region.

Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayan Region: An ICIMOD Project

The establishment of the International Centre for Integrated Mountain Development (ICIMOD) in 1983 was a consequence of the growing global concern for the degradation of the Himalayan environment. Within its first ten years of existence, ICIMOD has had a good measure of success in functioning as a multidisciplinary documentation centre on integrated mountain development. This documentation is largely based on a systematic exchange of knowledge and experiences through an organised information network. Working thus as a focal point for the mobilisation and coordination of applied research activities, for training, and as a consultative centre, ICIMOD provides expert services on mountain development and resource management to the countries of the HKH region.

ICIMOD's Mountain Natural Resources' Programme, formerly the Mountain Environmental Management Programme, is focussed on responding to the challenges of ecologically sustainable development of mountain environments and natural resources, namely, land-soil, water, forests, pastures, and biodiversity. There is a special focus on the natural resources used commonly by the people in the mountains. In response to the UNCED Agenda 21, ICIMOD has proposed follow-up actions in several areas of its programme activities. One directly related ongoing activity under the programme is the rehabilitation of degraded lands in mountain ecosystems. This is being conducted with technical support from the International Development



Location map of field sites: ICIMOD Project on Rehabilitation of Degraded Lands in Mountain Ecosystems in the HKH Region

Research Centre (IDRC), Canada. This programme has direct relevance to Agenda 21 in the context of an integrated approach to planning and management of land use, as well as combatting deforestation with enhanced protection, sustainable management, and rehabilitation of degraded forest lands.

This project was designed to examine comprehensively the problem of degraded lands in different mountain ecosystems of the HKH region. Its main objectives are:

- to develop a better understanding of the extent, forces, and processes underlying land 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.

Regional countries participating in the implementation of the project are China, India, Nepal, and Pakistan and the collaborating institutions in those countries are as follow.

China - Kunming Institute of Botany, CAS
- Kunming Institute of Ecology, CAS
- Chengdu Institute of Biology, CAS

India - G.B. Pant Institute of Himalayan Environment and Development

Pakistan - Pakistan Forest Institute

Nepal - Department of Forests, Ministry of Agriculture and Forests, Government of Nepal
- Forest Users' Groups of two village VDCs, Kavrepalanchok district, and the District Forest Office

A principal focus of this project is to systematically identify and document land degradation, to make a comparative study of farmers' options, and to identify land rehabilitation alternatives in different mountain ecosystems through field case studies in the region. The search for viable solutions must, therefore, begin with an understanding of the land users' group in relation to allocation of resources in the project areas. This is to be achieved by developing and implementing community action plans in close consultation with the collaborative institutions and local people through on-site activities in all participating countries of the project in the HKH region. Thus, five field sites were chosen in four countries for this action-oriented project (Report of ICIMOD Workshop, 1993).

Objectives

The Methodology Workshop on Rehabilitation of Degraded Lands in Mountain Ecosystems of the HKH Region was conducted in May 1993 in Kathmandu, Nepal. It was organised as an initiating activity, prior to project implementation, to orient collaborating agencies on methodologies to rehabilitate degraded mountain lands in different mountain ecosystems in the region.

The second of the series of workshops was held in Baoshan, Yunnan province, China. Discussions were held to explore alternative approaches for rehabilitating degraded lands in mountain ecosystems of the HKH region. The choice of the Baoshan site for the workshop was to demonstrate the success of the ICIMOD project and also to give participants from collaborating institutions from other participating countries a chance to visit the field site in Baoshan. The site is located 45km from the city on the Sino-Burmese highway in the upper Salween River Valley. The objectives of the workshop were:

- to examine the major output generated so far from the implementation of the ICIMOD project;
- to discuss the important findings from field-based case studies of the project being implemented in all participating countries and other relevant studies from the region, including action research, field demonstrations, and extensions;

- to discuss the type of training materials that could be prepared by collaborating institutions, including future follow-up in the field studies; and
- to discuss and identify priority programme activities for the future, including the necessity and scope of the next phase of the project.

Country	Location of Site	Project Land Area	Land Tenure	Started
China	Damay village, in Pupiao sub district of Baoshan, Yunnan.	- 45ha denuded forest land - 7.5ha farming land. Alt. 1370-1750m	Community forest land. 136 house- holds involved	- Field survey and PRA training, Sept. 1992 Planting July, 1993
India	Arah village in Kature Valley, Almora, U.P.	- 9.5ha abandoned farming land Alt. 1,490m	86 Individual households involved under village forest panchayat management	- Field survey Feb. 1993 - Planting & water harvesting, fencing July , 1993
Nepal	Site I: Godawari in Lalitpur District of Central Nepal	- 3ha degraded forest land with bushes. Alt 1,600m	ICIMOD Field Demonstration site. Land was given by the government	- Field survey February, 1993 Site development March , 1993
	Site II: Bajrapare and Dhaireni in two villages in Kavrepalanchok District of Central Nepal	- Bajrapare 6.76ha - Dhaireni 15.93ha Alt. 8,900-1,000m All denuded forest land	Community forest land under two users' groups	- Field survey March 1993 - Site development July, 1993
Pakistan	Sinkari Valley in Manshra District of Abottobad Hill Division	15ha. abandoned farming land in Tarbela and Mangla catchment. Alt: 1,400-1,550m	Individual land- 18 households involved	- Field survey Aug. 1993 - Site development October, 1993

Eco-Regional Approach in the Himalayan Context

Rehabilitation of ecosystems and their sustainable development, more specifically the sustainable management of natural resources, are closely interlinked. 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.

There is a great deal of research being undertaken in the Himalayan region. Ives and Messerli (1989) pointed out that most of the existing research projects are "too narrowly defined" and "too local" and "limited in duration." "They reflect specific interests and often a process of one-way thinking ....,"without any real correlation to the broad regional-scale problems." They further suggest that what is needed is " a systematic and more nearly interdisciplinary approach tilted at seeking to understand the magnitude and intensity of key processes and [it] should fit into a regional concept." It is, therefore, imperative to develop a regional approach for rehabilitation of degraded ecosystems in the Himalayan region.

Approach

An eco-regional approach for rehabilitation of degraded lands of the Himalayan mountain ecosystems was then identified through project implementation. This approach was based on the following fundamental facts in the context of Himalayan environmental degradation.

1. Human interventions influencing land use in mountain areas are many. Population growth is often cited as a prime cause of land mismanagement. Changing farming practice with intensive crop production by means of modern technology is seen as another cause of land degradation. In the middle hills of the Himalayan region not only is the population density very high, but commercialisation of agriculture is also a rapidly developing process. Thus, considering the regional scale problem of the project and that the nature of ecosystem rehabilitation and management is site specific, the middle hills (from 1,000-1,600masl) were chosen as the bioregional area for the project.
2. An understanding of the ownership and use patterns of natural resources, such as private, common, public, or any combination of these three patterns, is critical for elaborating and defining rehabilitation strategies; which may require different rehabilitation tactics. This project focussed on common lands (degraded community forest land), but in the region land could often be under a combination of three ownerships which could not be practically separated from each other for resources' management.
3. The impact of land degradation extends deeply into the economy and the environment. Rehabilitation ecology has to effectively integrate ecological, economic, sociocultural, and political dimensions of the setting in which it is attempted. In this vein, ecological concepts and processes should be adapted to social processes and perceptions. In order to achieve long-term environmental benefits and goals, short-term economic benefits to local villages must be prioritised in project implementation.
4. Community participation is crucial for rehabilitation of degraded lands, building-up community/users' group institutions with support from local governments is the key to success.
5. Ecosystem rehabilitation and management are part of a dynamic process and should be monitored continuously and, therefore, should be designed to be flexible and responsive to modification. Baseline survey and monitoring systems should be established at all field sites from the very beginning.

Methodology

The specific methodological components of the ecoregional approach to the rehabilitation of degraded lands in the Himalayan ecosystems being implemented in the field case studies of the project are the following.

1. Integrated biomass development and water-soil management technologies are being employed as the major technical components for rehabilitation. Use of fast growing and nitrogen-fixing tree species (native and exotic) adapted to degraded sites can accelerate forest rehabilitation and improve soil fertility. While native species may be the best option (such as *Alnus nepalensis, Tephrosia candida*), exotics can be used as facilitators after careful evaluation (such as *Robinia pseudoacacia* and *Flemingia macrophylla*). Since soil and water conservation and management are crucial for ecosystem rehabilitation, integrated indigenous water harvesting and mud-rock check-dams, improved mini-water tanks, and other water-soil erosion control methods, such as hedgerow planting and cost-efficient checkdam constructions, are being tested at field level.
2. In order to integrate the components, effective linkages amongst the local people, their institutions, government agencies, NGOs, and scientists involved in project implementation are essential. The peoples' active participation in the site villages is seen as the central issue for the success of the project. While rehabilitation work should provide a wide range of benefits to various stakeholders, the socioeconomic needs of the local communities and user groups should be a major consideration. The project, therefore, introduces and promotes high-value crops and high-production fodder species into the site areas, while introducing rehabilitation of water harvesting and irrigation systems, providing better opportunities for villagers to improve their farming and daily life.
3. Environmental monitoring is seen as the basis for systematic study at the ecosystem level. The monitoring network has to be maintained and data collection at all sites has to be a continuous process

in order to acquire long-term data on precipitation, runoff, erosion, soil fertility, biomass, and socioeconomic conditions. Thus, all measurements of rainfall, discharge, sediment transport through storms, soil erosion on erosion plots, and biomass recovery on site areas, will be available during the project. Changes in land use, soil fertility, population, and socioeconomic conditions are to be measured by conducting an up-dated survey in the next phase, if possible.

4. Data evaluation and watershed management during the second phase of project implementation, if applicable.
   The GIS database will be expanded and models will be superimposed on it to arrive at scenarios for watershed management. With sufficient information on rates of change in population, resources, fertility, land use, and production we will be able to forecast the possible consequences induced by development efforts. A watershed management plan will be developed in collaboration with the local community. This should include components of forest management, water distribution for irrigation and consumption, soil fertility, crop rotation, biomass production, and socioeconomic conditions. All of these should be integrated, but individual sub-models will be developed with those community groups most affected or most intimately involved in the management of the resource (e.g., women's groups in forest management for firewood and animal feed).
5. Socioeconomics and community-based initiatives for soil-water conservation and fodder-fuelwood production from site areas.
   Maintaining sufficient and healthy soil-water resources in the site area of the watershed is clearly the most important issue in sustaining the mountain population. The rehabilitation trials on improving soil fertility through nitrogen fixers, promoting changes in fodder supplies to generate more manure, altering the crop rotation sequence, and introducing trickle-irrigation are all aimed at improving the conditions and production capacity of the watershed.These approaches also prevent damage from erosion and sedimentation in downstream systems. To bring about such changes, it is necessary to examine the socioeconomic conditions and community-based initiatives. The fodder tree initiatives and rehabilitation of degraded lands are to be carried out with women's groups. This will be initiated by conducting a socioeconomic survey to document perceptions and concerns about animal feed and firewood production. The trials are being carried out in collaboration with user groups on degraded slopes and marginal lands since these sites are the most vulnerable.

Progress Summary of Project Activities (1992-94)

The focus of the regional project has been to improve the condition of degraded lands through the mobilisation of local people and institutions. It has been carried out in four countries in the Himalayan region and initial results and efforts, both in participatory management and performance of trial treatments, have been very encouraging and promising.

Progress, however, in research and development activities (1992-94) at different sites, was uneven due to the different dates of actual commencement of the project. The China Site started on September 23, 1992; the India Site started on January 6th, 1993; Nepal Site I started on March 1st, 1993; Nepal Site II started on April 19, 1993; and the Pakistan Site started on October 23rd, 1993 (all these are the dates on which MOUs with country collaborative institutions were signed).

To date, some of the most important project milestones are summarised as below.

1) Institutional collaboration and local mechanisms for project implementation have been established. A Methodology Workshop on Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayan Region was held in 1993 at ICIMOD to develop guidelines for project implementation.
2) An interdisciplinary research team was established to examine resource problems in cases where local community user groups are an integral part of the research programme.
3) Baseline information has been developed for understanding key environmental processes that lead to degradation. The main concerns are water deficiencies during the dry season, declining soil fertility, and excessive use of forests. Cheap water-harvesting tanks with plastic sheet lining have been introduced

to promote biomass development on degraded lands, thereby improving the site condition. Biogas technology has been promoted for recycling organic wastes into high quality manure and gas fuel to relieve the pressure exerted on forest lands.

4) A very intensive monitoring network was established to document environmental processes. Monitoring includes hydrology, soil erosion, soil fertility changes, rate of biomass recovery, and changes in socioeconomic conditions. The quantitative data generated are now advanced on key environmental variables that influence degradation processes.
5) On-site training and education were major focuses of this research programme. ICIMOD professional team members were exposed to advanced GIS techniques and database management. Local farmers and community user groups were trained on the uses of A-frames (Sloping Agricultural Land Technology) to establish contour lines for hedgerow plantations. Besides, local user groups were exposed to appropriate technologies on nursery establishment, gully management and control, construction of inexpensive check-dams, and simple water storage and management systems for smooth running of the project.
6) Attempts have been made to translate the research results into development in collaboration with local farmers at the several demonstration sites. Initial results have been very promising. Rehabilitation techniques, such as hedgerow planting, the use of pioneer species that are native nitrogen-fixing, exotic species as facilitators, soil amendments, planting leguminous crops and grasses, and intercropping with species with low nutrient demand, have had a positive impact on the restoration process and biomass development. Tree nursery establishments to regenerate a pool of all the native nitrogen-fixing fodder trees have enhanced local biodiversity and assured the community of a constant supply of local species.
7) It is anticipated that short-term economic benefits will be enjoyed by the local community through sustainable biomass development and conservation methods which improve the ecological restoration processes.

Future Follow-up in Perspective

Rehabilitation has to operate in various socioeconomic conditions and biophysical environments. The objectives of rehabilitation may differ. Therefore, one may have to consider different time-frames, for instance short-term (up to 10 years) or long-term (over 10 years).

The project activities initiated in the past two years or more have already built up the necessary foundations for better development of alternative approaches and technologies at field level. Furthermore, there is a critical need for follow-up actions for the success of the project. As biomass management, soil and water conservation, community participation, and better understanding of micro- and meso-level biophysical processes are important for rehabilitation, and to further promote sustainable use of mountain resources and management of sloping lands, these processes need to be continuously tested, refined, and developed. Any work on biomass restoration and soil-water conservation with community participation requires a long-term perspective, the shortest time-frame of such projects ought to be six years at least. Therefore, we propose a three-year extension for the second phase of the project that is being implemented, for the donor agency to consider and support.

References:

ICIMOD, 1993. *Report of the ICIMOD Methodology Workshop on Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayan Region*, held at ICIMOD, Kathmandu, Nepal, 29 July to 3 June, 1993. Kathmandu: ICIMOD.

Ives, J.D. and Messerli, B., 1989. *The Himalayan Dilemma; Reconciling Development and Conservation.* London and New York: UNU&R.

Chapter 4

Country Reports*

INDIA

The country report, given by B.P. Kothyari of the G.B. Pant Institute of Himalayan Environment and Development, was an update of the ICIMOD Project on Rehabilitation of Degraded Lands in Mountain Ecosystems of the HKH Region at the Almora site in Uttar Pradesh (U.P.), India.

Summary of progress in project activities in India in 1994

Work on the site covering an area of 9.4 hectares at Arah village in the Gomati Basin of Almora was continued in 1994. Planting of fodder and legume crops started again on the abandoned land of the site area and plantation was completed in 1994. Studies in vegetation, soil biology, and the socioeconomy of the participating community were also completed. Water harvesting and weed composting technologies were introduced at the project site. Peoples' participation was well organised by the site village community forestry committee (*panchayat*).

Site description

The study area is located in Almora district of Kumaon District Commissionary of Uttar Pradesh (India). This district is physiographically characterised by the Greater Himalayas and the Lesser Himalayas which have been separated by the Main Central Thrust (MCT). The project site belongs to Arah village in Kature Valley. The project site consists of approximately eight hectares of abandoned agricultural land owned by 60 per cent of the households in the village.

Climatically, the region enjoys a monsoon climate. The minimum temperature during the winter falls below freezing point, while maximum temperature reaches 38 °C during the summer. The area receives moderate rainfall. Monsoon reaches this area in the first week of August and the maximum rainfall has been recorded during August - September (about ⅓ of the annual rainfall).

Approximately 70 per cent of the village population is engaged in agriculture. The majority of households own less than 0.5 of a hectare of agricultural land, whereas only a few own between one to two hectares. The village has a total population of 458. According to the Census report (1991), the village has an overall literacy of 17.25 per cent and the literacy rate for women is lower than for men.

The detailed activities completed in 1994 are highlighted below.

Plant Seedling Production and Plantation

- Plant seedlings were produced at the plant nursery established on the site.
- Since only 50 per cent of plantation had taken place in 1993, it was completed in 1994. In all, 12 species were planted (a total of 6,955 plants) and have so far shown a promising survival rate (97% survival on average).
- Soil amendment, by digging pits of 75x75x75cm^3, approximately two metres apart, filled with topsoil collected during terracing or during terrace repair, for plantation was the method used for rehabilitation.

* The country reports are recorded in the order in which they were presented

- Planting of fodder and legume crops started again in October on land which had been abandoned for the past twenty years without any plantation.

Study of Natural Vegetation, Soil Biology

- A vegetation survey took place and comparative studies were carried out in an adjacent pure oak forest, among pure pine stands, and in agricultural fields.
- Monitoring of phytosociology, soil characteristics, and soil micro-organisms continued.

Study of the Socioeconomic Conditions of the Area

- A socioeconomic study - including an agricultural calendar, rainfed and dryland agriculture, fruit production, and land use - was completed.
- Consumption of fuelwood in the project area was analysed.
- The energy expended by women in different household/agricultural tasks was studied.

Construction and Repair

- Two underground tanks of 10x6x1.5m^3 dimensions, as well as a tank of 11x6x1.5m^3 dimensions, were constructed in the upper and middle elevation of the study area.
- Repair of abandoned and damaged terraces and construction of checkdams in gullies were carried out.

Others

- Weed composting technology was introduced.

PAKISTAN

This report, prepared by B.H. Shah of the Pakistan Forest Institute, Pakistan, briefly described the project activities on the Mansehra site in Pakistan.

Summary of progress in project activities at the Mansehra site in Pakistan in 1994

The project funds for the project in Pakistan were made available towards the end of 1993, thus this is a preliminary report of activities so far.

Site Description

The study area lies in the catchment area of Siran River in Mansehra district at 34° 4' N, 73° 2' E.

The area falls in a humid, subtropical continental highland climatic region. Two thirds of the annual rainfall in the area is received from July to August. The soil is generally shallow and loamy and the natural vegetation on the site is subtropical pine forest. The study has selected two catchments, one of 21.1ha and another one of 20.3ha. In the former catchment, the work carried out is to enhance production and for soil water conservation, while the latter is treated as a control.

At Tarbela site, two adjacent catchments, having an area of 0.15 of a hectare, were earmarked for the study. Both these sites are on private agricultural land and have a typical land-use pattern, i.e., lower elevations are composed of traditional, terraced agricultural land, middle elevations with medium slopes are pastureland, while the upper steep slopes have some scattered tree growth.

At Mangla site, the two catchment areas are near the reserved forest, have barren stony soil, and are used for grazing domestic animals. The study area is situated in the subtropical chir pine zone and has an annual average rainfall of about 1,100mm under monsoon influence. About 70 per cent of the precipitation is received from July to the middle of September.

Both sites are in the catchment area of the Siran River, which is an important tributary of the River Indus. The area is thickly populated and is under increasing pressure to meet demands for food, timber, and fuelwood.

The detailed project activities conducted are described below

Plantation of Fodder Grasses, Legume Plants, and Other Plants for Land Improvement

- 24,700 seedlings of nine different species were planted on the project sites.
- A total of 600 fruit trees (apples, citrus, peaches, apricots, persimmons) were planted on agricultural land.
- For improvement of agricultural land, biotechnical techniques were used, such as plantation of *Robinia psuedoacacia* and *Poplus,* on terrace risers and between gaps in agricultural lands.
- A SALT model was established on a sloping agricultural field with nitrogen-fixing hedgerows of *Leucaena leucocephala* and *Amorpha fruticosa*.
- Two plots totalling about two hectares were planted with tea plants in collaboration with the National Tea Research Institute, Shinkiari.
- On 0.5ha of abandoned agricultural, land plantation of different species of grass and six species of legumes was carried out for forage production.

Monitoring of Hydrology, Meteorology, and Soil Erosion

- Hydrological studies are being carried out, and these include the monitoring of surface runoff and sediment yield.
- A meteorological observation station has been established. It is equipped with instruments to record temperature (minimum & maximum), wind speed, relative humidity, evaporation, the number of hours of sunshine per day, and precipitation.

Others

- Loose stone checkdams and other types of checkdam have been constructed in gullies.
- *Ailanthus altissima* and *Robinia pseudoacacia* were planted on channel banks and gullies to reduce erosion.
- Three earthfill dams have been constructed for possible use in fish production or irrigation, to recharge groundwater, to reduce surface runoff, and to trap silts.
- A water harvesting tank was dug ($20x8x2m^3$) on the upper boundary of the agricultural land to trap runoff from the upper slopes.

NEPAL - Site I

This country report, given by B.R. Bhatta of ICIMOD, was a description of the activities of the project for "Rehabilitation of Degraded Lands in Mountain Ecosystems" on the Godavari site, Site I, Nepal.

Summary of progress in project activities at Nepal Site I in 1994

Experiments on and production of the various species useful for rehabilitation of degraded lands were continued in 1994. Studies of useful local plants and soil and biomass surveys were completed. The trial plots were largely expanded during this year and now total an area of six hectares of the sloping area.

The detailed project activities conducted for 1994 at the site are reported below.

Site Description

The project site is 30ha of government-owned land, 15km south-east of Kathmandu, which has been provided to ICIMOD for the purpose of setting up a demonstration farm. The land has been characterised as degraded land on account of lack of significant numbers of economic species and poor biomass volume.

The altitude of the site varies between 1,550masl to 1,780masl and slope gradients are between 0.5° to 60°. The site encompasses 12 mini-subcatchments of four streams and swamps. The climate varies from sub-tropical to warm temperate to cool temperate. The mean annual temperature is 16°C, with a minimum of -1.7°C and a maximum of about 24°C.

The land has been classified into four categories: a flat land/valley floor area suitable for intensive farming; an intermediate gentle slope area for conservation farming and agroforestry (including SALT); higher steep slopes for forestry; and sites for soil conservation, watershed management, and water harvesting.

Project Activities in 1994

Plant Seedling Production, Plantation, and Experimentation

- 50,000 seedlings of 21 plant species were produced in the Godavari nursery. Seed collection, storage, treatment, and germination studies were also carried out. Seeds, seedlings, and appropriate materials were distributed.
- Trials to assess the performances of nitrogen-fixing tree species were continued. Among the 15 species tried, the observations so far show that *Albizia lebbeck* has the lowest mortality (7.07%) and *Amorpha fruticosa* the highest (72.43%). The maximum growth was attained by *Alnus nepalensis* (girth, 1.20-5.98cm; height, 36-285cm).
- SALT model establishment and development were continued, as well as study of species' performances and production of various crops.
- Experiments with biofencing/live fencing were carried out and demonstrate high survival rates and good growth of *Zanthoxyllum* and *Pyracantha crenulata*, which also bear useful fruits.
- Germplasm collection and Species' trials of various species such as *Paulownia elongata, Anomum sobulatum cv. Golshahi*, and *Thysanoloena maxima* are being carried out.

Surveys of Soil, Biomass, and Useful Species and Monitoring

- Baseline surveys of soil and biomass were completed and reports have been compiled.
- A list of useful plant species for rehabilitation of degraded mountain ecosystems was conducted. The

usefulness and number of species were identified in various categories such as nitrogen fixers and conservation plants, fast growing fuelwood species, plants of economic value, and so on.

- A meteorological station has been established and plots were established to study and monitor natural regeneration.

Training/Visits

- Demonstration, training, dissemination of information, and networking were important project activities. Farmers from various parts of Nepal and other professionals, both from within and outside the country, visited the site.

Others

- Introduction of other appropriate technologies, such as compost making and biomass mulching, silage making and urea molasses block, beekeeping with improved boxes, and plastic film technology application, took place.
- Inspection trails were completed.

NEPAL - Site II

This was a report of the project activites of the ICIMOD project for "Rehabilitation of Degraded Mountain Ecosystems" at the Kavrepalanchok site or Site II, in Nepal. The report was given by S.R. Chalise, S. Karki, and B.G. Shrestha of ICIMOD.

Summary of progress in project activities at Nepal Site II in 1994

Plant seedling production and extension in plantation areas were the major activities undertaken in 1994. Monitoring of natural regeneration, planted species' performance, and soil erosion were continued. Training and visits were organised for members of participating forest users' groups. The site trial plots established in 1993 were extended considerably (from 3.9ha in 1993 the plantation was extended by a further 3.56ha in 1994, totalling 7.46ha of plantation) due to site villagers' active participation in the project.

Site Description

The site description for the project site is presented in Table 1.

The detailed project activities implemented in 1994 are described below

Plant Seedling Production and Plantation

- 12,261 saplings of 14 plant species were produced at the Bajrapare Forest Users' Group Nursery and 12,414 saplings of 13 species were produced at Dhaireni Forest Users' Group (FUG) Nursery for plantation at project sites and for distribution among the Users.

Table 1: Selected Socioeconomic and Biophysical Characteristics of the Project Sites

	Bajra Pareko *danda* (Site I)	Dhaireni Pakha (Site II)
• Total Households	18	259
• Total Population	130	1667
• Number of settlements in FUG	1	10
• Ethnic Composition	Brahmin and Kshetri only	*Brahmin* and *Kshetri* 34% HH, *Newar* 29% HH, *Danuwar* 21% HH, *Sarki, Kami* and *Damai* 11% HH, *Tamang* 4% HH, *Magar* 1% HH
• Land holding	Mostly between 0.5 to 1.5 hectares/household	Mostly between 0.1 to 0.5ha/hh
• Accessibility	All weather road nearby	Seasonal dirt track
• Area of forest land	6.76ha	15.93ha
• Altitude	925-1150masl.	900-1,000masl.
• Climate	Sub-tropical (sub-humid)	sub-tropical (sub-humid)
• Rainfall	1000-1200mm	1,000-1,200mm
• Temperature	Min. 0°C; Max 35.5°C	Min. 0°C; Max 35.5°C
• Slope	15°-25°	10°-25°
• Aspect	South facing	South facing
• Soil	Red clay loam. Poor in organic matter, pH 4.44 to 6.81. and low CEC; Low N, Available P low, gully erosion prominent	Red clay loam. Poor in organic matter and low CEC, Low Ph, Low P, Low N, gully erosion prominent
• Degradation of forest	Deforestation started around 1947. Pines planted by the government in 1986, only a few remain.	Deforestation date unknown. Pines planted in 1973.
• Land Use (1993)	6ha (38%): Chir pine trees planted in 1973 by the Forest Department, 3.08ha (19%): scattered Chir pine, 2.22ha (14%): barren land, 1.2ha (8%): gullies, 1.2ha (8%): seasonal streams 0.6 0.6ha (4%): stunted pines.	2.44ha (36%): scattered shrubs, 1.73ha sal and other broad-leaved trees, 1.24ha (18%): barren land, 0.75ha (11%): Seasonal stream (*Kholchi*), 0.6ha (9%): area under natural regeneration of *sal* and other plants

- Plantation work at Bajrapare mainly concentrated this year on replacement of plants planted in 1993 and the plantation at Dhaireni was extended to three main plots. The first plot of 2.29ha in area represents the most degraded area in the forest area, the second plot (0.22 of a hectare) was designated as a 'fruit plot' and mainly fruits were planted. The third plot has an area of 1.04ha. The trials at the site were largely extended this year due to the farmers' active participation and interests.

Monitoring of Natural Regeneration, Planted Species' Performance, Soil Erosion

- Measurements of biomass production through natural regeneration and species' emergence were carried out as well as of the performances of species planted in 1993/1994.
- The project has established four soil erosion monitoring plots this year: two at Bajrapare and two at Dhaireni. Manual rain gauges were also stationed near each erosion plot to measure the rainfall. A field laboratory was established at the project field office on the Dhaireni site for filtration of erosion samples collected from the erosion plots of both sites.
- A baseline socioeconomic survey was completed.

Training / Visits

- Training relevant to actual field activities, such as nursery techniques for seedling production, erosion plot in-charge training, and refresher training on A-frame use for contour establishment, was carried out. FUG members also participated in study and observation tours and exposure training. Visits to Godavari and a visit to Perani (Dang) to look at a successful example of rehabilitation of degraded forest with various grass species by the local forest users' group were organised. FUG members also participated in an Agroforestry Exposure Training course in Kunta and a beekeeping training course at ICIMOD, Kathmandu.

Others

- At the request of the Bajrapare FUG, the project supplied 3,000m of high-density polythene pipe to bring water to the village for the plant nursery and for the use of the FUG.
- Seventy bamboo-woven checkdams and many small loose stone checkdams have been constructed at Dhaireni for gully control.
- The baseline survey maps prepared in 1993 on the contours and types for both Bajrapare and Dhaireni have been digitised on the computer.
- A video film has been produced about the activities of the project.

CHINA

The country report from China gave an account of the ICIMOD project for "Rehabilitation of Degraded Mountain Ecosystems" on the Baoshan site in China. The report was prepared by Xu Jian-chu and Tong Shaoquan of the Kunming Institute of Botany, CAS, Yang Qixiu, of the Chengdu Institute of Biology, CAS, and Qiu Xuezhong of the Kunming Institute of Ecology, CAS.

Summary of progress in project activities in China in 1994

The maintenance of the established trial plot on a site totalling 45 hectares was continued in 1994. Site development was also continued and construction of erosion control checkdams and rehabilitation of irrigation ponds, as well as biogas demonstrations in two households in the site village, were completed. Monitoring and research activities, including a socioeconomic survey and studies on indigenous knowledge of local plant species, were the other major activities carried out. Capacity building of local institutions and training of manpower were continued at the site village.

Brief Introduction to the Project Site

The Baoshan project site is located about 40km south of Baoshan Municipality, near *Damay* village in Pupiao Township. The village has 136 households belonging to two production units.

The annual rainfall in this area is 600mm, most of which falls during the monsoon season between May and September. The soil is nutrient poor with phosphorus deficiency and generally shows low water-holding capacity. The project site can be divided into five zones, which include an air-seeded pine forest, shrub land, pasture, upland fields, and paddy fields. The altitude of the area is from below 1,400masl to 1,600masl. The slope is between 0 to 400 degrees.

The project used Participative Rural Appraisal (PRA) tools to formulate community action plans to manage the different zones as well as to study the indigenous knowledge on plants in the area.

Project Activities

The detailed activities completed in 1994 are highlighted below.

Plant Seedling Production and Plantation

- Supplementary planting was carried out at the rehabilitation site, with 10,000 seedlings produced in five private nurseries operated by local farmers from the site village under contracts from the project.

Continuation of Assessments on Species' Performance, Monitoring of Soil Erosion

- Regular monitoring of rainfall, water-soil losses from erosion plots established, and species' performances were a major research component of project activities in 1994.

Studies of Indigenous Knowledge, Useful Indigenous Species

- An inventory of indigenous species available; which include suitable nitrogen-fixing trees for soil conservation and bank stabilisation, fruit trees, cash crops, fast-growing timber, and fuelwood trees; was completed.
- Studies of indigenous technical knowledge for rehabilitation and upland resources' management; such as terracing, erosion-control checkdams, non-timber forest products' harvesting, live fencing, crop rotation and cover crops, and indigenous agroforestry and indigenous plant species' profile were completed.

Training/Visits

A cross-farmer visit was organised to several project areas in Chengdu, Sichuan Province, for farmers from the project area.

Land-use Inventory and Management Plans

An inventory of land use in the project area was completed and with the help of the PRA method community action plans were formulated for management of these different land use types.

Other Activities

- Biogas plants were installed in two households in the site village for demonstration of this alternative energy source.

- Fodder crops and cash crop cultivation were introduced in the home gardens and these performed pretty well.
- Four cement checkdams were constructed in the gullies as well as another four, simple stone walls (indigenous-based checkdams) with living barriers, which were also tried.
- Two water ponds, which are important for paddy irrigation, were rehabilitated in the site area.

The project has identified that participation of local people and the use of indigenous technical knowledge, combined with local leadership development and security of tenure, are important factors for sustainable rehabilitation of degraded upland ecosystems.

Part II

Issues and Themes of Rehabilitation of Degraded Land and Training Materials - Technological and Socioeconomic Aspects

Chapter 5

Understanding Degradation Processes in the Middle Mountains of Nepal

Hans Schreier
and **Pravakar B. Shah**

Abstract

The processes of deforestation, soil erosion, and soil fertility deterioration are discussed in a case study on the Jhikhu Khola Watershed, 50km east of Kathmandu, Nepal. Forest degradation over the past 50 years has not been gradual but has passed through at least two major cycles of active deforestation, followed by afforestation. Unfortunately, the afforestation period has never been sufficient to re-establish the former forest and its soil-productive capacity. Removal of forest cover and excessive collection of litter, firewood, and fodder have left the forests in a highly depleted state, with chances of recovery being slow and difficult. Recent afforestation efforts have focussed on intermediate slopes, while agricultural expansion has occurred on steeper and more marginal slopes. This is leading to higher soil erosion losses in spite of well-adapted indigenous techniques to divert runoff. Large pre-monsoon storms are responsible for massive losses of soil, and these degraded areas in turn are the largest contributors to sedimentation. Agroforestry efforts are needed to rehabilitate these degraded sites since they currently produce little biomass and make the largest contributions to sediment load.

Introduction

Renewed concern about the rapid growth of the global population is once again raising the question about the capacity of the globe to supply sufficient food to meet increasing demand (Bongaarts 1994). This predicament is nowhere more apparent than in China where large numbers of rural people have migrated to urban centres where their consumption habits have shifted from basic staples to a more meat rich diet (Brown 1994). The question is increasingly being asked: "Can agricultural intensification meet the demand or is expansion of the agricultural land base necessary?" (Penney and Solberg 1994). It is likely that both these processes will be needed. As is evident from experience in the developed world, agricultural intensification has resulted in very widespread soil and water pollution problems (Hallberg 1989, Schuyler 1994, Owens 1994). Since high quality agricultural land is scarce, agricultural expansion will mean converting marginal lands for cultivation. This will mean great environmental risks, resulting in further deterioration of soil and water resources. Both of these processes dominate land use in the Himalayan region of Nepal. Some of the resulting degradation processes are described in this paper.

A case study is presented from the Jhikhu Khola Watershed located in the middle mountains of Nepal, 50km east of Kathmandu. This shows that the basin is used intensively for agriculture. Double and triple annual crop rotations are widespread. The land-use dynamics and degradation processes have been monitored over the past five years in this 11,000ha watershed. The specific focus of this paper is to highlight: a) deforestation, b) soil erosion, and c) soil nutrient declines.

It is our belief that rehabilitation programmes are unlikely to succeed if the processes of degradation (socioeconomic and biophysical) are not well understood. However, in this presentation the discussion is confined to the biophysical processes.

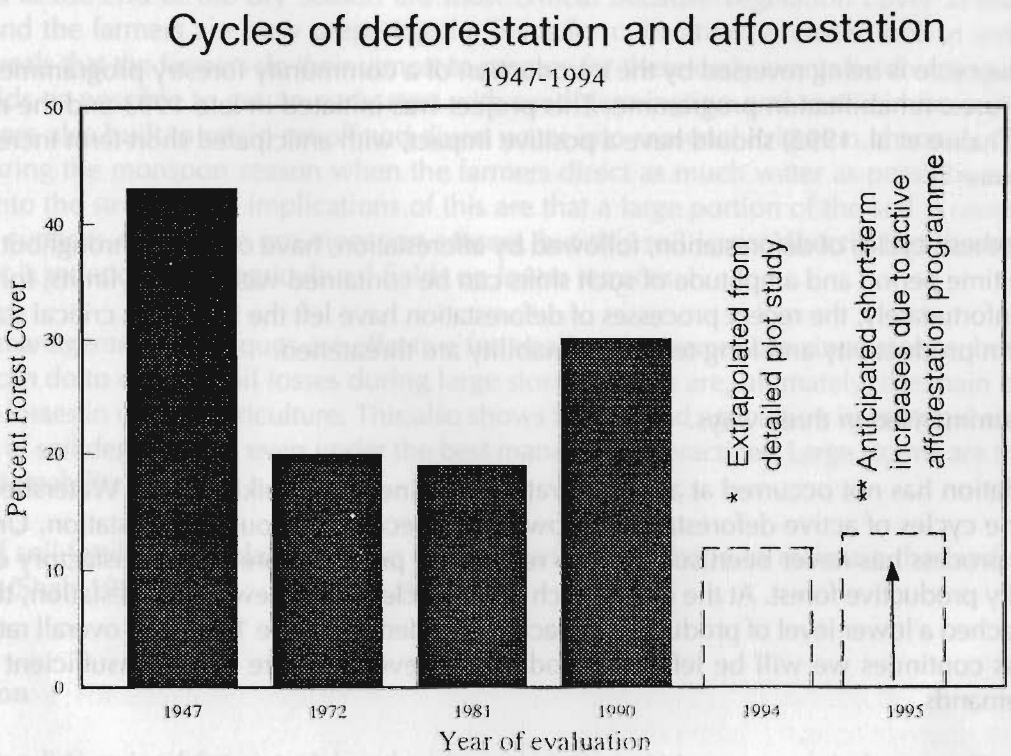
Forest Dynamics and Deforestation

Much has been written about rapid deforestation in the middle mountains and the resultant findings are often contradictory. The World Bank presented a rather bleak picture on the rate of deforestation in 1979

(FAO/World Bank, 1979), while Gilmour and Fisher (1991) suggested that in many places the forests have actually improved.

Using historic land-use maps from 1947 and 1981 and large-scale aerial photos from 1972 and 1990, a quantitative evaluation has been carried out to determine the historic forest dynamics in the Jhikhu Khola Watershed. All information was digitised and the changes were quantified using the GIS overlay technique. The results from this evaluation are provided in Figure 1 which shows a rapid rate of deforestation in the 1950s. This is attributed to the initiation of the Forestry Act in 1957 which gave the responsibility for managing the forests to the National Forestry Department. During the transition period, many forests were cleared under the assumption that, once the trees were removed, ownership would revert to the local farmers or local community. But this did not happen, instead the results were a marked decline in forest cover over about a 25-year period. In the early 1980s, active afforestation programmes were introduced through the Nepal-Australia Forestry Programme. Large areas were converted into forests over a 10-year period by initially creating chir pine plantations, with the expectation that, once the forest was well established, native secondary forest cover would become predominant and the pine could then be removed by harvesting the trees for timber and firewood. The GIS analysis shows that forest cover, indeed, expanded over this period and almost 50 per cent of the previously removed forests were re-established.

Figure 1: Cycles of deforestation and afforestation in the Jhikhu Khola Watershed Based on historic maps, aerial photo interpretations, and plot analysis



Unfortunately, the ever-increasing demand for animal feed could only be met by harvesting all palatable secondary forests and many pine plantations which were 10-15 years old. These forests have marginal utility for the local people since they neither provide good firewood nor animal feed. The removal of the understorey for animal feed, and the use of forest litter to supplement organic matter input for agriculture, left many of these forests depleted of nutrients and devoid of palatable biomass with little protective cover against soil erosion. To make matters worse, the selective GIS analysis showed that most of the forests established in the 1980s were planted on intermediate slopes (20-35%), while a proportionately larger expansion of agriculture occurred on steeper slopes (36-49%). This is quite contrary to conventional wisdom which favours forest cover on steep slopes for soil conservation and the use of the more gently sloping terrain for agriculture. It can thus be concluded that, during this period, the forest cover expanded but the quality, as well as the biodiversity, of the forests declined.

In the last two years, a new phase of deforestation has occurred and this is attributed to democratisation. The impact of the forests over the past five years was measured by re-sampling 12 forest plots (20x20m size) which were originally calibrated in 1989 (Schmidt et al. 1993, Feigi 1989). These plots are widely distributed throughout the watershed and cover private and community forests, as well as forests controlled by the National Forestry Department. A total number of 614 trees was measured for standing biomass in 1989, and five years later the forest plots were re-surveyed to establish forest use dynamics and biomass growth. A total of 386 trees was lost during this five-year period, representing 63 per cent of the trees originally surveyed. This represents an average loss of 28 per cent over the 12 plots. Three plots, located in a well protected community forest suffered no tree losses, while all the trees were removed from two plots previously under private ownership. All other plots had small to very large losses. A further point of interest is that sal trees (*Shorea robusta*) and not chir pine were the preferred species removed. The losses were in part attributed to democratisation, and this resulted in several local groups reacting against former landowners who were no longer in political favour. The frustration experienced by local farmers was further accentuated by the delay in transferring the management and control of the forests from the national agency to local community groups. An additional factor was the increasing demand for firewood resulting from population increase and the associated demand for bricks for house construction. *Sal* wood provides a far superior heating source to fire the bricks than chir pine. These have been the predominant reasons for the most recent decline in forest cover.

Once again the cycle is being reversed by the introduction of a community forestry programme initiated by the ICIMOD forest rehabilitation programme. This project was initiated in late 1993 and the results of the programme (Chalise et al. 1995) should have a positive impact, with anticipated short-term increase in forest cover (see Figure 1).

It is likely that these cycles of deforestation, followed by afforestation, have occurred throughout history, but, as long as the time period and amplitude of such shifts can be contained within small limits, forest recovery is possible. Unfortunately, the recent processes of deforestation have left the forest in a critical stage in which both short-term productivity and long-term sustainability are threatened.

This can be summarised in three ways.

Forest degradation has not occurred at a gradual rate of decline in the Jhikhu Khola Watershed. Instead, it has undergone cycles of active deforestation followed by a recovery through afforestation. Unfortunately, the recovery process has never been sufficient to restore the previous forest to a satisfactory degree or re-establish a fully productive forest. At the end of each down cycle after renewed deforestation, the forest site conditions reached a lower level of productive capacity as evident in Figure 1, with an overall rate of decline. If this process continues we will be left with productivity levels that are clearly insufficient to meet the increasing demands.

The forest decline cannot be measured by forest cover alone. It is the biodiversity, understorey biomass, forest floor coverage of the soil, and the annual biomass yield that give the true picture of forest productive capacity.

The removal of all understorey and forest litter is resulting in a marked decline in forest soil fertility, since nutrient cycling via forest litter is interrupted. These same processes also result in significant soil losses through erosion, since the natural protective capacity of forests is no longer effective. It is clear that the combination of these processes leads to non-sustainability of the forests, and the long-term production and protection capacities of the forests are in jeopardy.

Soil Erosion Processes

As part of the land-use dynamics, it was shown that agricultural expansion has mostly occurred on steeper and more marginal slopes, and this has serious environmental consequences, particularly in relation to soil erosion. As part of our study we measured soil erosion from upland and dryland agricultural sites. This was accomplished by monitoring five plots of 100sq.m. each through three monsoon seasons from 1992-1994. All plots were established in the upper portions of the watershed and were built in such a way as to cover a sequence of two terraces. All runoff and sediments were collected in a series of three drums, and after each storm the accumulated water and sediments were quantified. The results showed that the erosion between storms and between plots was highly variable. The measured rates ranged from one to 43 tonnes per hectare per year over the three-year period of monitoring. Given the weathering rates in this region, we can assume that a 15 tonne per hectare soil loss is tolerable. What our results also indicate is that physical surface conditions are of great importance. Two plots were established on relatively coarse-textured soils with high infiltration capacities. Very little runoff occurred from these two sites throughout the three years. In contrast, the three plots on finer textured soils all reached levels that are of concern for the long-term maintenance of the agricultural production capacity. What is even more important is the fact that 50 per cent of the annual sediment load occurred in one single storm and 80 per cent in two storms. This suggests that the large storm events have the greatest impact on upland agriculture, and these, in turn, are also the most difficult for farmers to control.

When we examined the runoff and sediment transport in the stream, we found that the sediment rating curve for the pre-monsoon season was consistently higher than during the monsoon season. This suggests that the early storms at the end of the dry season are most critical because vegetation cover at that time is at a minimum and the farmers are busy preparing the fields for cultivation. A closer look at indigenous farm practices reveals that the farmers do their utmost to prepare for these early events by diverting as much water into the fields as possible to get an early start with seed germination and to minimise erosion. Many of checkdams are also built to retain runoff and divert water into seasonal irrigation channels. This process is reversed during the monsoon season when the farmers direct as much water as possible away from their fields and into the stream. The implications of this are that a large portion of the soil is removed from the agricultural surfaces during the pre-monsoon season, but this soil is not directly lost through the stream transport but is redeposited in agricultural fields on lower terraces.

All of these management techniques are effective for small and intermediate sized storms, but there is little the farmers can do to control soil losses during large storms. These are, ultimately, the main culprits of soil and nutrient losses in upland agriculture. This also shows that upland agriculture in marginal areas has a high risk in terms of soil degradation, even under the best management practices. Large storms are thus a constant threat to sustainability.

The topic of soil fertility degradation is also of importance if we hope to maintain the land's capacity for productivity (Shah 1995).

Rehabilitation

The understanding gained from studying the above-mentioned processes was then applied to initiate a rehabilitation programme in the watershed. A demonstration site was selected where soil degradation had advanced to a point at which the soils were deeply gullied and surface vegetation was minimal. This was one of the most degraded sites in the lower portion of the Andheri Khola. The site is about two hectares in size, has deep gullies with dissected red soils on intermediate to steep slopes, and can be classified as a badland landscape. The site was chosen because the area contributes a very large proportion of the total annual stream sediment load, and this creates problems with irrigation in the downstream portion of the basin. It is also the only non-productive area in the watershed and rehabilitation will significantly improve the moisture regime, reduce the sediment production from streamflow in the watershed, and produce much needed biomass.

Our rehabilitation programme consists of establishing a tree nursery entirely made up of native nitrogen-fixing fodder trees. A series of hedgerow terraces was formed to stabilise the soils and to improve nitrogen and organic matter in the soils. Some of the soils were modified by adding lime in order to reduce the possible problem of aluminum toxicity resulting from the excessively low PH (phosphorus) in the red soils. Vegetables and leguminous crops are grown between the hedgerows to improve the soil conditions. Our goal is not to create a forest, but to establish an agroforestry system that can provide a variety of outputs, and, at the same time, stabilise the soils and improve the overall soil nutrient conditions. The demonstration site is now one-year old, and it is too early to evaluate the successes and failures of the experiments conducted on that site. We have successfully produced a number of crops during the monsoon season and some of the fodder trees, particularly *Dalbergia sisoo*, were very successful colonisers during the first year of the experiment.

Conclusions

Understanding degradation processes is the key to successful rehabilitation of degraded lands and, as shown in this paper, deforestation, soil erosion, and soil fertility are important biophysical factors that need consideration. The following lessons have been learned.

Forest degradation in the watershed is not a process of gradual increase but has undergone at least two major cycles of deforestation and rehabilitation over the past 50 years. After each degradation cycle, the overall forest conditions decline and the recovery is never sufficient to reach previous carrying and production capacities. Major changes in policies were mainly responsible for the creation of the downward cycle.

Forest degradation cannot be measured effectively by forest cover but needs to include measures of biodiversity, biomass yields, soil fertility, and other site conditions;

The overall losses of forest land have been substantial and, combined with the changes in soil fertility and biodiversity, the current situation in the watershed is of serious concern in terms of maintaining production capacity and resilience.

Soil erosion is of key importance since agricultural expansion has moved onto marginal lands which are more vulnerable to degradation.

Farmers are doing an effective job in preventing runoff and minimising soil losses during low and intermediate sized storms. However, the large storms do most of the damage and are responsible for causing soil erosion losses that can reach up to 43 tonne per hectare in the steeply sloping dryland agricultural systems in the middle mountains. These marginal sites are most vulnerable during the pre-monsoon period.

Active afforestation programmes should focus on the degraded areas since they are the greatest cause of sediment transport. At the same time, afforestation in these areas is more effective if it is carried out in the context of agroforestry where nitrogen-fixing fodder 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.

References

Bongaarts, J., 1994. 'Can the Growing Human Population Feed Itself?' In *Scientific American*.

Brown, L.R., 1994. 'Who Will Feed China'?' In *World Watch*, Vol. 7 (10-19pp).

Chalise, S.R.; Karki, S.; and Shrestha, B.G., 1995. 'Rehabilitation of Degraded Lands in Mountain Ecosystems. Nepal Site II: Kabhrepalanchowk'. In *Proceedings: International Workshop on Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayan Region* (51p)

FAO/World Bank, 1979. *Nepal's Development Performance and Prospects* (77p). South Asia Regional Office, World Bank Staff Report. Washington D.C.

Feigi, F., 1989. 'Peliminary Assessment of Forest and Forest Soil Properties in the Lower Jhikhu Khola Watershed, Nepal' (69p). Diploma Project, Ludwig Maximillian University, Forestry Faculty, Munich.

Gilmour, D.A. and Fisher, R.J., 1991. *Villagers, Forests and Foresters* (212p). Kathmandu: Sahayogi Press, Pvt. Ltd.

Hallberg, G.R., 1989. 'Nitrate in Groundwater in the United States'. In Follett, R.F. (ed.) *Nitrogen Management and Groundwater Protection* (35-74pp). New York: Elsevier Press.

Owens, L.B., 1994. 'Impacts of Soil N Management in the Quality of Surface and Subsurface Water'. In Lal, R. and Stewart, B.A., (eds.) *Soil Processes and Water Quality. Advances in Soil Science* (137-162pp). Baco Raton: Lewis Publishers.

Penney, D. and Solberg, E., 1994. 'Conservation Cropping Systems. The Good, The Bad, and The Ugly'. In *Proceedings of the 31st Annual Alberta Soil Science Workshop* (51-60pp). Edmonton.

Schmidt, M.; Schreier, H.; and Shah, P.B., 1993. 'Factors Affecting the Nutrient Status of Forest Sites in a Mountain Watershed'. In *Journal of Soil Science*, Vol. 44 (417-425pp).

Schuyler, L.R., 1994. 'Nutrient Management, an Integrated Component of Water Quality Protection'. In *Journal of Soil and Water Conservation*, Vol. 49 (5-7pp).

Shah, P.B., 1995. 'Soil Fertility Issues under Irrigated and Rainfed Agriculture in the Middle Mountains of Nepal'. In *Proceedings: International Workshop on Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayan Region* (13p). Kathmandu: ICIMOD.

Chapter 6

Soil Fertility Issues under Irrigated and Rain-Fed Agriculture In the Middle Mountains of Nepal

P.B. Shah
and Hans Schreier

Introduction

Rapid population growth and resources' constraints are placing severe pressure on the subsistence economy in the middle mountains of Nepal. Over the past few years, an interdisciplinary research project was carried out to document the resource status, examine land-use dynamics, determine soil fertility conditions, and quantify the soil erosion, and hydro-meteorological processes affecting resource use and causing degradation. This cooperative study between ICIMOD and the University of British Columbia (UBC) has been very challenging as it contains an extensive environmental monitoring programme and data integration using GIS techniques.

Over the past few years, soil fertility conditions in relation to land use have been monitored in the Jhikhu Khola Watershed in the middle mountains of Nepal. The watershed is located 50km east of Kathmandu and covers 11,000ha of land between 700 to 1,900m in elevation. The land use within the watershed is typical of the middle mountains and land-use pressure is high. The watershed area is dominated by an elaborate system of man-made terraces. There has also been a gradual transformation from single to multiple annual crop rotations in the area, wherever irrigation water is available. Soil fertility maintenance with limited input and intensive farming systems suggest that the middle mountains of Nepal are facing serious problems.

Land-use Patterns and Cropping Intensity

The study area displays the typical land-use pattern found in densely-populated parts of the middle mountains. Agricultural crop production is carried out on *khet* (irrigated lands) and *bari* (rain-fed uplands). Rice-based farming systems are predominant on *khet* and the general cropping patterns are spring maize followed by rice, or two crops of rice followed by wheat, tomatoes, or potatoes. Under rain-fed farming systems, typical annual cropping sequences are maize intercropped with millet, followed by wheat or mustard, depending on soil moisture conditions.

Cropping intensity, as revealed through socioeconomic surveys, averages out at 2.7 crops/year grown under irrigated conditions and 2.5 crops/year under rain-fed conditions. Increases in cropping intensity over the past 10 years have resulted from increasing demand for food, availability of short-growing season crop varieties, and, most important of all, market-oriented cash crops.

Soil Inventory

Soil inventory and mapping were carried out for the study area on a scale of 1:20,000. The major soils of the watershed can be broadly divided into two main types: red soils and non-red soils. The more prevalent red soils are **Rhodustults** and **Paleustults,** developed on phyllitic parent material, and the non-red soils are mainly **Ustochrepts** and **Dystrochrepts**, formed on phyllite and schists. The red soils have developed on old river terraces and are the oldest soils in the middle mountains. They are known to be highly prone to erosion and under low organic matter input, therefore it is very difficult to maintain soil fertility. All red soils have a diagnostic clay enriched Bt horizon with higher clay content in the B horizon than in either the A or C horizons.

Soil Fertility Survey

A 1:20,000 scale soil survey was conducted in the watershed, and some 340 soil pits and auger holes were sampled for nutrient analysis and texture characterisation. Subsequently, the soils were examined in more detail and a red versus non-red soil map was produced and digitised. This allows us to display the nutrient status of the different soils in a spatial manner and will assist us in modelling production in relation to soil constraints.

In addition to the general soil survey, three detailed fertility surveys were conducted during the 1992-93 season. First, 200 sites were selected according to the major land-use types and various biophysical conditions in the watershed. Forest soil evaluations were completed by Schmidt (1992) and Schmidt et al. (1993) and dryland agriculture by Wymann (1991). As a result of these surveys, it became evident that the biophysical conditions (aspect and elevation) and the soil types are key components influencing land use and productivity. As a result a 2 x 2 x 2 x 3 factorial survey was carried out in the middle section of the watershed to cover elevation (above and below 1,200m), aspect (north versus south), red versus non-red soils, and land use (irrigated-*khet*, rain-fed-*bari*, and grazing land). The aim was to document differences in soil fertility due to land use, while keeping some of the main biophysical conditions constant.

Of the 24 combinations of the biophysical types, only 20 occurred. This was because there is little irrigated land above 1,200 metres, particularly on the south facing slopes, and insufficient grazing land occurred on high elevation, red soils on northern aspects. An overview of the combination of classes and the number of fields in which samples were collected is provided in Table 1. All sampling sites were identified on the enlarged (1:5,000 scale) aerial photographs and surface samples were collected for nutrient analysis. The samples have been duly analysed in the soil laboratory at the University of British Colombia (UBC).

Table 1: Sampling Design for Detailed Nutrient Analysis

Soil Type	Elevation	Aspect	Land Use	Sample #
Red Soils	< 1,200m	South	*bari*, grazing, *khet*	10 each
Red Soils	< 1,200m	North	*bari*, grazing, *khet*	10 each
Red Soils	> 1,200m	North	*bari*	10
Red Soils	> 1,200m	South	*bari*, grazing	10 each
Non-Red Soils	< 1,200m	South	*bari*, grazing, *khet*	10 each
Non-Red Soils	< 1,200m	North	*bari*, grazing, *khet*	10 each
Non-Red Soils	> 1,200m	South	*bari*, grazing	10 each
Non-Red Soils	> 1,200m	North	*bari*, grazing, *khet*	10 each

Two detailed soil surveys were carried out to document the changes in soil fertility over time, due to alterations in nutrient input and intensification in production. First, a site was selected consisting of a pine forest planted 17 years previously, situated adjacent to dryland agricultural fields and irrigated fields. All three originated on the same soils, and, based on the historic aerial photos and farmers' surveys, it was clear that the land uses remained the same over the 17-year period, but the inputs, use, and intensity of production had changed significantly. This was a relative comparison since we did not have historic soil samples. The differences in soil fertility between the three land uses could be attributed to the difference in management. The prime concern of this study was that the nutrients under forests had not been sustainable as a result of extensive litter collection. Similarly, irrigated and rain-fed agriculture under increasing crop intensification had also not been sustainable because of insufficient nutrient inputs. This comparison was made to provide long-term rates of change and relative degradation in soil fertility between different land uses that receive different inputs. Ten surface soil samples were collected in each of the three land-use types and profiles were analysed in each.

The second detailed survey was conducted on 12 forested sites and seven agricultural sites originally sampled in 1989. These sites were used to determine potential soil fertility changes over a five-year period. These plots were re-sampled in April 1994. Ten composite samples were gathered and combined into one bulk sample per plot during each of the two surveys. The 1994 set of samples was sent for analysis in the soil laboratory at UBC. The samples were representative of typical pine and *sal* forests and *bari* agricultural fields.

Analysis of variance, t-tests, and Mann Whitney U-tests were used to determine differences between soils under different land uses. The test site results were extrapolated for the entire watershed by comparing the mean values of key soil fertility variables collected from different soil and land use surveys.

Results and Discussion

Soil Profile Comparison

Our basic assumptions are that all red soils in the test area are of similar origin and original composition, and that differences in surface horizons result from recent changes in land management. Results for soil profiles in the forest and agricultural fields (Table 2) support these assumptions. The sequences of horizons are the same, and the overall chemical composition of the Bt and BC horizons are also similar. The forested site has slightly greater pH, greater base saturation, and total Fe and Al and clay contents than the agricultural site. The differences, however, are small and do not contradict the suggestion that the soils have a common origin. About two-thirds of the total iron is in the active CBD extractable form. This has implications for phosphorus availability. In addition, 16 per cent of the total iron is in the amorphous (ammonium oxalate extractable) form, this is more than 25 per cent of the active iron.

Table 2 also shows that these strongly weathered and oldest soils in Nepal have very low nutrient status. They have large amounts of clay ($<2um$), and mineralogical analysis of the B and BC horizons (Schreier et al. 1990) indicates a predominance of illite and kaolinite. The illite is a result of the weathering of mica, a mineral that is most prevalent in the parent materials of the watershed. The kaolinite results from rapid weathering on acid, freely-drained sites; it influences soil fertility because of its small cation exchange capacity.

Long-term Land Use Effects on Soil Fertility Differences

Soil fertility differences were compared for three land uses (Tables 3 and 4). The forested soils had significantly less ($P = 0.05$) exchangeable Ca, Mg, base saturation, available P, total N, and organic C than those under the other land uses, and CBD-extractable Fe in the surface horizons was significantly greater. Nutrient removal by biomass collection in the forest plantation over the past 17 years helps explain the low nutrient status of its soils. By contrast, the agricultural sites receive nutrient inputs from manure and chemical fertilisers. The differences between dryland and irrigated agriculture are smaller: P is significantly greater ($P = 0.05$) on the irrigated sites than on the rain-fed sites, but the differences in Ca and Mg are significant at only $P = 0.20$ and $P = 0.10$, respectively. These differences suggest that the irrigated fields receive nutrients and cations from irrigation water and sediment suspended in the water in addition to the nutrient inputs in manure and chemical fertilisers (Schreier et al. 1990).

Table 2: Comparison of Profile Characteristics between Forested and Agricultural Sites

	Agricultural sites			Forested sites		
	AB (0-20)	Bt (20-50)	BC (50-100)	AB (0-20)	Bt (20-50)	BC (50-100)
pH ($CaCl_2$)	4.8	4.6	4.7	4.3	5.1	5.4
P (mg/kg)	1.9	1.9	0.3	0.8	1.9	0.5
N (g/kg)	0.76	0.43	0.21	0.62	0.43	0.32
C (g/kg)	7.5	4.5	1.9	7.9	4.5	3.4
Ca (cmol/kg)	1.72	1.59	1.04	1.47	1.45	1.48
Mg (cmol/kg)	1.99	2.00	1.48	0.82	1.25	1.54
K (cmol/kg)	0.30	0.31	0.09	0.26	0.09	0.20
CEC (cmol/kg)	15.7	16.6	12.8	15.8	14.9	10.9
BS (%)	25.8	23.7	20.6	16.4	18.9	29.7
CBD %Fe	2.91	3.25	3.39	3.01	3.34	3.53
CBD %Al	0.4	0.43	0.47	0.48	0.56	0.53
PYR %Fe	0.08	0.02	0.01	0.15	0.06	0.01
PYR %Al	0.08	0.07	0.05	0.13	0.05	0.04
AAO %Fe	0.79	0.88	0.39	0.75	0.99	0.93
AAO %Al	0.21	0.22	0.13	0.21	0.24	0.20
Clay (%)	47.5	52.6	42.7	43.9	56.2	53.8
Silt (%)	30.2	25.6	28.8	28.8	22.3	24.2
Sand (%)	22.3	21.8	28.5	27.3	21.5	22.0
Ca (% total)	0.09	0.08	0.08	0.06	0.06	0.05
K (% total)	1.65	1.60	1.60	1.30	1.40	1.50
Mg (% total)	0.36	0.34	0.34	0.30	0.35	0.34
Fe (% total)	4.67	4.77	4.77	4.69	5.90	5.72
Al (% total)	8.54	8.62	8.62	8.27	10.20	9.98
P (% total)	0.03	0.03	0.03	0.03	0.03	0.02
% Active Fe/total	62.3	68.2	71.0	64.1	56.6	61.7
% Active Al/total	4.7	4.9	5.4	5.8	5.5	5.3
% Amorphous Fe/total	16.9	18.5	8.2	16.0	16.7	16.3
% Amorphous Al/total	2.5	2.6	1.6	2.5	2.3	2·

CEC = Cation exchange capacity
BS = Base saturation
CBD = Citrate-bicarbonate-dithionite extractable (= active)
PYR = Pyrophosphate extractable
AAO = Ammonium oxalate extractable
Amorphous = CBD-AAO

Table 3: Mean Values of Fertility Characteristics of Soils under Forests, Rain-fed, and Irrigated Agriculture

	Forested (n = 10)	Rain-fed Agriculture (n = 10)	Irrigated Agriculture (n = 10)
pH	4.2	4.5	4.9
C (g/kg)	4.5	11.4	10.9
N (g/kg)	0.45	1.21	0.98
Ca (cmol/kg)	1.47	2.63	2.79
Mg (cmol/kg)	0.55	1.28	1.77
K (cmol/kg)	0.25	0.52	0.3
P (cmol/kg)	1.4	6.4	8.6
CEC (cmol/kg)	15.18	12.03	11.94
BS (%)	16.1	37.6	40.3
CBD Fe (%)	3.28	2.48	2.5
CBD Al (%)	0.36	0.23	0.33
AAO Fe (%)	0.37	0.35	0.59
AAO Al (%)	0.32	0.19	0.03

Table 4: Variables Found to be Significantly Different between the Three Land Uses Using the t and U Test ($P < 0.05$)

	Rain-fed Agriculture	Irrigated Agriculture
Forested	C, P, Ca, Mg, BS, N Fe(CBD), Al(CBD), pH, Al(AAO)	C, P, Ca, Mg, BS, N, Fe (CBD), pH, Fe(AAO), Al(AAO)
Rain-fed Agriculture		P, N, Al(CBD), Fe(AAO), Al(AAO),pH

To assess nutrient input from irrigation, water sampled from the nearby spring and stream during the dry season of 1990 was analysed (Table 5). The water is alkaline and contains moderate quantities of Ca, Mg, and PO_4; it also contains some Na, K, and nitrate. Non-irrigated fields receive several times more organic matter and chemical fertiliser than irrigated fields (Riley 1991), and this results in significantly greater organic carbon (P + 0.10) and total nitrogen (P + 0.05) in the soils of rain-fed systems. Overall, the nutrient status is best on irrigated land (Shah et al. 1991). Nutrient addition through irrigation water, possibly supplemented by nitrogen enrichment through blue-green algal fixation (Sanchez 1976), and reducing conditions, with slow organic matter decomposition, are thought to be the main reasons for the differences. Also, the rice grown by irrigation seems to be less nutrient demanding than maize or wheat.

Table 5: Chemical Composition of Irrigation Waters, April 27, 1990

	Spring	Stream
Ca (mg/l)	20.1	20.0
K (mg/l)	1.9	1.8
Mg (mg/l)	3.3	1.4
Na (mg/l)	9.8	9.6
NO_3(mg/l)	1.7	1.9
PO_4(mg/l)	0.25	0.26
pH	8.2	8.7

Nutrient losses by harvesting and erosion are significant in the middle mountains. The forested and rain-fed sites are clearly affected by erosion. Runoff losses from irrigated fields are smaller than from rain-fed sites, and this might contribute to the differences in nutrient conditions between the two agricultural uses.

Detailed Soil Fertility Survey

The soil fertility survey included the sampling and analysis of 200 sites with special reference to red versus non-red soils, north versus south-facing slopes, high elevation versus low elevation sites, and irrigated versus non-irrigated agriculture and grazing. The 2 x 2 x 2 x 3 factorial survey was carried out in the middle section of the watershed and the analysis of the soil samples was completed by June 1994. An overall summary table of mean values per factorial combination is provided in Table 6. It is apparent that low elevation sites are clearly enriched, except in the case of north-facing red soil sites which show no difference between elevations. Irrigated fields were generally found to have more cations and base saturation than their non-irrigated counterparts and grazing lands. Grazing lands are generally lowest in cations P and pH. The explanation for this is that the soil fertility of dryland agricultural fields is declining, whereas the irrigated fields, which receive more fertilisers, water, and sediments, are being enriched. A more comprehensive statistical analysis of the data is underway.

Rates of Soil Fertility Decline

These data do not allow us to determine the exact rate of soil fertility decline because: (1) we do not know the initial soil fertility of the agricultural and forestry sites at the time the forest was established; and (2) we do not know the actual inputs and outputs of each land-use system without monitoring nutrient cycling over several years. However, we believe that the differences in nutrient status are induced by land-use management, leading to poor overall soil fertility conditions even in those fields receiving the largest inputs. This is particularly true for N, P cations and pH, all of which are in the low to deficient range in the case of most of the basic crops grown in the area (Landon 1984; Sherchan et al. 1991).

Extrapolation of Results to Adjacent Areas

Comparison of the soil survey data with our results (Table 7) shows that the differences between rain-fed and forested sites are similar, though the organic carbon content is not significantly different between these two land uses. No comparison can be made between irrigated and non-irrigated uses, because irrigation of red soils is rare and no data were available for the test area.

A fuller comparison is possible between our data and those from the surveys by Schmidt (1992) and Wymann (1991), both of which included many forested, irrigated, and rain-fed agricultural sites. The differences between and uses shown in Table 7 are not as pronounced in the Dhulikhel watershed survey because of additional variability introduced by differences in parent material, topography, and micro-climate. Nevertheless, the soils of irrigated fields are less acidic than under rain-fed agriculture or forests, and exchangeable Ca and available P are found least in forested sites. The organic carbon and nitrogen trends are less consistent, carbon being most abundant under rain-fed agriculture and nitrogen under forests. These comparisons suggest that the conclusions from the test site are representative of most conditions in the middle mountain region east of Kathmandu and confirm that the long-term soil productive capacity is not being sustained.

It is also significant that soil nutrients are in the low to deficient range for almost all the major crops (wheat, maize, mustard, rice) grown in the rotations on the study site. The conditions are adequate only for millet, which has especially small nutrient requirements. We suggest that in the absence of sufficient fertilisers, incorporation of green manures into the soil or the addition of nitrogen-fixing crops in the rotation system, are the only effective ways of limiting further deterioration.

Table 6: Summary of Nutrient Analysis for the Detailed Survey of 200 Sites

South facing slopes/red soils

Land use	ph	p ppm	C %	CEC cmol +/kg	K cmol +/kg	Mg cmol +/kg	Ca cmol +/kg	Base Sat %	
Khet	5.5	6.8	1	14.4	0.27	2.94	5.49	61.6	Low elevation
Bari	5.1	8.5	1.1	13.1	0.33	2.18	4.23	51.7	below 1200
Grass	4.9	8.5	1.7	15.6	0.35	1.71	4.33	39.7	
Khet	No khet fields on red soils								High elevation
Bari	4.8	9.8	1.1	12.5	0.3	1.77	3.14	40.1	Above 1200
Grass	4.6	4.7	1	11.4	0.21	1.35	2.15	32.5	

North facing slopes/red soils

Land use	ph	P ppm	C %	CEC cmol +/kg	K cmol +/kg	Mg cmol +/kg	Ca cmol +/kg	Base Sat %	
Khet	5.2	10.3	0.8	12	0.28	1.09	5.74	60.3	Low elevation
Bari	4.8	13.8	0.9	13.9	0.58	1.59	3.96	44.7	below 1200
Grass	4.7	4.5	0.5	12.3	0.38	1.81	2.76	40.1	
Khet	No khet fields on red soilsh								High elevation
Bari	4.7	21.5	0.9	12.3	0.59	1.52	3.55	49.3	Above 1200
Grass	No grazing land on red soils								

South facing slopes/non-red soils

Land use	ph	P ppm	C %	CEC cmol +/kg	K cmol +/kg	Mg cmol +/kg	Ca cmol +/kg	Base Sat %	
Khet	5.3	22.5	1.1	9.8	0.14	2.06	4.91	70.7	Low elevation
Bari	5	21.4	1.2	8.7	0.24	1.45	3.74	63.2	below 1200
Grass	4.6	10.3	1.1	7	0.14	0.83	1.68	43.1	
Khet	No khet fields on non-red								High elevation
Bari	4.7	19	0.9	6.5	0.15	0.88	2.71	58.7	Above 1200
Grass	4.7	8.1	1	6.5	0.17	0.87	1.65	41.1	

North facing slopes/non-red soils

Land use	ph	P ppm	C %	CEC cmol +/kg	K cmol +/kg	Mg cmol +/kg	Ca cmol +/kg	Base Sat %	
Khet	5	39	0.8	9.6	0.29	0.79	5.48	59.4	Low elevation
Bari	4.7	18.8	0.8	8.6	0.23	1.18	3.56	58.6	below 1200
Grass	4.6	9.9	1	9.9	0.23	1.14	4.25	59.1	
Khet	4.8	29.6	0.9	10	0.23	0.73	4.83	59.8	High elevation
Bari	4.8	50	1	9.1	0.39	1.19	3.56	76.5	Above 1200
Grass	4.6	10.3	1.4	11.8	0.19	0.81	2.85	37.2	

Table 7: **Comparison of Soil Fertility Conditions between Agriculture and Forestry from Soil and Land Use Surveys in the Jhikhu Khola Watershed**

Land Use	Source	No. of Samples	pH	C g/kg	N g/kg	Ca cmol/kg	Mg cmol/kg	K cmol/kg	P mg/kg
Rain-fed	(1)	7	4.8	6.9	0.68	2.15	1.31	0.27	2
Forested	(1)	5	4.6	6.6	0.54	1.54	1.08	0.30	0.6
Rain-fed	(2)	60	4.3	7	0.70	2.16	0.69	0.14	22.3
Irrigated	(2)	37	4.8	5.4	0.58	3.46	0.44	0.18	21.1
Forested	(3)	136	4.3	6.0	0.90	1.80	0.65	0.28	3.5

(1) Shah and Shreier (1991), Soil survey data
(2) Wymann (1991), Agricultural land use survey
(3) Schmidt (1992), Forestry survey data

Conclusions

The increasing demands for food, animal feed, and fuelwood by the expanding hill population in the middle mountains of Nepal have resulted in a serious depletion of soil nutrients in both agriculture and forestry systems.

The overall soil fertility conditions on the test site are generally poor under all three land uses (rain-fed, irrigated, and forested). Soil carbon, nitrogen, and available phosphorus are particularly depleted, and the soils are acidic and have low base saturation.

As the soils have a common origin and were probably similar in nutrient composition originally, the different surface soil conditions result from the dominant land use practices over the past 17 years. Because of massive litter removal and no inputs, the soils of the forested sites have the least, N, P exchangeable bases and pH values. The rain-fed sites have the most C and N because they receive the largest amount of organic matter. The irrigated sites have the most P, Ca, and Mg, because of enrichment of irrigation water and suspended sediments.

The rate of soil fertility depletion can only be estimated when the original soil fertility status is known. However, it was found that, because of nutrient removal by litter collection and crop harvesting, N and P are being strongly depleted.

When compared with other subsets of survey data collected within the 11,000ha watershed, it is evident that the results are representative of the entire area, suggesting that declining soil fertility is a widespread problem.

Fundamental changes in management are needed to sustain soil nutrients and biomass in the long run. This will require a decrease in biomass removal and additional inputs such as incorporation of green manure into the crop rotation. A short-term option is to plant nitrogen-fixing trees and to introduce nitrogen-fixing arable crops into the annual rotation. Without additional nutrient input, further decreases in biomass production are inevitable.

References

Landon, J.R., 1984. *Booker Tropical Soil Manual.* London: Booker Agriculture International Ltd.

Riley, K.W., 1991. 'Soil Fertility Maintenance for Sustainable Crop Production in the Mid-Hills of Nepal'. In Shah, P.B.; Schreier, H.; Brown, S.; and Riley, K. (eds). *Soil Fertility and Erosion and Issues in the Middle Mountains of Nepal (3-14pp).* Ottawa: IDRC.

Sanchez, P.A., 1976. *Properties and Management of Soils in the Tropics.* New York: J. Wiley and Sons.

Schmidt, M., 1992. 'Forest Land Use Dynamics and Soil Fertility in a Mountain Watershed in Nepal: a GIS Evaluation'. Ph.D Thesis. Department of Soil Science, University of British Columbia, Vancouver.

Schmidt, M.G.; Schreier, H.; and Shah, P.B., 1993. 'Factors Affecting the Nutrient Status of Forest Sites in a Mountain Watershed in Nepal'. In *Journal of Soil Science,* Vol.44, (417-425pp).

Schreier, H.; Brown, S.; Kennedy, G.; and Shah, P.B., 1990. 'Food, Feed and Fuelwood Resources of Nepal: A GIS Evaluation'. In *Environmental Management,* Vol.15 (15-822pp).

Shah, P.B. and Schreier, H., 1991. 'Nutrient Deficiency and Soil Fertility Issues'. In Shah, P.B.; Schreier, H. Brown, S.; and Riley, K. (eds.) *Soil fertility and Erosion Issues in the Middle Mountains of Nepal (pp 260-266).* Ottawa: IDRC.

Sherchan, D.P.; Gurung, G.B.; and Chand, S.P., 1991. 'A Review of Current Soil Related Research Activities at Pakhribas Agricultural Centre'. In Shah, P.B.; Schreier, H.; Brown, S.; and Riley, K. (eds) *Soil Fertility and Erosion Issues in the Middle Mountains of Nepal* (83-104pp). Ottawa: IDRC.

Wymann, S., 1992. 'Landnutzungsintensivierung und Bodenfruchtbarkeit im Nepalischen Hugelgebiet.' Diploma Project. Institute of Geography, University of Berne, Switzerland.

Chapter 7

Living Terrace Edge — An Effective Method of Slope Utilisation in the Upper Reaches of the Yangtze River

Li Xiubin

Abstract

Very similar to Sloping Agricultural Land Technology (SALT) developed in the Philippines, Living Terrace Edge (LTE) is a special erosion control practice in the traditional systems of land use in the sloping areas in eastern China. It is a biological measure for protecting terrace edges from soil erosion and to raise the economic status of farmers. Terraces are part of the landscape in China and the farmers take terracing as an effective way of using their sloping farmlands. Some 27 million hectares of terraces are constructed each year in the country. Terrace edges usually occupy 10-15 per cent of the total land area. If these edges are used appropriately, they provide potential land resources which are valuable for a populous country like China. The application of LTE has been very successful in both an ecological and an economic sense in many provinces of eastern China. This paper reviews the LTE practices in different parts of that region and makes suggestions for the further development of this technique.

Introduction

Upland rain-fed areas often face a serious problem of soil erosion which damages land productivity. This occurs due to heavy rainfall on very steep slopes. Recent developments in agroforestry provide probable ways of putting the development of upland areas on a sustainable footing. A typical example is Sloping Agricultural Land Technology (SALT), developed in the Philippines, which integrates nitrogen-fixing shrubs and trees to minimise soil erosion and maintain soil fertility in crop fields (Tacio 1993). However, upland areas are so diverse in their natural environmental and socioeconomic conditions that no single universally effective model exists.

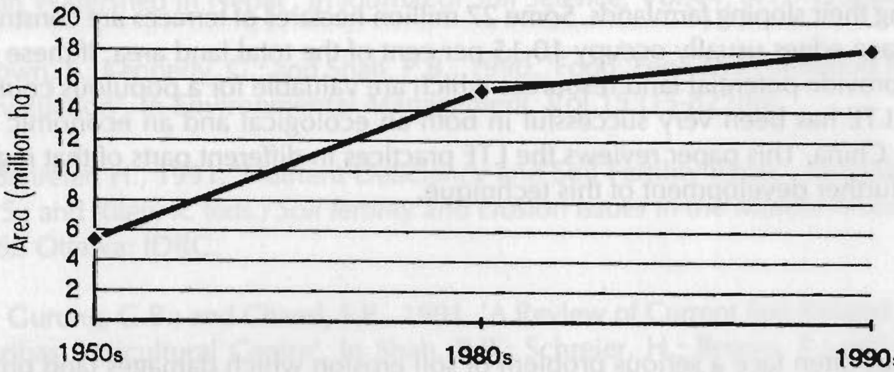
Many current agroforestry systems have evolved from traditional farming practices that have, over the ages, adapted to local circumstances. Living Terrace Edge (LTE) is one such farming practice, used mainly to control soil erosion in the terraced fields of eastern China. The LTE method involves planting small trees, shrubs, and grasses along the edges of terraced fields to protect terrace edges from runoff damage and to use slopeland resources to their full capacity. Species selected for LTE are often special local ones, or other plants, that can prove to be cost effective and raise the income of farmers.

Innovations intended to conserve soils and improve their fertility have not been readily and widely adopted because of the lack of technical adaptation to the farmers' circumstances (Fujisaka et al. 1994). Terracing as an effective way of using slopelands has a long history in China. However, this traditional measure needs updating in many respects, especially the collapse of terrace edges during rainstorms. The LTE method has proved to be effective in allowing surface water to run off a slope without causing much erosion. Another remarkable characteristic of the LTE method lies in its emphasis on direct income from terrace edge plants. (Without various LTE types, farmers can harvest products such as food, fodder, fruit, vegetables, medical herbs, fibre, and perfume materials.)

Problems of Slopeland Utilisation in Eastern China

Population increases and economic developments have placed a great pressure on croplands in China. The problem is especially acute in eastern China, since it is the most populous and fast-growing region in the country. Evidence of this pressure is the accelerating land degradation on sloping lands, which make up some 60 per cent of the total area in the said region. Figure 1 shows the soil erosion trend in the area south of the Yangtze River over the last 40 years. Now the total erosion area in eastern China is 961,898sq.km. This fact is related to the rapid expansion of sloping farmlands in the region in the past four decades. A typical example is that of Jiangxi Province where the total area of sloping farmlands during the 1990s reached 338,106ha, compared to 98,853ha in the 1950s. Over 30 per cent of the sloping farmlands in the province are on steep slopes with a gradient of over 25°. Reclamation of slopelands for cultivation is a major cause of soil erosion. This is evident from the fact that the eroded farmlands account for 76 per cent of the total eroded area in the Pearl River Basin, 47 per cent in the Loess Plateau, and 45 per cent in eastern China as a whole.

Figure 1: Soil Erosion Trend in the Area South of the Yangtze River in the last 40 years



Severe soil erosion has drastically reduced soil productivity and has had serious downstream effects such as sedimentation in river beds, reservoirs, and lakes and flooding in the lowlands. In this connection, farmers in the upland areas are encouraged by the government to control on-farm soil erosion by using various methods with great efficiency. Terracing is a traditional measure and plays a predominant role in on-farm erosion control in China. According to Guo (1992), the total area of sloping farmlands in China is about 33 million ha, of which over 22 per cent are terraced fields. In the Loess Plateau, about 200,000ha of sloping farmlands are converted into terraces each year.

As permanent structures, terraces have a number of advantages over other erosion control measures. For instance, irrigation becomes possible and field operations for farmers are made easy with the reduction of slope gradients. On the Loess Plateau, well-constructed terraces are reported to have reduced 70-95 per cent of the runoff and over 90 per cent of soil loss, increasing yields by up to 100 per cent compared to sloping farmlands without terraces (Yang 1994). Terraces are also effective in moisture retention for they usually have deep soils. The principal alternative to terracing is the contour hedgerow that harnesses erosive forces to form terraces naturally. For this process to be successful, it is essential to have excessive rainfall which, in turn, causes soil erosion and enables natural terracing to take place (Fujisaka et al. 1994). In areas such as the northern parts of the said region, where the application of contour hedgerows is limited because of low rainfall intensity, terracing is even more important.

Yet, terraces have some problems for a number of reasons. These include inadequate drainage, poor design of structures, and low quality construction. An obvious fact in eastern China is that terraces with earth risers constitute a large proportion in many areas due to the shortage of stone or the high unit costs of stone. Earth-riser terraces amount to 70 per cent of the total terraces constructed in recent years in southern Shaanxi Province (Zhu 1994) and 93 per cent in western Henan Province (Zhang et al. 1989). Earth risers are usually prone to failure in rainy seasons, especially in the early years of construction. One example is that from southern Shaanxi Province where 30-40 per cent of the earth risers collapsed the year following construction.

Some masonry terraces easily cave in owing to quick weathering of the stones, for example, the purple sandstone and shale used in Sichuan Province. In this connection, appropriate methods for terrace riser maintenance are vital for sustainable use of terraces.

The Living Terrace Edge — Effective Terrace Protection and Sustainable Slopeland Use

Terraces usually have masonry or earth risers and bunds at the top of the risers which determine the stability of terraced fields. Terrace edges in this paper refer to those parts of the terraces. The land area occupied by terrace edges depends on the original slope gradient and the style of the terrace structure. Terraces with earth risers usually have a large edge area owing to the acute angles of terrace risers. In eastern China, the area of terrace edge varies from five to 20 per cent of the total field area, but more often it is constrained within the range from 10 to 15 per cent.

The use of terrace edges, even for fruit tree plantation, is a long-time tradition among Chinese farmers, especially in southern China. This erosion control technique is gaining widespread acceptance in eastern China. For instance, some 52,200ha of terraces with LTE have been developed in southern Shaanxi Province (Xu et al. 1992) and the Tai'an Prefecture of Shandong Province uses terrace edges on 20 per cent of the land (Li and Xu 1994). Many places have developed successful LTE applications such as Chinese prickly ash in Shaanxi, citron day lily and Indian floating heart in Shandong, Korean lovegrass in Fijian, and mulberry LTE in the provinces of Sichuan, Shaanxi, Shanxi, and Hebei. A summary of plant species involved in LTE application in different provinces in eastern China is presented in Table 1. Most of the plant species involved in LTE are small trees, shrubs, and herbs with high economic values.

Many application projects in eastern China demonstrate the sustainability of the LTE technique. Enumerated below are some of the functions of the technique.

Erosion Control: The preliminary objective for LTE implementation is to enhance the stability of terraces by means of planting small trees, shrubs, and grasses along the edges of terraced fields. Terrace edges are most unstable and erosion prone because runoff is maximised there and the soil surface is exposed to the direct impact of rainfall. Terrace edge plants and their residues can minimise the impact of raindrops as they strike the soil, and they can also be used to form a physical barrier to slow down runoff and filter out sediment. Moreover, the deep and dense roots of terrace edge plants can protect terraces from collapse. According to a report (Xiang 1990) from Shaanxi Province, the bunge prickly ash LTE reduces terrace collapse by 60 per cent during rainstorms. Citron day lily LTE planted five years ago in Shandong Province reduced runoff by 70 per cent and soil loss by 87 per cent (Yang et al. 1993). In Henan Province, the Indian floating heart LTE reduced runoff and erosion by up to 90 per cent and 92 per cent respectively (Zhang et al. 1989).

Other Ecological Benefits: In addition to erosion control and terrace protection, LTE provides other ecological benefits such as improving soil properties, regulating microclimates, and increasing vegetation cover. Tables 2 and 3 present some examples of LTE's effects on temperature, humidity, wind speed, evaporation, soil nutrients, and other physical properties in different places in eastern China.

Economic Benefits: Economic benefits obtained by farmers from an erosion control project determine its sustainability to a large extent. In many respects, LTE implementation can translate into economic benefits for farmers. First, the LTE method saves terrace maintenance cost, which is expensive, especially for terraces with earth risers. Second, the cultivation index is enhanced by the use of terrace edges that would otherwise remain unused. The most significant merit of LTE lies in its emphasis on the direct economic benefit from the terrace edge plant. Many terrace edge plants have output values higher than those of field crops. In Hancheng City of Shaanxi Province, the average output value of terrace edge prickly ash is $1,058 per hectare, accounting for over 10 times that of food crops (Xiang 1990); the output value of terrace edge mulberry was reported to be $882 per hectare in Hebei Province in the early 1980s, amounting to three times that of peanuts and two times that of cotton (Liang 1990); the terrace edge rose in Shanxi Province has an output value as high as $12,970 per hectare (Li 1991).

Table 1: Plant Species Used for Living Terrace Edge Applications in Eastern China

Species Name	Common Name	Usage	Reported Area
Tree species			
Toona sinensis	Chinese toona	Vegetable	Shaanxi
Quercus hopeiensis	oak	Fibre	Shaanxi
Paulownia elongata	paulownia	Wood	Shaanxi
Trachycarpus fortunei	windmill palm	Fibre, oil	Shaanxi
Ziziphus jujuba	Chinese date	Fruit	Shaanxi, Shandong
Diospyros kaki	persimmon	Fruit	Shandong, Shaaxi
Citrus	citrus	Fruit	Shaanxi
Juglans cathayensis	Chinese walnut	Fruit	Hebei
Eriobotrya japonica	loquat	Fruit	Sichuan
Castanea mollissima	hairy chestnut	Fruit, food	Shaanxi
Eucommia ulmoides	eucommia	Medicine	Shaanxi
Shrub species			
Camellia sinensis	tea	Tea	Shanxi, Guizhou, Fujian
Hippophae rhamnoides	seabuckthorn	Fruit	Shaanxi
Ribes burejense	bureja gooseberry	Fruit	Jiangsu, Shaanxi
Morus alba	white mulberry	Fibre	Shanxi, Sichuan, Hebei, Shaanxi
Coriaria sinica	Chinese coriaria	Fibre	Shaanxi
Rhus chinensis	Chinese sumac	Medicine	Shaanxi
Nymphoides indica	Indian floating heart	Medicine	Shandong, Shanxi, Shaanxi
Rosa rugosa	rugose rose	Perfume	Jiangsu, Shaanxi
Jasminmum nudiflorum	winter jasmine	Medicine	Shaanxi
Gardenia jasminoides	cape jasmine	Medicine	Shaanxi
Ziziphus jujuba	spine data	Fruit	Shanxi, Shaanxi
Amorpha fruticosa	shrubby amorpha	Fibre, green manure	Hebei, Shandong, Shanxi
Caragana korshinskii	korshinsk peashrub	Fibre	Shaanxi
Tamarix ramosissima	branchy tamarisk	Fibre	Shanxi, Shaanxi
Fraxinus bungeana	ash	Fibre	Jiangsu, Shaanxi
Lespedeza dahurica	shrub lespedeza	Food	Heilongjiang
Salix integra		Fibre	Jiangsu, Shaanxi
Salix nigra		Fibre	Shaanxi
Salix cheilophila	sand willow	Fibre	Shaanxi
Coronilla emerus	coronilla	Green manure	Shaanxi
Zanthoxyllum bungeanum	bunge prickly ash	Flavouring	Shandong, Jiangsu, Shaanxi
Herb and grass			
Hemerocallis citrina	citron day lily	Vegetable	Shandong, Shaanxi, Shanxi
Dendranthema morifolium	chrysanthemum	Medicine	Shaanxi
Eulaliopsis binata	common eulaliopsis	Fibre	Shaanxi
Medicago sativa	alfalfa	Fodder	Shaanxi
Miscanthus sinensis	miscanthus	Fibre	Shaanxi
Eragrostis ferruginea	korean lovegrass	Fodder	Fujian
Glycine max	soybean	Food	Heilongjiang
Vicia faba	broadbean	Food, green manure	Hubei
Vigna sinensis	common cowpea	Green manure	Hubei
Vine species			
Vitis vinifera	grape	Fruit	Shaanxi

Table 2: Changes in Soil Properties (0 - 20cm) after Implementing LTE in Some Areas of East China

LTE type	Location	Physical properties		Chemical properties		
		Bulk density	Water content	Organic matter	N	P_2O_5
Indian floatingheart	Songxian, Henan	-16%	+32%	+43.1%	+42.5%	NA
Rugose rose	Linfen, Shanxi	-7%	NA	+22%	+32%	+2%

Note: based on Zhang et al. (1989) and Li (1991)

Table 3: Changes in Microclimatic Conditions (Summers) after Implementing LTE in Some Areas of East China

LITE type	Location	Soil surface temperature	Air temperature	Relative humidity	Evaporation	Wind speed
Prickly ash	Hancheng, Shaanxi	-0.57°C	-1.11°C	+4%	-23.7%	-30.25%
Mulberry	Qian'an, Hebei	-0.7 - 1.56°C	NA	+7%	NA	NA
Citron day lily	Tai'an, Shandong	NA	-1°C	+18%	-20%	-30%

Note: based on Xiang (1990), Liang (1990) and Li (1994)

Living terrace edges may, however, have negative effects on adjacent crops in terraced fields owing to their competition with field crops for light, water, and soil nutrients. According to Zhang's (1989) observation in Henan Province, shrubby *amorpha* has a strong impact on the soil water availability of adjacent crops and can affect the moisture level of the soil two metres away from terrace edges. Some yield reduction has also been observed in the rows nearest to terrace edge plants such as *paulownia* and korshinsk peashrub (Zhang 1986). However, yield reduction of field crops may not reduce the overall output value of the land-use system if the terrace plants are taken into account. To minimise the negative effects of terrace edge plants on field crops, appropriate species should be selected and the LTE technique should be well designed.

Towards Sound Technical Design for the Living Terrace Edge

It can be seen from the last section that the LTE is very successful in both ecological and economic terms in many places. However, poorly designed LTE projects are bound to fail due to the edge effects of LTE plants, or because of other reasons. Thus, it is necessary to formulate some principles for LTE design in order to make it a sustainable method of slopeland use. Several aspects of LTE design need to be considered.

LTE — A Component of the Land-use System

Living terrace edge, as well as being an erosion control measure is also a land-use type, considering the fact that both field crops and terrace edge plants make up an intercropping scheme. Ordinarily, when an intercropping practice fails it is because of the negative effects of minor components on the major ones. In this connection, the structures of this intercropping system, such as species' structure, production structure, and land-use structure, would be designed as part of overall land-use planning. In view of the economic benefits, the major products of the intercropping system may come from field crops or terrace edge plants. If the latter is determined to be the major component of the farming system, the edge effects of living terrace edges become no more significant. A well-coordinated interrelationship between field crops and terrace edge plants will ensure sustainability of the erosion-control function of living terrace edges.

Choice of Species

Factors affecting species' selection for terrace edge plants include environmental adaptability, erosion control capability, economic value, and edge effects. Plants with higher environmental adaptability are often chosen because of their easy establishment and management. Shrubs and perennial herbs with deep root systems and coppicing abilities are the best choice for erosion control, because it is easy to establish a vegetative barrier to slow down runoff and erosion from the ground surface with these plants. To minimise the edge effects of LTE, plants with a laterally spreading root system and a large canopy should be avoided at the time of selection. The income-generating capacity of the terrace edge plants' products determines the farmers' attitude to application of the LTE method. Experiences from eastern China show that special local plants often have higher income benefits and ensure LTE project success.

Planting Position

LTE can be established on both terrace risers and on the top earth bunds for earth-riser terraces. For masonry terraces, however, terrace edge plants can only be planted at the extreme edge of the earth terrace and choice of species is limited to small shrubs and perennial herbs which have little edge effect. An earth riser often has a slope so as to provide a larger space for LTE development. For earth risers with a relatively large height or small slope gradient, plantation of small trees and large shrubs is possible, but, at the top of terrace risers, plants must first be grass and shrubs with little edge effect. The trend of a terrace also affects the establishment of LTE. A north-south extended LTE usually has a smaller shading effect on field crops than an east-west one. Thus, the former has a wider choice of species than the latter.

Conclusion

Contour hedgerows have shown a number of advantages over other methods to deal with soil erosion in the humid tropics. In those mountain areas without the heavy rainfall intensity of the humid tropics, farmers are not easily persuaded to accept the method because natural terracing lasts longer. This is especially the case in China where large areas of terrace structures exist and farmers prefer artificial terracing to control soil and water erosion. Thus, the living terrace edge is an effectual way to solve the problem since it harnesses both the structures and vegetative techniques. Moreover, slopelands can be used to a greater extent with the implementation of living terrace edges.

Although some pilot projects in LTE application have been successful in eastern China, there are still some information gaps that need to be bridged. A common problem encountered in LTE applications is the edge effects of terrace edge plants. The performance of these plants in intercropping systems, especially their root systems, requires detailed trials since little knowledge is available. The method of economic appraisal for LTE implementation also deserves further research. Both the economic and ecological benefits of the vegetative method should be assessed in a quantitative way to assure the sustainability, as well as the productivity, of the land-use system.

References

Fujisaka, S.; Jayso, E.; and Dasgupta, A., 1994. 'Trees, Grasses and Weeds: Species' Choices in Farmed-Developed Contour Hedgerows'. In *Agroforestry Systems*, Vol. 25, (13-22pp).

Guo Tingfu, 1992. 'On the Potential of Terrace Edge Economy'. In *Soil and Water Conservation in China*, April 1992 edition (11-12pp).

Li Deping and Xu Gui Hua, 1994. 'Integrated Utilisation of Terrace Edge Resources Tai'an Municipality.' In *Soil and Water Conservation in China*, July 1994 edition (47-48 pp.)

Li Meili, 1991. 'Experimental Research on the Effects of Land Edge Protection and Soil Conservation by Planting Roses on Land Edges'. In *Bulletin of Soil and Water Conservation*, Vol. 11, No. 4 (61-64pp).

Liang Qisheng, 1990. 'Ecological and Economic Benefits of Terrace Edge Mulberry. In *Soil and Water Conservation in China*, August 1990 edition (43-44pp).

Tacio, H.D., 1993. 'Sloping Agricultural Land Technology (SALT): a sustainable Agroforestry Scheme for the Uplands'. In *Agroforestry Systems*, Vol. 22 (145-152pp).

Xiang Li, 1990. 'Soil and Water Erosion in Jiangxi Province: General Situation and Counter Measures'. In *Bulletin of Soil and Water Conservation*, Vol. 14, No. 3 (39-43pp).

Xu Benji, Ma Zhangguo, and Xiang Li, 1992. 'On the Utilisation of Terrace Edges and the Terrace Economy'. In *Soil and Water Conservation in China*, April 1992 edition (13-14pp).

Yang Jihua et al. 1993. 'A Study on the Effects of Citron Day Lily on the Water and Soil Conservation of Terrace Edges. In *Bulletin of Soil and Water Conservation*, Vol. 7, No. 2 (70-74pp).

Yang Ruizhen, 1994. 'Cultivated Land Soil and Water Loss for our Country and Control Measures'. In *Bulletin of Soil and Water Conservation*, Vol. 14, No. 2 (32-36pp).

Zhang Fu, 1986. 'A Preliminary Research on Shrubs for Terrace Protection'. In *Soil and Water Conservation in China*, October 1986 edition (39-42pp).

Zhang Zhixin, Wang Hongji, and Jin Jiemei, 1989. 'Comprehensive Utilisation of Terrace Edges in Western Henan Province'. In *Soil and Water Conservation in China*, January 1989 edition (26-31pp).

Zhu Jianqiang, 1994. 'An Analysis of Terrace Collapse and its Countermeasures in Southern Shaanxi Province'. In *Bulletin of Soil and Water Conservation*, Vol. 14, No. 3 (44-47pp).

Chapter 8

A Matter of Relativity — Design for Low-Cost Soil Erosion Monitoring under Differing Land-use Regimes

R.D. Hill

Colleagues who are subscribers to the electronic mail network, SE-LIST (Soil Erosion List), will be aware of the continuing debate concerning the use of absolute and relative measures in soil erosion studies. To some degree the debate is artificial in the sense that both kinds of measures have their place, and the latter, particularly, in studies directed towards elucidating the relationships between land-use systems and erosion. The use of rather crude relative measures, which may provide no more than order-of-magnitude estimates, is justified for several reasons, mainly economic, for they may be substantially cheaper than attempting to make more precise and absolute measures.

First, it is necessary to be aware of several problems of research design. The two major sources of materials moving on slopes (and delivered ultimately into streams), surface wash and slope failure, are not equally susceptible to measurement. Slope failure and sudden mass movement are difficult to measure for several reasons. In open terrain, where aerial photography is possible, it is a fairly simple matter to measure the scars of landslides and their runout paths. Using stereoscopy, such measurements can be further refined to estimate the volume of material that has moved. But, on well-vegetated terrain, whether covered with forests, woodlands, or tree crops, only large landslides which open up the canopy can be observed stereoscopically. Consequently, it is difficult under natural conditions to establish the necessary baseline against which a possible increase in incidence of landslides under various land-use systems may be compared. Very broadly, the incidence increases in the period roughly two to 12 years after deforestation, following which slopes tend to re-equilibrate themselves to the new conditions. However, there has been little study of this in tropical regions. A further consideration is that slope failure is frequently episodic and therefore difficult to research in short funding periods of two to three years.

The classical answer to such problems is one that dates back to Blackwelder, a half-century ago, when a small catchment study was conducted. In this, all the eroded materials, both suspended and in solution, which leave the soil, were measured. Such measurements are normally continued for five to ten years. In the conditions of tropical Asia, the difficulties of designing such studies are manifold, quite apart from the financial considerations. Except in forest reserves and on tree-crop plantations, the spatial scale of land use tends to be small, making it difficult to find small catchments with a single, stable land-use pattern, let alone similar soils, slopes, orientation, and other variables which may influence the amount and kinds of materials leaving them. Finding an unused control site to match with used catchments is not only difficult but the control may be vulnerable to fire or destruction by change of use.

These considerations have led to a substantial reliance on plot studies, despite the inherent difficulty in scaling these up to larger areas. One major difficulty is that sediments moving along slopes by surface wash are only one component, and not necessarily the largest, of the total quantity of material delivered into streams. That total also includes delivery in solution, substantial in limestone regions; delivery by soil creep; and, as indicated earlier, delivery by mass movement resulting from slope failure. The study of water movement is likewise difficult since runoff is only one component, groundwater being the other. In soils where soil pipes develop, some heavy clays for example, these may deliver significant quantities of materials in both solution and suspension into the streams. If the catchment is taken as the system, it needs to be recalled that as much as 70 per cent of the sediments moving on slopes may, for varying periods, be stored within the system as flood-terraces, point-bars, and so on — a basic fact that must be borne in mind during the implementation of soil erosion control measures.

Plot studies, because they are relatively simple to implement, though not cheap, are thus likely to continue to be carried out in many regions. Despite other disadvantages, their major advantage is that, at least in tropical and subtropical regions, they probably more nearly capture the reality of soil loss than a model such as the Universal Soil Loss Equation would, which is in actual fact designed for temperate conditions and for application on the global or large-region scale though it has been applied with varying success to specific sites. One basic problem of the Equation is that it is multiplicative rather than additive, so that shortcomings in any parameter weigh rather heavily (Rijsdijk and Bruijnzeel 1990).

But the standard approach, using a large trough at the foot of each plot to capture water and sediment or diverting such materials through one or more splitters, is relatively expensive to set up, especially if plots are walled in. The trough approach also has the inherent problem of satisfactorily sampling the materials caught, for, where the material is coarse, no amount of agitation will give a uniform dispersion of material in suspension, as a result larger materials tend to be under-represented. Splitters may have similar problems.

These considerations lead to the question: Is it essential that absolute measures be used? If relative measures suffice and are cheaper, especially if farmers themselves can apply the procedures for measuring erosion, are these measures not to be preferred? Given that within a single land-use regime, even on similar slopes, there are likely to be substantial site-to-site variations in surface erosion, is not a design strategy that allows a good number of replications, using relative not absolute, 'catch-everything' measures, to be preferred?

The designs which follow have been tried out in Hong Kong over the last three years and have proved to be cheap and satisfactory, showing very clearly differing orders-of-magnitude of erosion on grass/fernland (control), annually-cut grass/fernland, burnt grass/fernland, and land deliberately kept bare in order to establish the upper limits of erosion. The mean slope angles are about 15° and about 26°, and the soil is sandy clay loam (sand 62%, silt 12%, clay 26%).

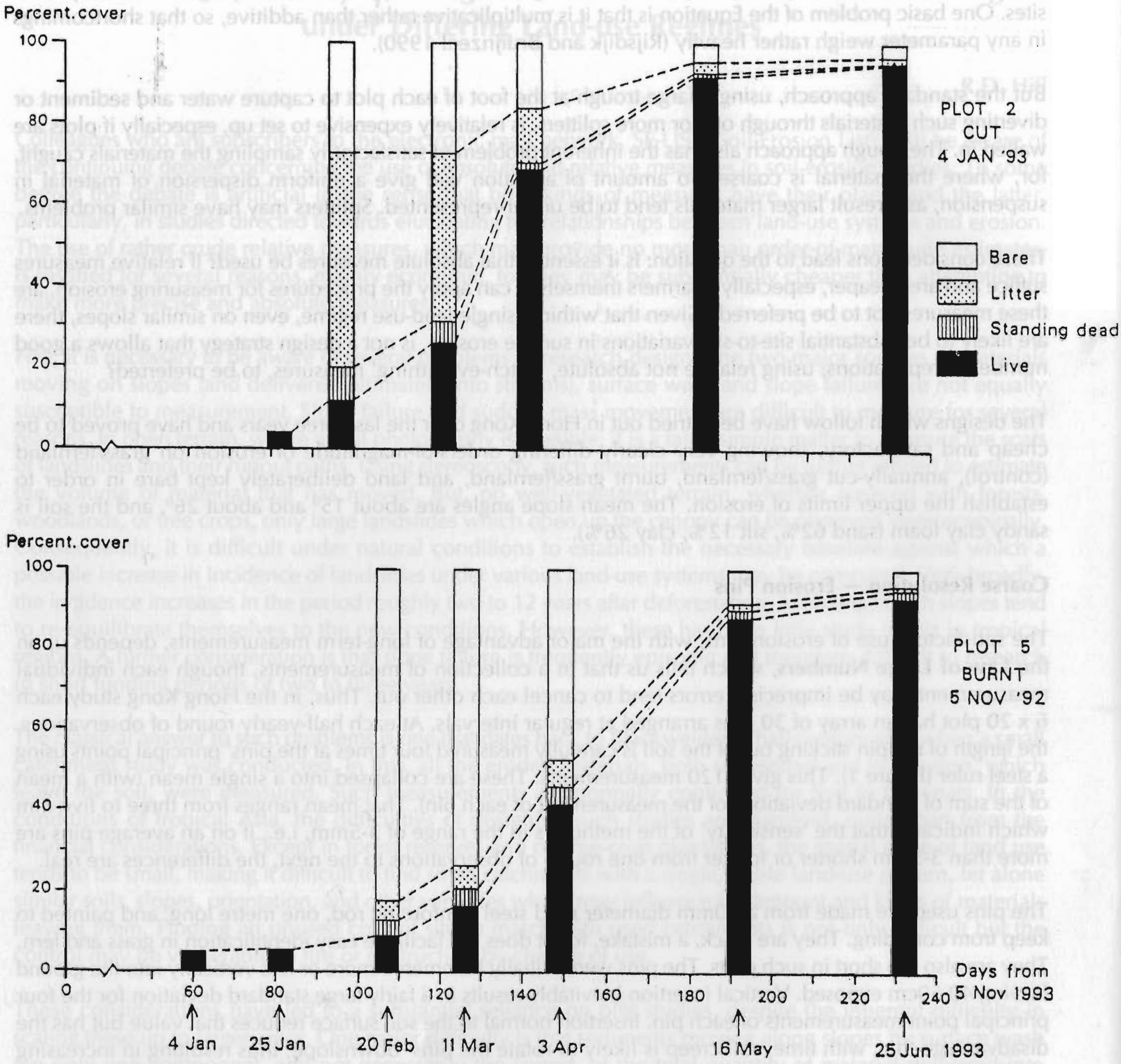
Coarse Resolution — Erosion Pins

The satisfactory use of erosion pins, with the major advantage of long-term measurements, depends upon the **Law of Large Numbers**, which tells us that in a collection of measurements, though each individual measurement may be imprecise, errors tend to cancel each other out. Thus, in the Hong Kong study each 6 x 20 plot has an array of 30 pins arranged at regular intervals. At each half-yearly round of observations, the length of the pin sticking out of the soil is carefully measured four times at the pins' principal points using a steel ruler (Figure 1). This gives 120 measurements. These are collapsed into a single mean (with a mean of the sum of standard deviations of the measurement of each pin). That mean ranges from three to five mm which indicates that the 'sensitivity' of the method is in the range of 3-5mm, i.e., if on an average pins are more than 3-5mm shorter or longer from one round of observations to the next, the differences are real.

The pins used are made from a 10mm diameter mild steel reinforcing rod, one metre long, and painted to keep from corroding. They are black, a mistake, for, it does not facilitate easy identification in grass and fern. They are also too short in such plots. The pins were initially hammered more or less vertically into the ground leaving 40-50cm exposed. Vertical insertion inevitably results in a fairly large standard deviation for the four principal point measurements of each pin. Insertion normal to the soil surface reduces that value but has the disadvantage that, with time, soil creep is likely to rotate the pins' downslope, thus resulting in increasing standard deviations. Obviously, at the expense of more labour, more than four measurements of each pin can be made, thus improving accuracy.

The pins thus readily detect erosion and sedimentation in the centimetre range. If used where the soil is cultivated a further, and possibly a large, source of error is introduced. Cultivation artificially bulks up the soil while also disturbing the pins. It is obviously not possible to insert pins immediately after cultivation and to expect valid measurements, for substantial compaction of clods and other aggregates may occur after cultivation and the soil surface is, in any case, highly irregular. The problem of surface irregularity at the base of each pin can be partly remedied by sliding a plastic disk over the pin just prior to each set of measurements and measuring to it rather than to the soil surface, an approach used in the study of sand movement on beaches where scouring around the base of pins occurs.

Figure 1: Regeneration Diagram, 1993



Fine Resolution — Measuring Splashed Materials

Under monsoonal conditions which produce a number of high intensity rainfall events every rainy season, the impact of drops upon the soil, resulting in the detachment of particles and their downslope movement, is probably highly significant, though the relative importance of this process, compared to overland flow, is not well established. (On light sandy soils and on soils with deep litter and a good granular structure in the A horizon, overland flow is probably fairly rare.) While it is true, as suggested earlier, that by no means all the mobile materials generated on slopes quickly find their way into streams, a measure of mobilisation is useful in that it reflects erosivity and the degree of slope protection offered by plants (and litter).

Since no standard method exists, a simple catcher (splash pan) was designed. This comprised of a plastic lunch box, square, with an area of 160sq.cm. and 7cm high. This was modified by cutting a hole in the side and glueing in a plastic filter-funnel into which a standard Whatman No 42, ashless filter paper was fitted, using double-sided cellulose tape to secure it in place (Figure 2). The purpose of this was to evacuate water and to retain materials splashed over the sides of the trap. (A rain-chamber test showed that the filter-funnel could cope with rainfall of 800mm/hr without the catcher overtopping.) The catchers were pegged to the soil surface, five on each 120sq.m. plot. These were replaced at 400°C, the last as a rough measure of the amount of organic matter present. In addition, each plot carried two catchers at a height of 60cm above the ground, the objective being to catch air-borne material so that the values for the ground-level catch could be deflated by the amount caught at 60cm, since air-borne material could also find its way into the ground-level catchers. (In this case, catches at the 60cm level were very small and highly variable, though there is a possibility that these were underestimated since strong winds could remove already enmeshed materials once these were dry — a probability also at ground level.)

In this experiment, substantial differences in the catch of mineral soil in the splash pans between closed grass/fernland and cut-over plots were found. For example, in 1992, pooled data (from 10 pans) in the 32 days following cutting of two plots showed a total catch of 27.5g of mineral soil from the cut plots compared to only 1.7g from the uncut ones. (Subsequently, as the live plant cover on the cut plots regenerated, the values for the two treatments converged).

Order-of-magnitude differences are thus so large and so obvious that greater sophistication (and expense) of design is not justified, though there is some scope for this. A clear weakness is the fact that dry, already-captured material may readily be evacuated by wind, especially on open sites. Coating the bottom of the pan with an easily soluble but non-drying substance, in order to keep the catch in the pan, may be a solution. Another problem is to avoid catching leaves shed by the vegetation as they senesce. This is basically insoluble since any kind of protector, e.g., a fine mesh set above the splash-pan, would inevitably change the characteristics of the falling raindrops. It is thus impossible to distinguish between organic matter falling directly into the catcher from that splashed up into it. In retrospect, it would also have been cheaper to have fabricated metal catchers, because the plastics become brittle and fragile with exposure — presumably to ultra-violet rays.

Fine Resolution — Measuring Downslope Material

Since the order-of-magnitude data for different treatments were required, a simple device to intercept some of the materials moving downslope sufficed. Traps, to a design shown in Figure 3, were made simply by cutting and bending the top of an oil tin to form an opening and a flap and by punching holes into the cap fitted with a standard glass-fibre filter (Whatman GFD, 4cm diam.), thus trapping sediment, but draining water. (Tins were painted inside out for preservation and required replacement only after three years.) Four such sediment-traps were dug into holes in the soil shaped to receive them, the surplus soil removed, and the soil between the sides of the holes and the traps being firmly tamped down to avoid artificial contribution to the supply of material on the slope. The flap was pressed firmly into the soil and sealed as flush pans. These catchers remain *in situ* to minimise soil disturbance, and their contents are later evacuated by scoop and brush into beakers for drying and analysing. Over these traps is placed a standard sized shelter to keep off direct rain and to minimise rain splash near the trap opening. We used sheet aluminum on painted steel rods (Figure 4A) with a simple attachment (detail in Figure 4B). This design is cheap, easy to make, and has successfully withstood three typhoon seasons.

A sample of results for the rainy season of 1993 (130 days) shows that the traps were indeed successful in establishing order-of-magnitude differences amongst treatments. On 25-27° slopes the total catches of mineral soil were for control (uncut), cut, and burnt plots respectively, 28g, 1,436g, and 7,700g. In no case had the traps been overtopped, though those on the burnt plot came close to it.

Figure 2: Mean Total Catch (Dry Weight) Per Trap and Rainfall (Cumulative)
July 1992 - Jan 1993

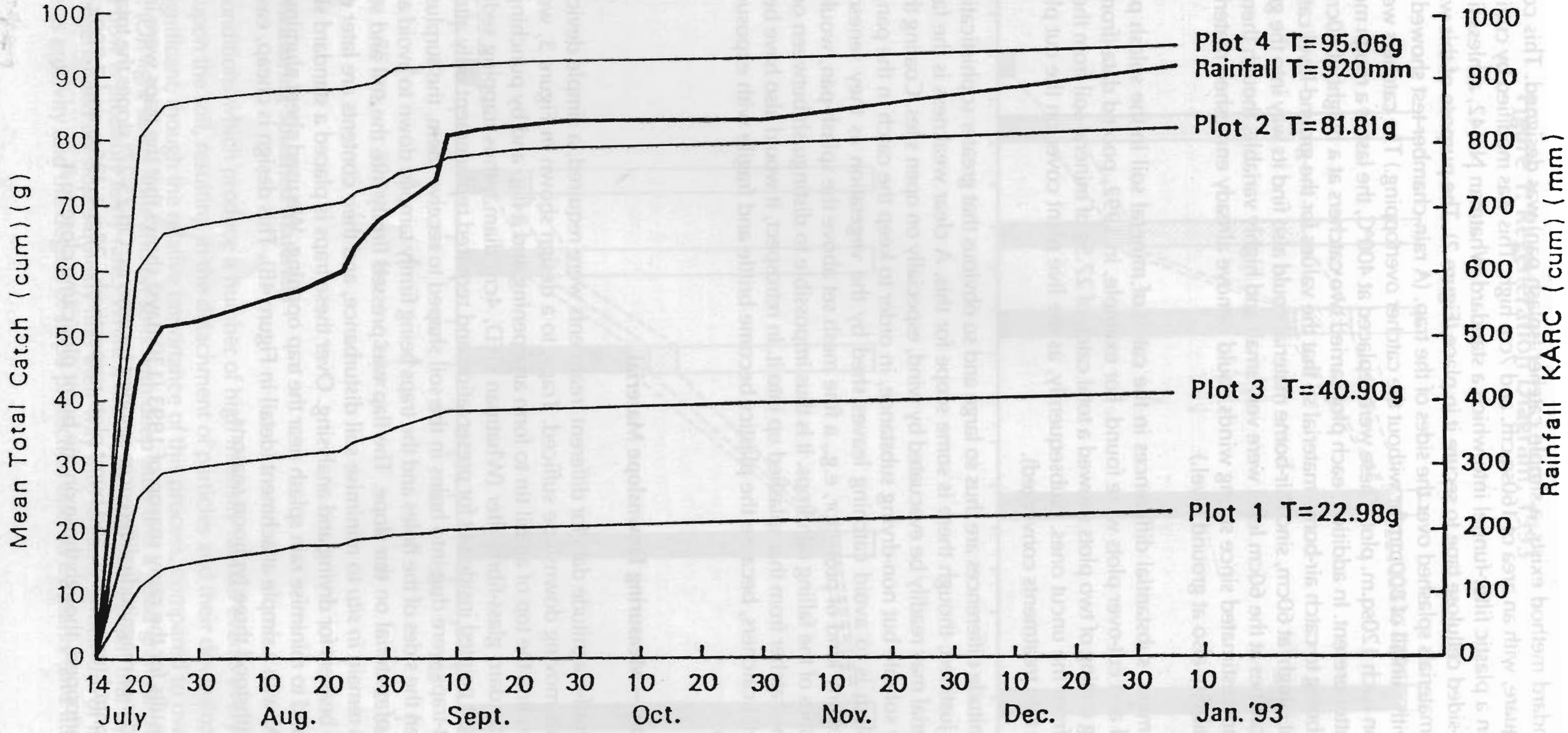


Figure 3: Total Dry Matter Catch and Rainfall, 1993

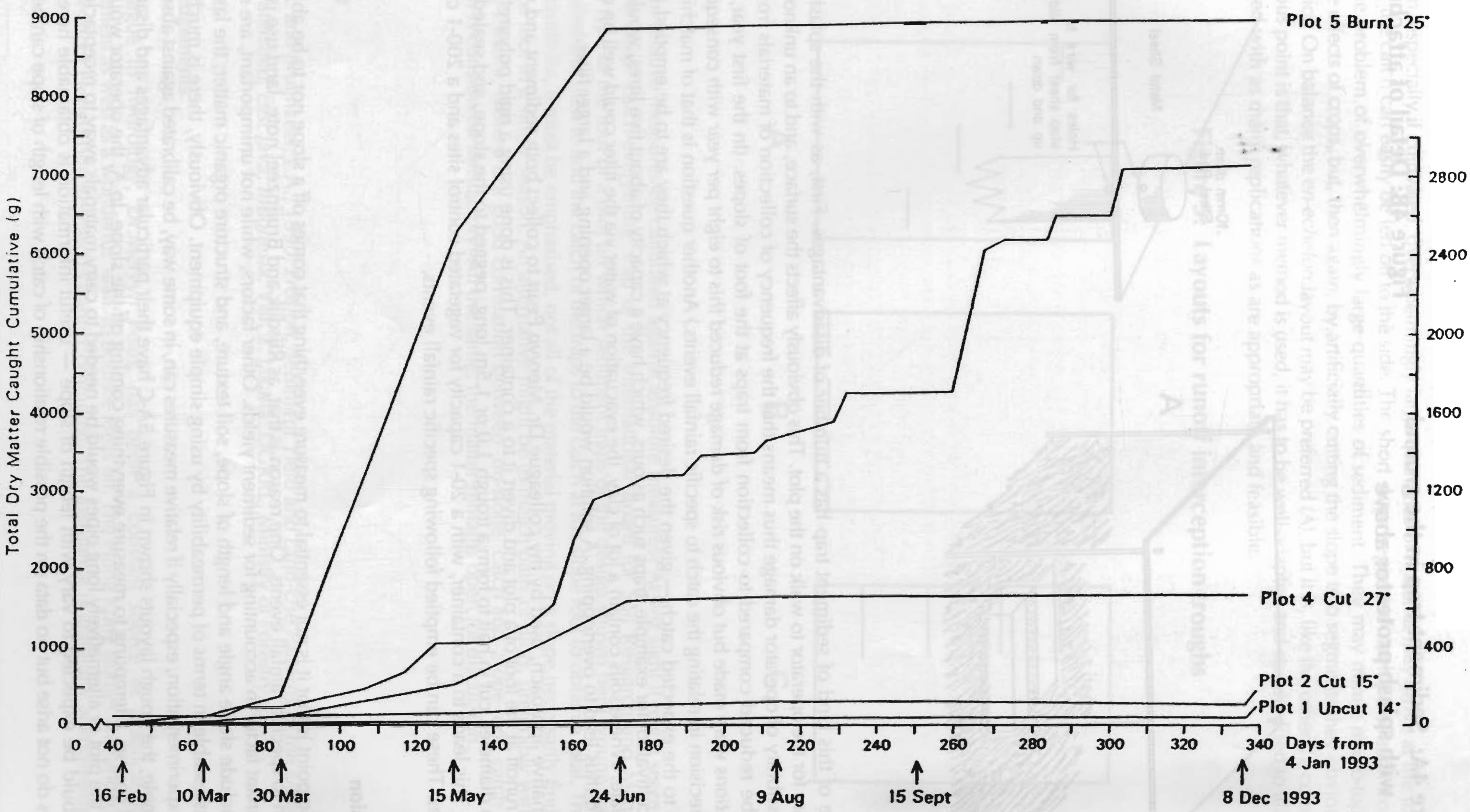


Figure 4A: Sediment trap in the ground with splash-protector above

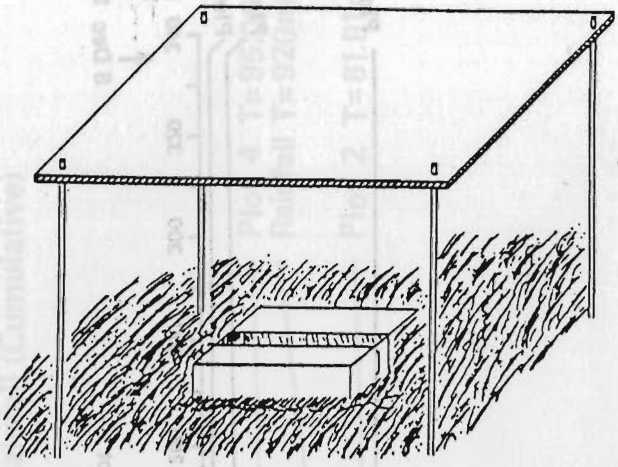
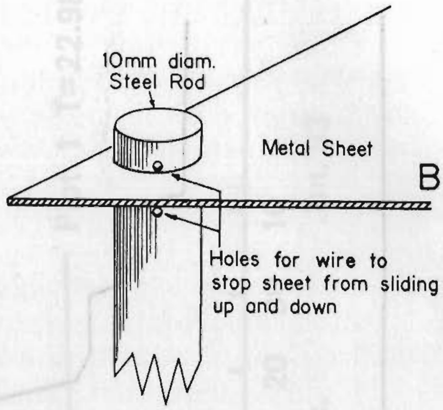


Figure 4B: Detail of attachment



The use of this kind of sediment trap has a number of disadvantages. First, as with the splash-pans, it is necessary for the operator to walk on the plot. This obviously affects the surface, and to an unknown degree. The possibility of operator damage thus means that the frequency of collection of materials from the traps has to be reduced compared to collection from traps at the foot of slopes. (In the first year, 18 sets of observations were made but obvious risk of damage reduced this to eight per year with consequent loss of some precision in relating the catch to specific rainfall events.) Another question is that of matching the size of traps to the expected catch — given the desired frequency at which they are to be emptied. Where the land is cultivated, for example, traps such as ours, which have a capacity of about five litres, would be totally inadequate. Where soils contain a lot of clay, the evacuation of water via the filter could well be excessively slow and thus lead to overtopping. A solution would be a larger opening and a larger filter.

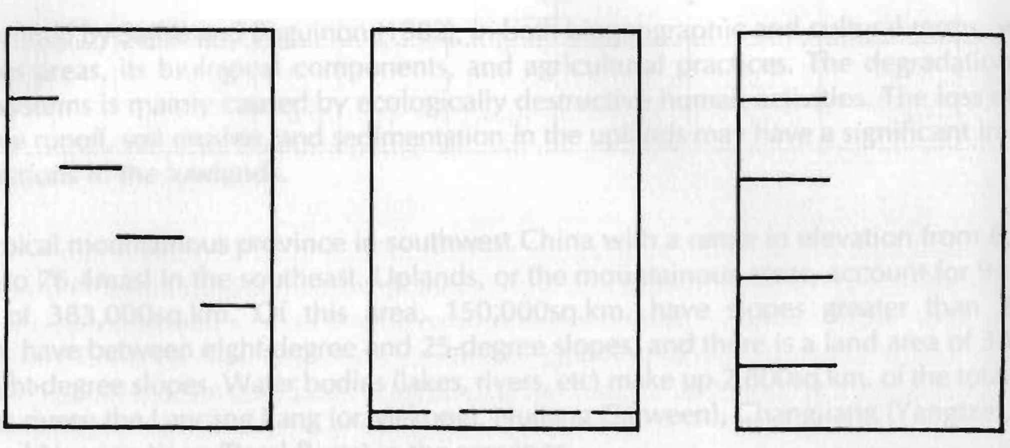
An alternative approach, used by my colleague Dr. Mervyn Peart to collect both sediment and water, is to capture runoff at the foot of a plot and divert it to a container. This is done using a rigid polyurethane pipe, 10cm in diameter, cut in half to form a trough 1.0 or 1.5m long, pegged to the slope, and sealed to the soil surface. This leads to a container, with a 20-1 capacity for vegetated control sites and a 200-1 capacity for bare sites. These can be emptied following specific rainfall events.

Conclusion

The basic point is that it is not essential to measure everything that comes off a slope nor to be able to relate the catch to specific rainfall events. One reason is that, as Rijsdijk and Bruijnzeel note, land use is by far the predominant factor in accounting for sediment yields. Other factors, while not unimportant, are secondary. These include slope angle and length of slope, soil texture, and structure organic matter; the last three are readily assessable in terms of permeability by using simple equipment. Obviously, there is much scope for further experimentation, especially if relative measures can, in some way, be calibrated against absolute ones. For example, the trough layouts shown in Figure 5A-C have their particular advantages and disadvantages, none, of course, attempting to measure everything coming off the slope. In A, the operator would have to walk on the plot or alternatively long pipes would be needed to carry materials away to receptacles. But the catch would be expected to vary with length of slope — useful information is obtainable here. In B, the problems do not arise but no data on the possible relationship of catch with length of slope can be obtained.

In addition, especially if cultivated, overwhelmingly large quantities of material may arrive at the foot of the plot. In C, the catch can easily be led off to the side. The short slope segments' upslope of each trough may reduce the problem of overwhelmingly large quantities of sediment. They may mimic micro-topography and/or the effects of crops, but, then again, by artificially cutting the slope into segments they obviously alter its dynamics. On balance the *en-echelon* layout may be preferred (A), but it is, like the others, a compromise. The obvious point is that, whatever method is used, it has to be well-adapted and standardised to all the sites investigated with as many replications as are appropriate and feasible.

Figure 5: Layouts for runoff interception troughs



How might relative measures be calibrated against absolute measures? At first sight it might seem possible to install a deep 'catch-everything' trap of the International Board for Soil Research and Management (IBSRAM) type at the foot of a plot on which sediment traps of the design shown here (young traps) have been installed and then to add the catch of the traps to the catch at the slope foot to obtain a total. This would be rather crude for, it must be emphasised, not all of the material moving on a slope necessarily finds its way to the slope foot in a single season. An alternative might be to match pairs of plots, preferably with several replicates. Clearly, if there is a good correlation between 'on-slope' catch and 'slope-foot' catch then the calibration is considered satisfactory. All the same, the matter remains open for discussion.

Reference

Rijsdijk, A. and Bruijnzeel, L.A., 1990. *Erosion, Sediment Yield and Land-Use Patterns in the Upper Konto Watershed, East Java, Indonesia*, Vol. 2. Jakarta: DGRRL, Ministry of Forestry.

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Footnote

Colleagues who are on-line may wish to join SE-LIST. The address is SE-LIST@ UNI-TRIER.DE. The list manager is Bodo Bernsdorf, University of Trier, Applied Physical Geography, D-54286, Trier, Germany. E-mail BB@UNI-TRIER.DE.

Chapter 9

Use of Native Plant Species and Indigenous Knowledge for Rehabilitation of Degraded Mountain Ecosystems

Xu Jianchu & Tong Shaoquan
Yang Qixiu
and Qiu Xuezhong

The Present Situation of the Uplands

Uplands are defined by Sajise and Baguinon (1982), in both biogeographic and cultural terms, which refers to mountainous areas, its biological components, and agricultural practices. The degradation of land in mountain ecosystems is mainly caused by ecologically destructive human activities. The loss of vegetative cover, excessive runoff, soil erosion, and sedimentation in the uplands may have a significant impact on the ecological functions in the lowlands.

Yunnan is a typical mountainous province in southwest China with a range in elevation from 6,740masl in the northwest to 76.4masl in the southeast. Uplands, or the mountainous areas, account for 94 per cent of a total area of 383,000sq.km. Of this area, 150,000sq.km. have slopes greater than 25 degrees, 196,000sq.km. have between eight-degree and 25-degree slopes, and there is a land area of 34,000sq.km. with below eight-degree slopes. Water bodies (lakes, rivers, etc) make up 2,800sq.km. of the total area. There are five famous rivers: the Lancang Jiang (or Mekong), Nujiang (Salween), Changjiang (Yangtze), Yuan Jiang (Red River), and Nanpan Jiang (Pearl River) in the province.

Poverty and environmental degradation have become an inevitable part of the socioeconomic and ecological landscapes in the uplands. There are about seven million people living below poverty line in Yunnan, mainly distributed throughout the remote and marginal uplands at present. Degraded lands, including forestlands, account for 42 per cent of the total land area in Pupiao township and 31 per cent of the total land area in Baoshan municipality (Table 1).

Table 1: Land Use in Pupiao Township and Baoshan Municipality

Category		Pupiao Township		Baoshan Municipality	
		area (ha)	per cent (%)	area (ha)	Per cent (%)
1.	Farming land	4691	19	96660	20
	Paddy field	1364	6	32831	7
	Rain-fed upland	3210	13	63413	13
2.	Forest land	15014	60	247805	51
	Good forest	7514	30	201640	42
	Degraded forest	7500	30	46165	9
3.	Permanent Garden	44		6241	1
4.	Pastureland	1285	5	4926	1
5.	Wasteland (degraded land)	2871	12	108296	22
6.	Settlement	590	2	10340	2
7.	Road	201	1	3231	1
8.	Waterbody	302	1	7492	2
	Total	24997		484992	

(Data source: Baoshan Land Bureau Statistics 1994)

Rehabilitation of Degraded Uplands

The resources' management agencies are often structured in terms of key sectoral categories (e.g., forests, agriculture, animal husbandry, and water). Thus, the resource management approaches are also formulated into technical areas which often ignore critical social, cultural, and economic factors and the interrelations between all the different factors. Government planning often causes administrative contradictions between sectors resulting in "poverty of the state". By regulation, any felling from different title lands has to be approved by the local forest bureau. The degraded land, called "wasteland", in Yunnan is considered suitable for reforestation by the forestry department, however it may be designated for grazing to raise more cattle by the animal husbandry department or for fruit-tree plantation by the agricultural department.

Approaches to Restoration

The existing approaches to restoration in Yunnan are as follow.

Plantation

There are many plantation initiatives within the province, such as the *Eucalyptus* Reforestation Project, supported by the World Bank. The programme has many advantages, e.g., fast-growing *Eucalyptus* can provide the materials needed by various industries such as plywood and essential oils. The trees also provide fuelwood, and the extension required for such monocultures is comparatively simpler.

However, this programme has its disadvantages, mainly ecological deterioration factors, particularly in degraded mountain ecosystems. Such programmes also require high investment and are highly market dependant. Degraded mountain ecosystems are usually also areas of low biodiversity.

Air-seeding

The advantages of air-seeding are that large areas can be covered quickly and require low labour input. However, this method is very dependant on natural conditions, such as soil pH, the fertility aspect, and need for strong protection from stray animals and human disturbance. The method is only suitable for a few species, such as pine trees, and is expensive.

Natural Regeneration

Natural regeneration is a low-cost method of natural succession with high biodiversity and better ecological functions, and it can provide multiple products for the local people. But it is a lengthy process and requires local institutions for social fencing and products are sometimes considered of `low value' as they are high in biodiversity but not economical.

Overall, the government forest department is the major implementing agency for reforestation. According to the present reforestation rate, it is very difficult to recover targetted areas within a predictable period of time because of the constraints of lack of well-trained manpower and continual investment.

Use of Native Plant Species and Indigenous Knowledge on Them for Rehabilitation

Whilst degradation of ecosystems is often caused by human activities, solutions to degradation can also be found by human species. Native or endemic plants are more adaptive to the local biophysical environment than introduced or exogenous plants. Exotic or exogenous plants alter the biotic composition of natural ecosystems, thereby changing the biodiversity, ecological processes and functions, and nutrient cycling. Thus, emphasis on the use of local species may prove to be a better option.

Likewise, indigenous people are more familiar with their environment and, therefore, more aware of the local problems than outsiders. They often lack opportunities in terms of land tenure, capital input and other services. Thus, applying indigenous information to rehabilitation is not only more appropriate but also saves time and expense.

Criteria for Selection of Species for Rehabilitation of Degraded Lands

Plant species' selected for rehabilitation of degraded lands should meet the following criteria.

They must be adaptive to extremely degraded habitats, low fertility soils, dry climates, and thin soil layers and they must be competitive to invasive plants.

They must be fast-growing to produce a high yield of biomass for habitat restoration to create sound conditions for succession by other species of organisms. Propagation and maintenance of such species must not require complex techniques and inputs. The species must be multipurpose, e.g., nitrogen-fixing and useful for fuelwood, fodder, and timber. They should contribute to the conservation and enrichment of soil, particularly on sloping uplands. Ideally they should be perennial and tolerant to constant harvesting, for example, fuelwood species should coppice vigorously after cutting. They must be economically and socially acceptable to the local people.

Methods for Identifying Useful Plant Species

Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) can serve as powerful tools for the inventory of native useful plant species and the documentation of indigenous technical knowledge, which could be used for rehabilitation of degraded uplands.

The types of RRA and PRA methods being used in the field include key informant interviews, semi-structured interviews, formal or informal interviews, and casual or focus-group interviews. Group discussions are very useful for obtaining systematic, holistic, and more accurate information on vegetation changes, deforestation, and indigenous taxonomy, such as land races, useful species, habitats, and ecosystems, in order to discover *emic* and *etic* distinctions; species' usefulness ranking and scoring -- valuing the usefulness of biotic species by their criteria and categories; transect walks – walking with informants through an area; observing, asking about, and discussing important species (plants, birds, reptiles, and mammals) in different land use zones; resources, problems, and opportunities; resources' mapping; and vegetative profiling – a sketch map to show resources' availability (forest products and non-timber forest products), vegetative cover, land use, and its changes. The vegetative profiling can be used, for example, to show the structure, composition, and function changes in different components of the ecosystem; quantification – often using short questionnaires and local measures to know where, what, when, and how many resources are available; different trees and crops to be planted; diagraming -- product-flows; seasonalities (rainfall, production); social relations; traditional knowledge analysis – indigenous practices and institutions for water and soil conservation and resources' access; and participatory planning and monitoring -- in which indigenous people prepare their own action plans on rehabilitation and sustainable upland resources' management.

Secondary data, such as a list of local fauna and flora, vegetation maps, and other publications (often called triangulation), is used to supplement or verify the information obtained.

Suitable Indigenous Species Available for Rehabilitation Work

Nitrogen-fixing Trees
Albizia mollis
Atylosia scarabaeoides
Bauhinia variegata
Bauhinia faberi var. microphylla
Caesalpinia decapetala
Cajanus cajan
Crotalaria assamica
Flemingia macrophylla

Soil Conservation and Bank Stabilisation Species
Agave americana
Contoneaster spp
Ficus tikoua
Musella laciocarpa
Pueraria lobata
Vitex negundo

Fruit Trees and Cash Crops
Diospyros kaki
Phyllanthus emblica
Punica granatum
Zanthoxyllum bungeanum

Fast-growing Timber and Fuelwood Trees
Betula alnoides
Camptotheca acuminata
Melia azedarach
Schima wallichii
Toona ciliata
Toona sinensis
Trachycarpus fortunei
Trema orientalis

Indigenous Technical Knowledge for Rehabilitation and Upland Resources' Management

On the basis of work carried out by the project to study the indigenous knowledge on local plant species, the project has come up with a detailed profile of plant species (Annex 1). Here, the use of various species by the people of Pupiao is given.

Terracing

Terracing is commonly practised by indigenous people for conservation of soil and water resources on sloping uplands. Natural barrier and rock-wall terraces can be found locally. Palm trees, *Vitex, Agave,* and other multipurpose plants are often planted on the beaches of terraces. Water storing or harvesting ponds are prepared for watering crops, particularly vegetables, during the drought season.

Non-timber Forest Products' Harvesting

Non-timber forest products provide local farmers with additional income. Edible mushrooms are quite a marketable product. Even pine cones are collected for fuelwood.

Live Fencing

Multipurpose species, such as *Vitex, Agave,* and palm, are planted along the sides of the paddy fields, uplands, and in home gardens for fuelwood, fibre, edible vegetables, and cash income. The thorny species, *Caesalpinia decapetala,* is planted for ornamentation and fencing out animals.

Crop Rotation and Cover Crops

Rotating food crops and legume cash crops is a good way to maintain soil fertility. Grains are usually planted first and alternated with legumes (soyabean, mung bean, peas, and peanuts, etc). Sweet potatoes are suggested as the best crop for the uplands, because they provide year-round cover, minimising soil erosion.

Indigenous Agroforestry

Combinations of perennial crops, for example, fruit trees and annual crops, are the indigenous agroforestry methods for efficient use of land resources. In Baoshan, many fruit species, such as chestnuts, walnuts, and *diospyros*, have been planted on terraced uplands for many generations.

Lessons Learned from the Baoshan Pilot Project

The work undertaken by the project at Baoshan has shown that the costs for the introduction of exogenous species and/or tree plantation are higher than the costs for work undertaken through the use of local species. And the survival and growth rates of native species are better than those of exotics. Natural regeneration can be achieved through the establishment of proper social fencing. Tenure security is a key component for land rehabilitation.

Reference

Sajise, P.E. and Baguinon, N.T., 1982. 'Upland Development: A Critical Resource Management Issue'. In Kamis Awang Al (ed) *Proceedings of [a] Workshop on [the] Ecological Basis for Rational Resource Utilisation in the Humid Tropics of Southeast Asia*. Malaysia: University Pertanian Malaysia.

Indigenous Plant Species' Profile

1. **Scientific name:** *Agave americana*
Local name: *laobzuang*
Description
Site requirement: It requires deep soil and is drought-tolerant.
Uses: It is a very important local fibre crop. *Agave* is commonly planted along the sides of the fields for bank stabilisation and soil erosion control. It is also a medicinal plant.
Propagation: Sucker separation

2. **Scientific name:** *Albizia mollis*
Local name: *yeheshu*
Description: It is a deciduous tree and attains a full height of 13m.
Site requirement: It is native at elevations from 1,300m to 2,800m.
Uses: The wood is quite hard and suitable for furniture. It grows fast with a beautiful crown, often planted along roadsides.
Propagation: Seeds should be pre-treated, soaked in hot water for a while, then submerged into warm water for 24 hours.

3. **Scientific name:** *Atylosia scarabaeoides*
Local name: *manbenchongdou*
Description: It is a legume vine.
Site requirement: It is a pioneering species for land cover. It is adaptive to drought-tolerant uplands.
Uses: It can be planted in loose sloping uplands to produce more biomass for land cover and soil improvement. The leaves are used for medicines.
Propagation: Seeds can be sown directly on upland fields.

4. **Scientific name:** *Betula alnoides*
Local name: *huapishu*
Description: It is a deciduous tree, attaining 16m in height, and yielding fruit in August and September.
Site requirement: It is native in mountainous broad-leaved forests at elevations of from 700m to 2,100m.
Uses: It provides good timber for housing and furniture. The bark is used for tannin extract.
Propagation: It is often recommended as a reforestation species, however, it is very difficult to reproduce the seedlings. Seeds should be stored and sowed in a well-prepared nursery for the coming year.

5. **Scientific name:** *Bauhinia variegata*
Local name: *baihuashu*
Description: It grows to a height of 15m.
Site requirement: It can be found from 750m to 1,900m in the valley, on sloping lands, and in sunny scrub areas.
Uses: The timber is hard and good for wood carving. Flowers and young bean pods are edible. Roots and flowers can be used for medicine. It is also planted for ornamental purposes and for fuelwood.

Propagation: Seeds should be pre-treated by soaking in warm water for several hours before sowing into a seedbed for reproduction of seedlings.
Note: Same as *Bauhinia faberi var. microphylla*

6. **Scientific name:** *Caesalpinia decapetala*
Local name: *tianliba*
Description: Climbing shrub with thorny branches.
Site requirement: It is adaptive to various conditions from stony uplands to water-logged stream sides.
Uses: Large volume of yellow flowers which have ornamental purposes. It is planted for live fencing alongside home gardens and agricultural fields. The seeds have medicinal value.
Propagation: Seeding.

7. **Scientific name:** *Cajanus cajan*
Local name: *mudou*
Description: It is a shrub or small tree from 1-5m tall.
Site requirement: It is a drought-tolerant upland crop and widely adaptive to different soil conditions. It can be planted at elevations of 1,500m. It does not tolerate water-logging and requires full exposure to sunlight to bear fruit.
Uses: The beans are nutritious and a tasty food source. The stem and branches are used for fuel, thatch, and basket fibre. The leaves provide excellent green manure for nitrogen-fixing.
Propagation: No pre-treatment of the seeds is required. It is usually directly sowed in the furrows.
Management: It is often intercropped with cereal crops. To manage as a perennial, cut stems at 50cm above ground.

8. **Scientific name:** *Camptotheca acuminata*
Local name: *xishu*
Description: It is a deciduous tree with a beautiful crown.
Site requirement: It usually requires loose soil.
Uses: It is often planted for industrial pulpwood and fuelwood because it is a fast-growing tree. The extracted compounds from seeds and bark are used for cancer medicines.
Propagation: Seeds are collected in October/November and sowed in the coming spring.
Management: Care from pest damage.

9. **Scientific name:** *Contoneaster* spp
Local name: *xunzi*
Description: Evergreen shrub, 1m in height.
Site requirement: It is widely adaptive to mountainous areas and soil conditions. It can be found at elevations of from 1,000m to 4,000m.
Uses: Fuelwood, ornament
Propagation: Cutting and sowing.

10. **Scientific name:** *Crotalaria assamica*
Local name: *dajushidou*
Description: Shrub attaining 1-2m in height.
Site requirement: It can be found both in drought-ridden uplands and water-logged fields.
Uses: Nitrogen-fixing for green manure.
Propagation: Direct sowing.

11. **Scientific name:** *Diospyros kaki*
Local name: *shizi*
Description: It is a deciduous tree with many horticultural varieties.
Site requirement: It is adaptive to temperate areas. It requires a well-drained deep soil with high humus content at pH 6-7.8.
Uses: High-value fruit tree commonly planted in the Yunnan uplands.
Propagation: Cleft grafting.

12. **Scientific name:** *Ficus tikoua*
Local name: *dishiliu*
Description: Stolon vine
Site requirement: It is adaptive to a wide range of elevation and soil conditions. It is drought tolerant.
Uses: Land cover for soil erosion control and bank stabilisation. Fruit is edible.
Propagation: Cutting and marcottage (air layering) in the rainy season.

13. **Scientific name:** *Flemingia macrophylla*
Local name: *yang wei dou*
Description: *Flemingia* is a shrub, attaining 2-3m in height. It has a deep root system and produces dense foliage.
Site requirement: *Flemingia* is moderately drought-tolerant and requires about 1,000mm/yr rainfall and not longer than a six month dry season. It is adaptive to a wide range of soils and elevations. It thrives on acid or infertile soils and heavy clays. It can also survive water-logging and occasional flooding. It can be planted at elevations of 2,000m but has been found to do best at about 700m. It is somewhat fire-resistant.
Uses: Flemingia is primarily grown as a source of mulch. The leaves decompose slowly, helping to suppress weeds while improving soil conditions. It provides a long-term release of nutrients to the soil as a green manure and is also used in contour planting to control soil erosion. Young leaves can provide an alternative source of fodder during the dry season but digestibility and palatability are not high. It can also provide small amounts of fuelwood.
Propagation: Seeds can be pre-treated, either by soaking in water for two days, immersion in boiling water for three - 10 seconds, or immersion in hot water for one minute. *Flemingia* is usually directly sown into contours or hedgerows.
Management: Check seeds carefully for insect damage before planting. Do not intercrop with *kadios* because *Flemingia* is an alternative host for the podfly pest. Wood can be harvested by coppicing after two years.

14. **Scientific name:** *Glochidion arborescens*
Local name: *pangshu*
Description: It is small tree, usually attaining 5m-8m in height.
Site requirement: It is a pioneering tree, drought-and-infertile-tolerant. It is native in sunny areas at elevations of from 830 to 2,000masl.
Uses: Fuelwood, bark for tannin extract and seeds for oil extract.
Propagation: Sowing seeds.

15. **Scientific name:** *Melia azedarach*
Local name: *kulian*
Description: It is a deciduous tree, attaining 30m in height and one metre in DBH, fast growing.
Site requirement: *Melia* has no specific requirements for soil. It is drought and water-logging tolerant, and can grow very fast even in infertile soil. It can be planted both in the uplands and lowlands, even in an air-polluted environment.

Uses: It provides popular timber for furniture, tools, and housing. No termite attacks. The root skin is a very useful medicine.

Propagation: Seeds can be harvested in November and December. Seeds should be pre-treated by soaking in water for two or three days. Seed sprouts in the nursery usually take 40 to 50 days.

Management: Usually no insect damage. Some crops can still be planted under the canopy since there is little shadowing.

16. **Scientific name:** *Musella laciocarpa*

Local name: *dibajiao* (ground banana)

Description: Ground banana is perennial with a short stem about 0.6m in height.

Site requirement: It is a native species from central and western Yunnan province. It is planted at elevations of from 1,000m to 2,000m. It requires sunny uplands.

Uses: It is a popular forage plant for pigs. Young leaves/shoots are edible in some places of Yunnan. It is also suitable for bank stabilisation and soil erosion control.

Propagation: Sucker separation.

17. **Scientific name:** *Phyllanthus emblica*

Local name: *ganlanguo*

Description: Shrub, 3m in height.

Site requirement: It is native from sea level, 300m to 2,250m in sub-tropical and tropical uplands. It likes the sun and is a drought-and-infertility-tolerant species.

Uses: Seeds can be used for oil extract. Fruits are rich in vitamin C and edible. Bark and leaves are used for tannin extract as well as for medicinal use.

Propagation: Seeds are collected from healthy mother trees with bigger fruits and soaked in warm water for 48 hours before sowing.

18. **Scientific name:** *Pueraria lobata*

Local name: *matenghu*

Description: *Pueraria* is a legume vine with expanded roots, widely distributed on grass and scrub lands.

Site requirement: It is a drought-and-infertility-tolerant species.

Uses: It can be used for fibre and paper-making. The roots are an important starch source for the local people and commercial drinks are also made from the plant. The plants as a whole can be used for medicinal purposes.

Propagation: It can be reproduced by root cuttings and seeds.

19. **Scientific name:** *Punica granatum*

Local name: *shiliu*

Description: It is deciduous fruit tree, but evergreen in the tropics.

Site requirement: It can grow at elevations of 2,500m. It is also drought-tolerant compared to other fruit trees. It requires sandy soil with a pH range of 4.5-8.2.

Uses: High-value fruit tree, often planted in the home garden and uplands.

Propagation: Cutting and young stem separation. The process of direct sowing is also used sometimes.

20. **Scientific name:** *Schima wallichii*

Local name: *maomaoshu*

Description: *Schima* is an evergreen sun-like tree. It is native at elevations of from 100m to 1,600m, the highest being 2,600m in northwest Yunnan. It can be planted with pine trees. It easily sprouts after repeated cutting.

Site requirement: *Schima* is a very important pioneering species recommended for reforestation in degraded uplands. It is drought-tolerant and requires acid red soil and a warm sub-tropical climate (more than -5°C).
Uses: It can be used for timber and fuelwood. *Schima* trees form a natural green belt and are fire-protective.
Propagation: Seeds can be collected from 20 year to 50 year old middle-aged mother trees in January and February. Dry seeds should be sowed within 50 days. Careful preparation of the nursery and shallow soil cover are very important for seed sprouting.

21. **Scientific name:** *Toona ciliata*
Local name: *hongchun*
Description: *Toona* is a semi-evergreen or deciduous tree.
Site requirement: *Toona* is usually planted in the valley or at low elevations.
Uses: *Toona* is a very popular tree for timber. The timber is very good for housing, furniture, and indoor uses.
Propagation: Seeds can be sown in well-prepared seed beds.

22. **Scientific name:** *Toona sinensis*
Local name: *Xiangchun*
Description: It is a deciduous tree called 'Chinese mahogany'.
Site requirement:
Uses: The timber is excellent for furniture and boats, also for housing, bridges, and agricultural tools. The young tips are edible. They are fragrant and a popular vegetable. The skin can be used for fibre.
Propagation: Seeds can be harvested in October and sown early next year. Roots can also be buried for propagation.
Management: Young seedlings should be planted in well-drained lands.

23. **Scientific name:** *Trachycarpus fortunei*
Local name: *zongbaoshu*
Description: Palm, an evergreen tree.
Site requirement: It is commonly planted south of the Yangtze River.
Uses: The sheath-fibre is widely used for ropes, boat cable, carpets, bedpads, raincoats, and brush. The palm is also ornamental. The timber can be used for handicrafts. The young female B is used as an edible vegetable in Baoshan and Yunnan province. The sheath-fibre is used as grain store cover for protection from rodents.
Propagation: The young seedling is shade-tolerant, therefore seeds can be sown in forest ground. The young seedlings grow very slowly. When seedlings have 5-8 leaves after four or five years, they can be transplanted in the fields.

24. **Scientific name:** *Trema orientalis*
Local name: *duiminshu*
Description: The *Trema* is a shrub or tree, attaining 2-10m in height, distributed from 1,000m to 3,800masl.
Site requirement: It is a pioneering tree for degraded uplands and requires sunny areas. It is drought-and-infertility-tolerant.
Uses: It is a fast-growing species and useful for fuelwood. The bark is used for medicine and pulpwood, the leaves as food for animals.
Propagation: Seeds.

25. **Scientific name:** *Vitex negundo*
Local name: *latagun*
Description: It is a shrub, 1-3m in height.
Site requirement: It is native at elevations of from 100 to 2,200masl. It is adaptive to a range of soil conditions from drought uplands and water-logged streams.
Uses: It is a very important source of fuelwood. It is used also for bank stabilisation and soil erosion control. A long period of flowering provides a good source for honey bees. The leaves are used as medicine for wounds.
Propagation: Cutting and direct sowing.

26. **Scientific name:** *Zanthoxyllum bungeanum*
Local name: *huajiao*
Description: The Chinese pepper berry is a small thorny tree.
Site requirement: It is widely tolerant to a range of elevation and soil conditions, but it grows better on deep fertile soil. It is commonly planted in the uplands and in home gardens.
Uses: It is a very popular spice in southwest China with high market value.
Propagation: Seeds should be pre-treated and soaked in warm soapy water to remove wax.

Chapter 10

A Study on Species' Screening and Techniques for Afforestation in the Hot and Dry Valley of the Jinsha River

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Abstract

The hot and dry valley of the Jinsha River in southwest China is one of the most difficult regions for regeneration of vegetation. In the past, many attempts at afforestation ended in failure due to aridity and soil sterility. From 1980, extensive and intensive studies on species' screening, appropriate techniques for afforestation, and investigation of benefits have been conducted.

The results show that *Leucaena leucocephala, Eucalyptus camaldulensis, Acacia confusa, Acacia auriculaeformis,* and *Robinia pseudoacacia* are the most promising species for afforestation in the hot and dry valley of the Jinsha River. In accordance with the principle of specific species for specific habitats, the screened species should be characterised by fast growth and high generating capabilities. The soil layer should be no less than 60cm. Appropriate techniques for afforestation include: nutrient packages for growing seedlings, preparation of large holes or horizontal furrows, planting in rainy season, and other appropriate management measures. Management and modification techniques for current artificial forests are also discussed in this paper. These forests can provide fuelwood, fodder, green fertilisers, and timber as well as play an important role in water and soil conservation. The research programme has solved many technique problems which were prevalent in the hot and dry valley for a long time. It has filled gaps in the field of afforestation in the Jinsha River and enriched the knowledge of silviculture.

Key words: Afforestation species' screening; planting techniques; the hot and dry valley; the Jinsha River

Introduction

The hot and dry valley of the Jinsha River in the upper reaches of the Yangtze River is an arid centre of southwest China. It harbours one of the most fragile ecosystems in China and is classified as an important region in terms of water and soil conservation. It covers 40,000sq.km. of which wasteland accounts for 60 per cent of the total area. In recent years, under the pressures of rapid population growth and agricultural development, the hot and dry valley environment has become degraded. The main indicators of degradation include heavy water and soil erosion, increased aridity, soil sterility, and desertification. It is reported that soil erosion in the area is 4,624.8 tonnes/km ^{2}/ year^{-1} and total soil erosion in the Jinsha River is over 18 million tonnes/year^{-1}. Therefore, it is essential to establish multipurpose and high economic benefit forests in order to improve the environment and accelerate the socioeconomic development of this region.

In the past, several attempts at afforestation ended in failure as a result of the harsh environment. Before 1980, the dry valley of the Jinsha River was considered to be a 'forbidden zone' for afforestation by the local people. The main reasons for this are described below.

a. Trees did not grow well because of the hot and dry climate. Evaporation in this region exceeded rainfall by several degrees. Water shortage was one of the primary constraints to vegetation development and, thus, the main vegetation types were scrub and savanna.

b. In the dry season, plants remained dormant and their growth was restrained by aridity and high temperature. They had low biomass and productivity.
c. There was little leaf litter on the soil surface. The litter decayed rapidly due to the relatively high soil temperature. The humus layer developed poorly and had weak water and soil conserving capacities.
d. Most of the waterland belonged to steep slopeland. In a fragile ecosystem of this nature, soil loss and degradation by agriculture and livestock proved to be serious constraints to forestry development.

Thus, an extensive research programme –"A Study on Species' Screening and Techniques for Afforestation in the Hot and dry Valley of the Jinsha River" – was initiated with the support of the Sichuan Science and Technology Committee for the purposes of species' screening; formulating appropriate techniques for afforestation; and management and modification of low-benefit forests into high- benefit forests. As a result, successful techniques for afforestation in the hot and dry valley have been developed.

Site Description

Site location

The site is located at Hulukou, Huatan township, Ningnan county of Sichuan province, just near the Jinsha River, in the upper reaches of the Yangtze River. The site is situated at 102°54' E and 26°54'15" N. The elevation ranges from 710 to 820 masl.

Climate

Geographically, the site lies in the subtropical monsoon climate region. Because the landform is dominated by high mountains and deeply dissected gorges, the foehn effect is very apparent. The site is characterised by a typical hot and dry valley climate. The annual mean temperature is 22.2°C, with a maximum temperature of 42°C in July and a minimum temperature of 4°C in January. The monthly mean relative humidity is 57 per cent. The annual sunshine duration is 2,257.7 hours. The annual mean precipitation is 740mm and the minimum mean rainfall is 569.7mm. The rainy season lasts from May to October, during which the rainfall accounts for 90 per cent of the total annual precipitation. The annual evaporation is 2,168.8mm, 3.5 times as much as the precipitation. In the dry season, the land surface maximum temperature can reach 75°C and the maximum wind speed reaches 20m/s. In summer, the site is referred to as the 'Flame Mountain' because of the high land soil temperature and exposed dry red soil.

Soil

The soil of this hot and dry valley is comprised mainly of dry red soil which is formed from calcareous rock and dolomite rock. The physical and chemical characteristics of the soil of the site are listed in Table 1.

Table 1: The Physical and Chemical Properties of the Soil at the Experimentation Site

Types of soil	Texture	pH	Organic matter %	Total nitrogen N%	Total phosphorus	Total potassium K_2O%	Quick-acting phosphorus ppm	Quick-acting potassium ppm	Alkalisation nitrogen ppm
thin (<30 cm)	light soil	7.35	1.24	0.167	0.427	2.67	15	187	103
medium (30-90cm)	heavy soil	7.60	0.87	0.094	0.085	1.89	11	240	88
thick (>90cm)	sandy soil	7.25	1.01	0.074	0.057	1.58	32	51	50

Vegetation

The current vegetation is of secondary origin, consisting of scrubs and savanna. The main species found here are *Heteropogon contortus, Eulaliopsis binata, Cymbopogon distans, Phyllanthus emblica, Jatropha curcas,* and *Dodonaea viscosa*, etc.

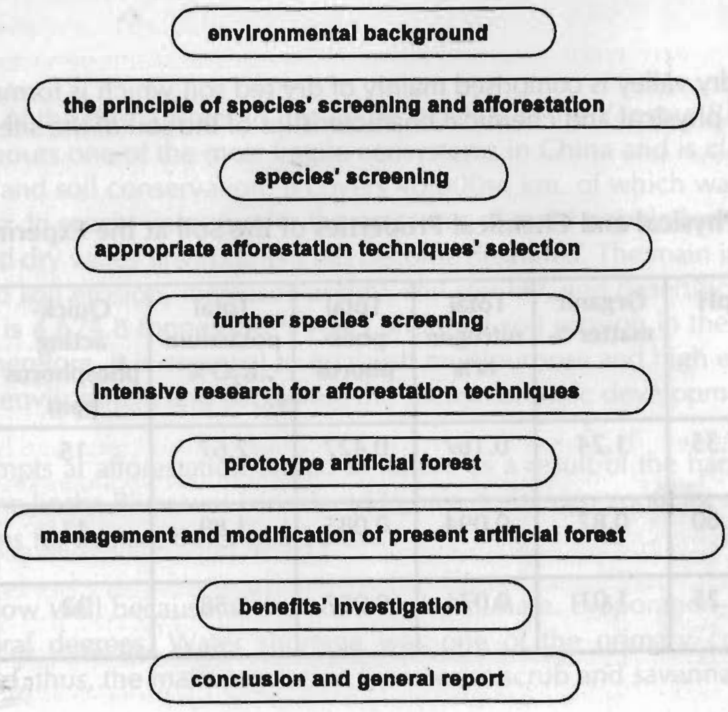
Method

The principles for species' screening and afforestation were:

a. ecological principle
b. diversity principle
c. combination of trees, shrubs, and grasses
d. specific species for a specific habitat
e. species for afforestation in the hot and dry valley should have the following properties :
 * fast growing
 * fast-sprouting and high-generating capacity
 * high biomass and productivity
 * drought resistance
 * deep root system
 * low wilting co-efficient
 * high survival and preserved percentage
 * water and soil conserving capacities.

Technique Route

Before 1980, afforestation in this area usually ended in failure because of the lack of suitable species and inappropriate planting techniques. Keeping these mistakes in mind, the research programme undertook the following steps: First, about 40 species were put through experimentation. A few species which had adapted to the local habitat were screened. A set of techniques for afforestation were also developed. Second, these adaptable species were further tested and appropriate techniques were selected for afforestation for each year. Finally, the successful methods and plant prototypes were demonstrated and their use encouraged. In conclusion, the research achievements were demonstrated.



Data Analysis

Using the analysis of variance (ANOVA) method, it was determined whether there were significant differences in treatment and tests on the data distribution or whether they were in accordance with normal distribution.

Results

Screening of Suitable Species for Afforestation in the Hot and Dry Valley

The suitability or unsuitability of the species for the local environment is the key factor in determining success or failure of afforestation. Only the species whose physiological and ecological properties adapt to the climate and the soil of the hot dry valley can survive. Therefore a variety of species was tested to screen the suitable afforestation species. In 1980, nutrient package seedlings, naked root seedlings, and seeds of 18 species, including *Leucaena leucocephala* and *Eucalptus camaldulensis,* were planted on the experimental site. In the following year, a series of experiments on artificial forests, consisting of 27 species, including *Leucaena leucocephala, Eucalyptus camaldulensis,* seven other species of *Eucalyptus*, and others, were carried out. Trials with over 40 species were undertaken (see Annex to Chapter 9) and 17 species were found to be among the most suitable.

Seedlings of these screened species were planted with nutrient packages in 1984. The seedlings were raised in October/November 1983, except for seedlings of *Leucaena leucocephala* which were raised in March 1984. All the seedlings were planted in horizontal strip furrows. After afforestation, the height increment, survival percentage, and preserved percentage were investigated once a year and the data were analysed. The status of growth is shown in Table 2.

The species selected for afforestation in the hot and dry valley should manifest a high survival rate and high growth increment. To some extent, the survival rate represents the adaptability of the species to a harsh environment. It is the basis of species' screening. However, if the species have a high survival rate but low growth increment, it is difficult for timber forests to form. Only when the forests have been established can the stands have a good effect on water and soil conservation and good economic benefits. According to the comprehensive standards of a high survival rate and growth increment, *Leucaena leucocephala, Eucalyptus camaldulensis,* and *Acacia auriculaeformis* are the most promising species for afforestation in the hot dry valley; they have fast sprouting and high-generating capacities. Dense seedlings have been found in the *Leucaena leucocephala* forest. *Acacia confusa, Robinia pseudoacacia,* and *Casuarina equisetifolia* are bitter. They are drought resistant, sterility tolerant, and fast growing species. Although *Casuarina equisetifolia* has relatively low survival rates and growth increments on sloping wastelands, it grows very well along the river bank of the Jinsha River and has positive wind-breaking and sand-fixing effects.Consequently, the cultivated land and highway along the river bank have been well protected. Thus, it is a suitable species for river bank afforestation.

Cajanus cajan, Tephrosia candida, and *Albizia julibrissin* are nitrogen-fixing leguminous species. They have relatively high growth increment, survival, and preserved rates making them suitable species for afforestation. *Cajanus cajan* helps in improve soil fertility and is a host of the lac insect. It has good ecological and economic benefits. However, its average lifespan of about four years is short. *Tephrosia candida* can last for eight years. *Albizia julibrissin* grows fast in the the early stages but, after four to five years, the growth rate decreases rapidly.Furthermore, its sprouts and young branches are easily destroyed by the hot and dry foehn winds, resulting in low biomass productivity. These three leguminous species are good pioneer species. *Eriolaena malvacea* has a high survival rate and it is also an adaptable species. But it grows slowly and has a low increment, especially in the Jinsha River Valley. The foehn here is very conspicuous in the dry season and the newly generating branches are susceptible to drought and experience difficulty in resisting the dry season. Thus, this species is not suitable for afforestation at low elevations and in heavy foehn regions. *Cupressus decloxiana* is a potential species for afforestation by virtue of its ecological and physiological properties. However, the experiments showed that its survival and preserved rates were low because this

Table 2 : The Status of Growth of Preserved Species

Species	mean increment (cm/year)	diameter (cm)	survival percentage (%)	preserved percentage (%)	biomass production	adaptability to climate	lifespan	comprehensive characteristic
Leucaena leucocephala	184.8	1.84*	high	94.5%	high	very good	long	best
Eucalyptus camaldulensis	155	1.60	high	92.5%	high	very good	long	best
Trema augustifolia	127	1.142*	low	13.2%	low	not good	short	not good
Cajanus cajan	94	/	high	90.2%	medium	good	short	good
Albizia julibrissin	87.5	0.95	high	90.2%	low	not good	short	good
Casuarina equiselifolia	67.4	0.809	medium	32.0%	high	good	long	better
Tephrosia candida	67.2	0.687	high	79.4%	high	good	short	good
Acacia auriculaeformis	57.8	1.024	high	86.1%	high	very good	long	best
Robinia pseudoacacia	52.7	0.873	high	73.5%	high	good	long	better
Acacia confusa	49.8	0.951	high	82.7%	high	very good	long	better
Eriolaena malvacea	33.3	0.703	medium	72.2%	medium	good	short	good
Dodonea viscosa	28	/0.541	high	83.5%	low	very good	long	good
Platycladus orientalis	25.3	0.453	medium	75.0%	low	not good	long	not good
Cupressus duclouxiana	25.2	/	low	19.4%	low	not good	long	not good
Jatropha curcas	25	0.42	medium	43.5%	medium	good	long	good
Melia azedarach	24.5	/	medium	62.5%	low	not good	short	not good
Cassia siamae	5		medium	81.8%	low	not good	short	not good

* diameter at ground level

species is susceptible to damage by white ants. It was reported that about 60 per cent of the loss was caused by white ants. With regard to growth increment, it displayed an annual increment of 25cm only. Due to the above reasons, this species is not suitable for afforestation, especially in the harsh environment of the hot dry valley.

Platycladus orientalis has a higher survival rate than *Cupressus ducloxiana*. However, it grows better in more fertile environments as its physiological metabolism needs are better met. It is inclined to form low effect forests in hot, dry, and shallow soil environments making it an unsuitable species for afforestation.

Jatropha curcas and *Dodenea viscosa* are indigenous species of the hot dry valley. *Dodenea viscosa* is suitable for afforestation in the hot and dry valley environment but it lacks economic benefits. It can be selected as the first species to afforest in the wasteland where it is not easy to regenerate vegetation. *Jatropha curcas* is a kind of oil-bearing plant. It grows well in sandy soils as well as in more humid habitats. Elsewhere it has low survival rates. *Trema angustifolia* has a high height increment, but its survival rate is too low for the dry season. The growth rates of *Melia azedarach* and *Cassia siamea* are slow and they cannot adapt to the harsh environment of the hot dry valley.

A large part of the wasteland of the hot dry valley has low fertility. At present, it would be difficult to achieve success if arbors were selected for afforestation. But it is feasible to select a few adaptable shrubs of the leguminous species. Leguminous shrubs can fix nitrogen, increase soil fertility, and play an effective role in barricading water and soil erosion. They can also provide fuelwood for local farmers. On the experimental site, a few leguminous shrubs, such as *Tephrosia candida* and *Cajanus cajan,* were mixed in the forest and the results show that the roots of leguminous shrubs developed quickly and had high biomass, making them ideal species for afforestation.

Wilting Coefficient

In the Jinsha River Valley, the annual evaporation is three times more than the annual precipitation. The dry season lasts for over six months and, from March to June, the soil temperature is quite high. The soil moisture evaporates quickly. The soil moisture and the minimum moisture that the screened species can bear are key factors in determining whether afforestation is successful or not. The wilting coefficient is the level of soil moisture at which water becomes unavailable to plants and permanent wilting ensues. In order to reach scientific conclusions, not only on species' screening but also on the adaptability to water factor, and estimate the prospects of the afforestation species, soil moisture in the dry season and the wilting coefficient of the afforestation species were obtained in 1986. The minimum water contents of different soil types are shown in Table 3.

The results show that the water contents vary in soil types, but the water contents of the same soil type at different slope levels are not significantly different. The wilting coefficients of 14 species are shown in Table 4. It is obvious that the wilting coefficients vary from 1.593 to 1.897 in sandy soil to from 4.403 to 5.207 in dry red soil. The minimum water contents of the soil in the dry season are 1.941 in sandy soil and 5.272 in dry red soil. All these are higher than the wilting coefficients of the 14 species. Therefore, as far as water content is concerned, the needs of the above mentioned species can be met. The experiment also shows that screened species such as *Leucaena leucocephala, Eucalyptus camaldulensis, Acacia auriculaeformis,* etc are suitable for afforestation in the hot dry valley (see Table 4).

In the hot dry valley of the Jinsha River, the problems facing afforestation are not caused mainly by water conditions but by the over sterile soil. As already discussed, the minimum water content in the dry season is much higher than the wilting coefficients of the majority of species. For afforestation in the hot dry valley, the natural quality of the soil is the most important factor, given the fact that only when the soil has a certain humus layer can it support regeneration of vegetation.

Table 3. The Minimum Water Contents of Different Soil Types in the Dry Season

Number of soil profile	Slope	Soil type	Layer of soil profile	Monthly minimum water content							
				Date	Water content	Date	Water content	Date	Water content	Date	Water content
I	18.4	sandy soil	0	30/3	0.799	30/4	0.925	30/5	0.858	10/6	9.881
			30		1.941	10/4	2.725		2.875		5.436
			50		3.174		3.102		3.197		6.017
			70		4.077	20/4	2.834		4.160		8.267
II	17.8	dry red soil	0	20/3	0.671		0.908	30/5	0.986	10/6	9.596
			30	30/3	5.272		6.494		6.316		7.803
			50		6.781		7.232		7.707		8.116
			70		7.283		7.072		7.857		8.814
III	15	dry red soil	0	20/3	1.000	10/4	1.054	30/5	0.809	10/6	9.728
			30		6.516		7.567		7.077		7.843
			50		7.465		7.612		8.049		7.180
			70		6.357		8.462		8.879		8.123

Table 4: The Wilting Coefficient of Different Afforestation Species

Species	Mean Wilting Coefficient (WC) in Different Soil Types			
	Soil Type	Wilting coefficient	Soil Type	Wilting coefficient
Eucalyptus camaldulensis	Sandy Soil	1.873	Dry Red Soil	5.073
Zisyphus jujuba		1.815		5.185
Robinia pseudoacacia		1.864		5.207
Tephrosia candida		1.897		4.438
Leucaena leucocephala		1.629		4.455
Acacia confusa		1.680		5.151
Acacia auriculaeformis		1.695		4.590
Casuarina equisolifolia		1.844		4.458
Melia azedarach		1.759		4.879
Albizia julibrissin		1.736		4.778
Trema angustifollia		1.523		4.575
Cupressus duclouxiana		1.880		4.678
Cassia siamae		1.612		4.403
Eriolaena malvacea		1.593		5.100

Afforestation Techniques

Whether the afforestation techniques are correct or not also plays an important role in the success of afforestation. In the past, in addition to species' screening, inappropriate techniques for afforestation were also instrumental for failure. Consequently, a set of techniques were tested to establish the appropriate ones.

The Effects of Different Seedlings on Afforestation

The results of the tests showed that seedlings in nutrient packages have higher growth increments and survival rates than naked seedlings. Experiments with the naked roots of *Eucalyptus camaldulensis* showed that its survival rates decreased as follow: leave-pruned naked root seedlings > stem-cut naked root seedlings > non-treatment naked root seedlings.

The Effect of Different Methods of Soil Preparation on Afforestation

The tests proved beyond any doubt that the large hole (60*60*50cm) method is the best method of soil preparation for afforestation and the horizontal furrow (150*60*50cm) is better than the small hole method (30*30*30cm).

The Effect of Different Soil Types on Growth Increment

Leucaena leucocephala and *Eucalyptus camaldulensis* are two of the most promising species. In accordance with the principle of specific species for specific habitats, the effects of soil thickness and soil type on growth have been studied.

The results showed that a soil layer of less than 60cm is not suitable for afforestation. In the hot dry valley of the Jinsha River, especially at the Hulukou site, the soil layer (less than 60cm) tended to crack and gaps were also formed by soil tension in the dry season. The fine absorbed roots are prone to being broken into pieces and mostly die. The survival of the planted trees under physiological water shortage conditions caused by injured roots in the dry season is difficult. *Eucalyptus camalduensis* was found to be suitable for growing in sandy rather than in dry red soil. But difference in soil types had no significant effect on the diameter growth of *Eucalyptus camaldulensis*. The thickness of the soil also plays an important role in the height growth and diameter of the *Leucaena leucocephala* and *Eucalyptus camaldulensis*.

In general, in the hot dry valley, afforestation seedlings must be nutrient package ones. Although it is less expensive to use naked root seedlings for afforestation, rainfall in the hot dry valley is not significant and the rainy season is short, thereby necessitating nutrient packages. Even if the weather is suitable for afforestation, continuous drought days may follow after afforestation, rendering the attempt futile. Moreover, the naked root is susceptible to injury and loss of water during transportation. The naked root is difficult to restore to activity in a short time. So the root and height cannot increase considerably in the rainy season. In the following half year of dry climate, survival is uncertain. Nutrient package seedlings, on the other hand, overcome the above shortcomings. Therefore, for afforestation in low elevation regions, nutrient package seedlings are the most effective.

The quality of soil preparation is also very important. As far as soil preparation is concerned, large holes and horizontal furrows are better than small holes for seedling growth. The main reason for this is that the hot dry valley of the Jinsha River consists mostly of dry red soil. This kind of soil is characterised by sticky, heavy soil which is shallow and rich in gravel. In addition to the rare vegetation, water seepage and soil erosion are heavy. The subsoil is exposed. Using large hole or horizontal furrow methods of soil preparation would help accelerate the soil forming process. After soil preparation, a great deal of surface soil is filled back into the hole. Loose soil is favourable for root development and can block surface runoff. Simultaneously, weeds are also effectively controlled. The large hole method has proved to be the most economical and conducive to growth increment among all the soil preparation methods.

The soil layer thickness is one of the primary constraints to growth increment, and different kinds of soil types have varying effects on growth increment. In general, soil less than 60cm is not suitable for afforestation in the hot dry valley of the Jinsha River.

Management and Modification of Present Artificial Forests

Effects of Different Intensities of Thinning and Cutting on Growth

Thinning and cutting are favourable to plant growth because they can regulate light, heat, water, and nutrient allocation and improve the environment. Thinning and cutting must begin when obvious individual growth differentiation appears in the plant growth. The *Leucaena leucocephala* forest should be selectively cut five years after afforestation because the primary density (2,500-10,000 seedlings per hectare) begins to restrict plant growth. But on the middle or upper slopes, thinning may be delayed for six to seven years as there is relatively low growth due to shallow soil and sterility.

The intensity of thinning has a positive effect on *Leucaena leucocephala* growth but no significant effect on *Eucalyptus camaldulensis.* When the cutting intensity is above 50 per cent; the remaining *Leucaena leucocephala* grow fast and, when cutting intensity reaches 70 per cent, the individual growth rate is maximum. With regard to *Eucalyptus camaldulensis,* only when cutting intensity reaches 60 per cent is the diameter at breast height accelerated. However, no significant differences in the growth of cut and non-cut forests were noted.

With respect to biomass accumulation, a seven-year old *Leucaena leucocephala* forest is maximum when cutting intensity is 50 per cent. Whereas *Eucalyptus camaldulensis* is not sensitive to cutting intensity. Thinning and cutting helps the pure *leucaena leucocephala* to develop a high sprouting ability and generating capacity. The seedlings can cover forest land in a relatively short time, thereby enhancing water and soil conservation.

Management and Modification of Low Effective Forest

Mixing leguminous species with *Eucalyptus camadulensis* and regulating the nutrient area by using the selective cutting method have proved to be effective ways of managing low effect forests. Fertiliser application is not economical and has no significant effect on the modification of low effect forests. In general, for modification, pure *Eucalyptus camaldulensis* forests in the wetlands and their low effect forests should be mixed with leguminous species to increase soil fertility as the low effectiveness of *Eucalytus camaldulensis* is caused by malnutrition.

Leucaena leucocephala Forest - The low effectiveness of *Leucaena leucocephala* is caused by extensive afforestation, mismanagement, goat grazing, and insect problems. The first kind of *Leucaena leucocephala* low effect forest has no active growth point. This is caused just after cultivation because of extensive afforestation. Weeding and compost fertiliser application are the best ways of modification. Intercropping with crops is another effective way, but this method can only be applied in regions rich in manpower and on flat lands.

Another kind of *Leucaena leucocephala* low effect forest (over three years old) has no apical dominance and has a number of sprouting branches as a result of goat grazing and pests. The best ways of modification in this case are stem-cutting and fertiliser application.

The Benefits of Afforestation

Water Conservation

The experiments (see Table 5) show that the water runoff in the rainy season of a nine-year old *Leucaena leucocephala* forest is 1,017.04 cubic metres per hectare less than wasteland - accounting for US$ 0.063/m^3.

Table 5: The Water and Soil Loss of *Leucaena leucocephala* Forest and Wasteland Water runoff (m^2), soil loss (ton) runoff site area: 80 m^2

Time	annual rainfall	rainfall in rainy season	water and soil loss in $80m^3$				water and soil loss in one hectare			
			Forest land		Wasteland		Forest land		Wasteland	
			water	soil	water	soil	water	soil	water	soil
1990	793	611.4	1.9484	0.0066	9.9662	0.2646	243.08	0.83	1245.8	33.08
1991	952	884.8	2.7718	0.0049	11.1185	0.2993	346.49	0.61	1389.9	37.41
1993	893	815.9	2.0445	0.0005	10.0874	0.2726	255.58	0.06	1261	34.07
mean	880	769.9	2.2549	0.004	10.3907	0.2788	281.87	0.5	1298.9	34.85

Soil and Nutrient Conservation

A nine-year old *Leucaena leucocephala* forest can conserve soil 34.35 ton/year.ha, accounting for US$ 47.75 depending on the costs of local manpower and fertilisers (see Table 5).

Increasing Fertility

Table 6 shows that a nine-year old *Tephrosia candida* pure forest can account for US$4002.39/ha, mean annual US$444.71/ha/year. It is the most promising forest for increasing soil fertility. The abilities for increasing soil fertility of different forests are: *Tephrosia candida* pure forest > *Eucalpytus camaldulensis* and *T. candida* mixed forest > *Leucaena leucocephala* forest > *E. camaldulensis* and *L. leucocephala* mixed forest > *Acacia confusa* forest > *A. auriculaeformis* forest > *E. camaldulensis* forest (see Table 6).

Economic Benefits

Timber - 12-year old *Eucalyptus camaldulensis* forests can produce timber at the rate of $72.98m^2$/ha/year. The price of this timber is US$ $13.75m^3$ mean annual value, accounting for US$ 83.62/ha/year. Nine-year old *Leucaena leucocephala* forests can produce $40.1m^3$/ha. year, with a mean annual value accounting for US$61.26/ha/year. Ten-year old *Leucaena leucocephala* and *Eucalyptus camaldulensis* mixed forests can produce 73. $41m^3$/ha/year, accounting for US$ 100.93/ha/year.

Fuelwood - 12-year old *Eucalyptus camaldulensis* forest can produce by-product fuelwood at the rate of $21.45*10^3$kg/ha depending on the local price of US$0.02/kg, accounting for US$35.75/ha/year. Nine-year old *Leucaena leucocephala* forest can produce fuelwood at the rate of $36.76*10^3$kg/ha, depending on the price of US$0.018/kg, accounting for US$ 73.5/ha/year.

Fodder - A nine-year old *Leucaena leucocephala* forest can produce $5.53*10^3$kg of leaves, accounting for US$73.73/ha/year, depending on the price of green fodder at US$0.12/kg. The *Leucaena leucocephala* and *Eucalyptus camaldulensis* mixed forests can produce US$ 31.88/ha/year.

Green Fertiliser

The leaves of a nine-year old *Leucaena leucocephala* forest can produce green fertilisers at the rate of $5.53*10^3$, the price is US$ 0.04/kg, accounting for US$ 221.76, the mean annual is return is US$ 24.6ha/year. A 12-year old *Eucalyptus camaldulensis* forest can produce $6.13*10^3$kg of leaves, accounting for US$ 245.2, amounting to US$20.43/ha/year. *Leucaena leucocephala* and *Eucalyptus camaldulensis* mixed forests can produce $2.31*10^3$kg and $4.48*10^3$kg of leaves respectively, accounting for US$271.6 mean annual US$ 27.2/ha/year.

Table 6: Increasing Fertility Effect of Different Stands

Type of Stand	organic matter %	total N %	total P %	quick-K mg/10g soil	fertiliser of 0-40cm soil OM* US$	NUS$	PUS$	KUS$	Total value US$/ha	increment US$/ha	mean annual US$/ha/yr
1 Eucalyptus camaldulensis	0.43	0.11	0.0021	1.51	569.81	2108.4	13.9	12	2704.1	147.84	12.3
2 Leucaena leucocephala	1.08	0.29	0.0034	1.94	1431.1	4419	22.5	15.4	5888	3331.8	370
3 Acacia confusa	0.79	0.16	0.0023	1.59	1046.8	2438.1	15.2	12.6	3512.7	956.44	95.6
4 Tephrosia candida	1.13	0.33	0.0021	2.36	1497.3	5028.7	13.9	18.8	6558.7	4002.4	445
5 Acacia auriculaeformis	0.71	0.15	0.002	1.47	940.8	2285.8	13.3	11.7	3251.5	695.23	69.5
6 Mixed forest of 1 & 2	1.01	0.24	0.0037	1.26	1138.3	3657.1	24.5	10	5030	2473.7	225
7 Mixed forest of 1 & 4	1.05	0.3	0.0027	2.22	1391.3	4571.5	17.9	17.7	5998.4	3442.1	382
8 Control	0.42	0.13	0.0017	0.94	556.53	1981	11.3	7.47	2256.3	0	/

* OM: Organic matter

* The price of different fertiliser: organic matter US$ 0.0125/kg: Nitrogen US$ 0.144/kg; phosphorus US$ 0.0625/kg; Potassium US$ 0.075/kg.

Climate and Social Benefits

Hulukou was referred to as the 'Flame mountain' and the 'Forbidden region' for afforestation by local people. Before afforestation, the mean annual temperature was 22.2°C, relative humidity was 57 per cent, and evaporation was 2618.8mm and 3.5 times that of rainfall. After afforestation, the climate has changed and improved. According to four years' meterological data from 1982-85, the mean annual temperature dropped to 21.7°C. From 1990 to 1993, the mean annual temperature dropped to 20.95°C, evaporation decreased to 1,604.73mm, and relative humidity was 70 per cent. Also, the response of the local farmers was favourable. In the past, mountain floods in the rainy season destroyed the crops. Afforestation has greatly reduced the occurrance of floods. The weather is no longer hot and arid. The forests have barricaded the wind and sand and the animal and bird populations have increased.

Conclusion

The hot and dry valley of the Jinsha River has rich heat and wasteland resources. But the soil is very sterile and has a low carrying capacity. Rainfall distribution is low and the dry season lasts for over six months. The weather is hot and dry in the dry season. Therefore, species and afforestation techniques are essential. Once close forests are established, good ecological and economic benefits will accrue as a result of a rapid growth rate under favourable climatic conditions.

Regeneration of vegetation, water and soil conservation, and provision of fuelwood are the tasks at hand. Therefore, the screened species must adapt to the special habitats of the hot dry valley and be characterised by fast growth; high survival rates; high biomass and productivity; high generating capacities; and drought resistance.

Afforestation should be carried out in accordance with the principle of specific species for specific habitats. The afforestation seedlings should grow in nutrient packages. In addition, the depth of the soil should be over 60cm. Large holes and horizontal furrows are the suitable methods for soil preparation. Mixing with leguminous species or intercropping with crops are effective ways of promoting growth increment and increasing soil fertility.

The low effect forests must be cut periodically.The thinning and cutting intensity should be 70 per cent for five-year old *Leucaena leucocephala* forests and 50 per cent for seven-year old *Eucalyptus camaldulensis* forests. Mixed forests are suitable for accelerating growth. *Leucaena leucocephala* and *Eucalyptus camaldulensis* are the most promising species for water and soil conservation and for solving the fuelwood shortage problem in the hot dry valley. They provide green fertilisers, fodder, fuelwood, timber, and other ecological and economic benefits.

For afforestation in the hot dry valley of the Jinsha River, *Leucaena leucocephala* and *Eucalyptus camaldulensis* should be selected as planting species and mixed with other adaptable leguminous species. *Tephrosia candida* is the most suitable pioneer species as it helps to increase soil fertility. Forestry development in the hot dry valley must keep the above measures in mind in order to be sustainable.

Bibliography (not cited in the text)References

Zhang Rongzu, 1992. *The Dry Valleys of the Hengduan Mountains Regions*. Beijing: Science Press.

Zheng Haishui, 1991. 'Screening of Fuelwood Species in the Arid Area of Hailan Island'. In *Science and Technology of Forestry*. Guangdong: (Publishers not given)

Luo Ruying, 1983. *The Soil of Forests*. Beijing: Science Press

Zing Shuzhi, Jiang Deqi, 1981. *Introduction to Chinese Water and Soil Conservation.* Beijing: Agriculture Press.

Zhang Jiabin, 1982. *Forest Ecoeconomics.* Kunming: Yunnan People's Publishing Press.

Ying Chuntai, 1990. *The Proctive Forest System of the Mid-upper Reaches of the Yangtze River in China.* Chengdu: Sichuan Science and Technology Press.

Northeast China Forestry Science University, 1981. *Forest Ecology.* Beijing: Forestry Science Press of China.

Huang Zhijie, Wei Taichang, 1991. *A Study on Country Comprehensive Energy Construction.* Chengdu: Chengdu University of Science and Technology Press.

Annex 1 to Chapter 10

1. List of species used for screening in Hulukoku, Ningnan County.

*	1.	*Eriolaena malvacea*
*	2.	*Casuarina equisetifolia*
*	3.	*Dodonea viscosa*
*	4.	*Melia azedarach*
*	5.	*Toona sureni*
	6.	*Quercus variabilis*
	7.	*Quercus pannosa*
*	8.	*Eucalyptus camaldulensis*
	9.	*Eucalyptus badjensis*
	10.	*Eucalyptus bunii*
	11.	*Eucalyptus amplifolia*
	12.	*Eucalyptus uiminalis*
	13.	*Eucalyptus citriodora*
	14.	*Eucalyptus umbellata*
	15.	*Eucalyptus exerta*
*	16.	*Jatroppa curcas*
	17.	*Aleurites fordii*
	18.	*Aleurites moluccana*
	19.	*Ricinus communis*
*	20.	*Bombax malabaricum*
	21.	*Choerospondia axillaris*
*	22.	*Trema angustifolia*
*	23.	*Ficus lacor*
*	24.	*Cupressus duclouxiana*
*	25.	*Platycladus orientalis*
	26.	*Ziziphus jujuba*
	27.	*Schima wallichii*
	28.	*Grevillea robusta*
*	29.	*Cajanus cajan*
*	30.	*Robinia pseudoacacia*
*	31.	*Leucaena leucocephala*
*	32.	*Acacia confusa*
*	33.	*Acacia auriculaeformis*
*	34.	*Albizia julibrissin*
*	35.	*Cassia siamea*
*	36.	*Tephrosia candida*
	37.	*Zenia insignis*
	38.	*Tamarindus indica*
	39.	*Prunus dehisens*
	40.	*Pinus kesiya*

N.B. "*" stands for the species still preserved.

Chapter 11

Rehabilitation of Degraded Lands in Mountain Ecosystems: A Technical Report of Plantation Establishment in Nepal

Lu Rongsen

Background

Situation of Degraded Mountain Lands

The world's future food supply is threatened because of the damage done by mankind to more than a tenth of the earth's fertile soil since 1945, an area the size of China and India combined. A report on the study 'World Resources 1992-93', released by the Washington D.C.-based World Resources' Institute, estimates that about 1.2 billion hectares of land (about 11 per cent of the earth's soil cover) have eroded in the last 45 years. A global assessment of soil degradation found two-thirds of all seriously eroded soils in Asia and Africa where most of the world's poor live. The vast majority of the damaged land is in Asia, with 45.3 million hectares, and in Africa, with 321 million hectares, where most of the world's poor subsistence farmers live.

According to Dr. Frank J. Dent, a soil scientist from the FAO, the unabated erosion of topsoil - the thin uppercrust of the earth's surface on which man plants his food crops - is most evident in the following countries of Asia.

Bangladesh - The total degraded land area is now 989,000 hectares, or 7.9 per cent of the country's total land area.

China - The average annual soil loss through erosion is estimated at five billion tonnes. Areas classified as degraded or "critical" are estimated to total 43 million hectares, or about 24 per cent of China's total land area.

Laos - The total degraded land area is estimated at 8.1 million hectares, or about 35 per cent of the country's land area.

Myanmar - The total eroded land area is approximately 210,000 hectares, or 3.2 per cent of Myanmar's total land area.

Pakistan - About 8.1 million hectares have been lost through wind erosion and another 7.4 million hectares through water erosion.

Sri Lanka - The total degraded land area is estimated at 0.7 million hectares, or 10.8 per cent of the country's total land area.

Thailand - Some 17.2 million hectares, or 33.7 per cent of the total land area, have been lost through water erosion.

The Philippines - Soil erosion has been identified as one of the most pressing ecological problems. About 60 per cent (8.25 million hectares) of the total agricultural land is severely eroded. In addition, 9.3 million hectares of hilly and mountainous land are highly susceptible to erosion.

Nepal is a country of hills and mountains which cover about 83 per cent of its total area. Only about 17 per cent constitutes the plains, also called the *terai* region. Some 240 million tonnes of soil are being lost annually. As a result, the bed levels of the *terai* rivers are rising by 15 to 30 centimetres every year. About

70 to 80 per cent of the slopes are cultivated to produce more food to feed the country's growing population. Farmers cultivate their steep lands on the hills without making terraces, thus increasing the slope length and accelerating soil erosion. Overgrazing is another cause of accelerating soil erosion. People keep a small number of unproductive cattle. They barely get one to two litres of milk from each cow. As they cannot feed the cows themselves they leave them in the forests for random grazing.

Degradation of mountain ecosystems is a global problem and the Himalayas constitute one of these threatened ecosystems. Environmental degradation in the Himalayan region is basically a result of human intervention in the use of various natural resources, namely, land, forests, pastures, water, and minerals. Land degradation has a serious impact on the economy and environment. On public land, the immediate impact is evident from the loss of forest cover, directly affecting fuelwood and fodder supplies, and also from changes in livestock output which influence household food and income levels. On private land, the impact is seen in terms of the lower output of different land-based products. The long-term effects on ecosystems are even greater, resulting in the irreversible loss of productive resources, options for survival, and habitable environments.

Approaches to the Rehabilitation of Degraded Mountain Lands

Rehabilitating degraded mountain land and making it more useful and productive is a big challenge. The different approaches to solving degraded land problems can be divided into three basic categories.

- Direct interventions on degraded lands, focussing on various types of land maintenance activities, changes in land use, and many other related, on-site activities affecting soil erosion and land productivity
- Indirect interventions such as those dealing with the development of suitable technology, reforms in land holding and tenurial structures, reducing population pressure, land-use planning, and policy-related incentives or disincentives for promoting positive land use
- Interventions outside degraded lands, focussing on off-farm employment, intensifying land use in other more suitable areas, and reducing off-site impacts

It is obvious that for on-site development direct interventions are important and will account for all the field work. This paper discusses the findings of two field-based case studies in Nepal.

The problems of degraded mountain land in different mountain ecosystems of the Hindu Kush-Himalayan Region are many and varied. Generally, there are four types of degraded land in this region.

- Bare sloping lands in temperate areas distributed throughout the trans-Himalayan mountains

  Basic characteristics: altitudes from 2,500-4,000m; cold and dry climate; precipitation from 300-600mm; scarce vegetation cover

- Bare sloping land in subtropical areas distributed throughout the middle Himalayan hills

  Basic characteristics: altitudes below 1,500m; warm and dry climate; precipitation from 800-1,500mm; scarce vegetation cover

- Degraded forest land in temperate areas distributed throughout the middle Himalayan hills

  Basic characteristics: altitudes from 1,500-2,500m; cool and wet climate; precipitation from 800-2,000mm; rich vegetation cover

- Degraded forest land in subtropical areas, distributed throughout the lower Himalayan hills

  Basic characteristics: altitudes below 1,500m; warm and dry climate (for six months in a year); precipitation from 800-1,500mm; rich or moderate vegetation

The methods are not the same for dealing with different types of degraded lands, but the principal measures can be summarised as follow:

- biological control measures which are primarily used and are sustainable and cheap,
- engineering control measures which are secondary, limited, and expensive, and
- agronomic control measures which are ordinary, limited, and cheap.

Biological control measures are commonly used and have achieved remarkable results in many countries, being the best way to rehabilitate degraded land in mountain ecosystems.

In order to test and demonstrate possible approaches to solving the problem of land degradation, a project entitled 'Rehabilitation of Degraded Lands in Mountain Ecosystems', funded by IDRC, Canada, was established in 1993 and two comprehensive case studies have been implemented in Nepal. Encouraging results have been seen which can be shared with other areas with similar problems.

Description of Trial and Demonstration Sites

Godavari Site

Location: Godavari is in the southeast of the Kathmandu Valley. It is under the administration of Lalitpur district. Its total area of 30 hectares varies in altitude from 1,550m to 1,800m. The whole site is located on a sloping catchment base (5°-30°) with a wide range of gradients, ridges, gullies, and many small watersheds and swamps.

Climate: Most of Godavari is in a warm, temperate area but its northern corner, situated at the lowest place on the site, is warm enough for growing subtropical plants. The mean annual temperature is 16.6°C, with a minimum of -1.7°C in January and a maximum of 23.9°C in May. The average annual precipitation is about 2,000mm and most of it is concentrated in the monsoon season (June to September). The relative humidity is approximately 76 per cent. Occasionally, there are hailstorms, normally in May or June.

Soil: The soil in Godavari is mostly brown-forest soil. This can be divided into three major groups: loam/silty loam over loam; loam over clay loam/silty clay loam; and clay and clay loam silty loam. (Soil classification is according to the United States Department of Agriculture [USDA] Soils Taxonomy). The soil depth at middle range is moderate to deep (approximately 25-100cm, more in some places) due to the fact that it is colluvial soil. The soils on site are generally fertile compared to those on land uncovered by vegetation. The chemical properties are: pH 4.6 - 7.6; organic carbon 0.1 - 6.4 per cent; nitrogen content 0.03 - 0.6 per cent; available phosphorus content 1-22ppm; and exchangeable potassium 0.1 - 0.8me/100g. The nutrient conditions on site are fairly good except for the deficiency of phosphorus due to the acidic soil.

Vegetation: The natural vegetation of the whole Godavari Watershed Area is very rich. It is dominated by mixed forests with evergreen and deciduous forests. On the upper part of the site, there is a dense forest of *Schima wallichii, Castanopsis indica, Castanopsis tribuloides, Alnus nepalensis, Stranvaesia nussia, Machilus gamblei, Michelia champaca, Michelia Kisopa, Carpinus vimineu, Myrsine semiserrata, Rhododendron arboreum, Lyonia ovalifolia, Litsea oblonga, Lindera* sps., *Symplocos* sps., *Cleyera ochnacea*, and *Albizia mollis*. Unfortunately, parts of this forest have been destroyed through continuous and excessive removal of the most useful species by human beings for fodder, fuel, timber, and charcoal-making and also by forest fires. On the lower part of the site, natural forest species have been overwhelmed by the invasion of thorny shrubs, bushes, and weeds such as *Flacourtia indica, Pyrus pashia, Rubus* spp., *Rosa brunonii*, and *Eupatorium adenophorum* which are neither used by human beings nor eaten by cattle. The remaining coppices, stumps, and defaced scattered trees represent the natural vegetation of the Godavari site. In spring and winter the local people go daily to Godavari to collect fodder and fuelwood. As a consequence of human intervention, less useful species have gradually dominated the biomass on the site, i.e., they account for 79 per cent of the natural forest and 96 per cent of the shrubland on the slopes. The Godavari site is a typical degraded forestland with poor biomass and less useful species, a landscape common in the Hindu Kush-Himalayan Region.

<u>Dhaireni Site</u>

<u>Location</u>: Dhaireni is located in Kavrepalanchok district about 45 kilometres from Kathmandu. The total area is 15.9 hectares and the altitude is from 900-1,900 metres. The whole site is on a south-facing slope (10° - 25°) with a wide range of gradients, ridges, and gullies.

<u>Climate</u>: Dhaireni is in a subtropical area. The mean annual temperate is 21°C, with a minimum of 0°C in January and a maximum of 35.5°C in May. The average annual precipitation is about 1,000-1,200m, mostly during the monsoon season (June to September). As this area receives no water apart from the monsoon rains, drought is the basic problem.

<u>Soil</u>: The soil on this site has been identified as mostly red earth soil, the same as in most degraded areas in the Jhikhu *Khola* watershed of Nepal. The main soil type is red clay loam, characterised by its poor organic matter and low infiltration due to a lack of vegetation cover. The soil pH varies between 4.4 and 6.6 and the cation exchange capacity (CEC) is fairly low. If the soil pH drops below 4, the low CEC inhibits the availability of nutrients to the plants. The organic carbon content of the soil is 0.02-0.89 per cent and the nitrogen content is 0.02-0.12 per cent. Both the carbon and nitrogen content are very low and cannot satisfy the needs of most plants. The available phosphorus content is 0.2-2.6 ppm. The soil under *sal* (*Shorea robusta*) trees and in mixed forests has a good phosphorus content (2.4- 2.6 [ppm]?).

<u>Vegetation</u>: On the Dhaireni site, natural vegetation is scarce and thriving natural forests are rare. About 3.8 per cent of the land is under chir pine (*Pinus roxburghii*) trees which were planted in 1973, 10 per cent of the land is under scattered chir pine, and 22 per cent of the land is barren with gullies. Seasonal streams account for eight per cent of the area and four per cent of the land is covered with stunted pines. The experimental study mainly concentrates on the barren land and gullies. Due to frequent intervention by felling wood, collecting fuel and leaves, and grazing, both natural and planted forests have been heavily damaged and thus vegetation types and species are poor. The main trees on the site are *Pinus roxburghii, Ficus semicordata, Lyonia ovalifolia, Shorea robusta, Castanopsis indica,* and *Terminalia* spp. The main shrubs are *Woodfordia fruticosa, Lantanu camara, Rhus parviflora, Colebrookia oppositifolia*, and *Euphorbia* spp. The main grass species are *Heteropogon contortus* and *Eupatorium adenophorum*. The soil condition and soil moisture in Dhaireni are so poor that very few trees and shrubs, useful or otherwise, can grow well. The total vegetation coverage, most of which consists of less useful species, is 10-15 per cent of the total land area.

Establishment of Plantation Models

The farmers in the hills and mountains of the Hindu Kush-Himalayan Region are small landholding farmers with very limited land for cultivation. Their daily subsistence, therefore, relies very much on community or public forests for fuelwood, fodder, grazing, and, sometimes, for generating cash income. The idea of establishing plantations is based on the farmers' own demands.

Farmers in the mountains have been practising terraced agriculture for centuries, but population pressure has forced mountain farming communities to encroach upon unstable and steeper sloping areas which are prone to soil erosion and slope failures. Sloping Agricultural Land Technology (SALT), developed in the Philippines, has proven to be effective for soil and water conservation, minimising runoff and soil erosion, and enhancing soil fertility to improve productivity. SALT methodology takes into consideration soil erosion control and provides opportunities for the optimal use of sloping land through bioterracing, e.g., using hedgerows to stabilise slopes without terracing. This technology is cost-effective and easy to operate and, therefore, in designing models for degraded land on the Godavari and Dhaireni sites the key concept of SALT has been used and tested.

The following models have been established for trial and demonstration.

Model 1 - Multicrops and Hedgerows

The area of Model 1 on the Godavari site is approximately one hectare with a slope of 10°-20°. The purpose of the model is to set up a 'multicrops' system in alleys between hedgerows in order to produce as many crops as possible to meet farmers' daily needs. The crops include various cereals, legumes, vegetables, and fruit trees. The crop rotation system has been introduced in different alleys in order to maintain the soil fertility level. Ten hedgerow species have been tested, out of which five are promising.

Model 2 - Fruit Trees, Fodder Crops, Timber Trees, and Hedgerows

The area of Model 2 covers about 0.7 of a hectare with a slope of 20° - 30°; it is on the Godavari site.

The model aims to set up a tree crop-dominated plantation to meet farmers' needs for fodder, timber, and cash income as the slope is steep and unsuitable for cereal and vegetable cultivation. The fruit trees planted include apples, plums, pomegranates, grapes, chestnuts, and walnuts and the fodder crops include Napier grass (*Pennisetum purpuream*), *Crotalaria, Sesbania, Cajanus*, Jack beans (*Canavalia ensiformis*), Velvet beans, Oats, Vetch, *Bauhinia*, and Mulberry. Hackberry (*Celtis australis*), *Lapsi* (*Choerospondia axilliaris*), Soapberry (*Sapindus mukorossi*), and Michelia (*Michelia champaca*) were selected as timber trees. Most of these trees and fodder crops performed very well. Eight hedgerow species were tried, out of which five were successful.

Model 3 - Vegetation Cover and Hedgerows

The Model 3 area covers about 5.5 hectares with a slope of 10° - 25°; it is on the Dhaireni site.

The model's purpose is to cover the severely-degraded land with as much vegetation as possible and try out some useful plants to meet farmers' demands for fodder, fuelwood, and cash income. The trees selected were Jackfruit (*Artocarpus lakoocha*), *Tanki* (*Bauhinia purpurea*), *Lapsi* (*Choerospondia axilliaris*), *Mashala* (*Eucalyptus camaldulensis*), *Kangiyo* (*Grevillea robusta*), *Bakaino* (*Melia azedarach*), Mulberry (*Morus alba*), and Guava (*Psidium guajava*). The fodder crops selected were Napier grass (*Pennisetum purpuream*), *Rahar* (*Cajanus cajan*), Jackbean (*Canavalia ensiformis*), and Velvet beans (*Mucua pruriens*). Some trees such as Jackfruit, *Bakaino*, and *Mashala* performed very well but the rest of them did not due to the poor soil conditions and lack of water. Four species of fodder grew well and farmers especially preferred Napier grass and *Rahar*. Four species of hedgerow were tested of which *Tephrosia candida* and *Dalbergia sissoo* grew vigorously, producing more biomass. They also exhibited tolerance to drought.

Model 4 - Subtropical Fruit Trees and Fodder Grass

The Model 4 area covers about one hectare with a slope of 5° - 10°; it is on the Godavari site.

The purpose of the model is to establish a high yielding and good quality subtropical orchard in order to improve the cultivation level of existing orchards in hill areas. Citrus is the main staple fruit species with a potential for domestic and foreign markets, but the yield per unit area and the quality of citrus, unfortunately, cannot meet international standards. Some high quality (internationally appreciated) varieties of citrus have been introduced to the site from Pakistan, China, and other areas of Nepal.

An intensive experimental citrus plot has been established on the Godavari site and all the trees are growing well. Poor soil management is one reason why citrus orchards in Nepal have been unable to produce high quality fruit products. A high standard orchard-establishing technology (including making big pits, applying enough basic organic fertiliser, and high density planting) has been adapted to the orchard in Godavari. White clover has been introduced to improve soil fertility. All saplings and fodder grass are growing well.

Model 5 - Improving Plantation on a Degraded Forest Site

The Model 5 area, on the Godavari site, covers about 0.5 of a hectare with a slope of 25° - 30°

The model aims to improve the degraded forest which has been frequently felled or lopped and make it more productive in terms of producing timber, high quality fodder trees, and other useful trees. The site being very steep, it is impossible to grow hedgerows and carry out alley cropping. Improvement measures must include strictly controlling lopping, collecting, and grazing and the transplantation of useful trees, at proper distances, from adjacent degraded forests and nurseries on to the site. The trees selected were *Schima wallichii, Castanopsis tribuloides, Juglans regia, Prunus cerasoides, Quercus lamellosa, Myrica nagi, Pinus roxburghii, Pinus armandii, Rhododendron arboreum, Alnus nepalensis, Choerospondias axillaris, Sapindus mukorossi, Cedrus deodara,* and *Paulownia elongata*. In order to create a suitable environment for these trees, most of the useless trees, bushes, and weeds were removed. After two growing seasons, the trees are growing well, faster than those trees for which a proper growing environment was not initially created. This cost-effective measure needs minimal investment and labour.

Preparation of Planting Materials

Establishment of the Nursery

To establish various plantation models, plenty of planting materials, such as seeds, seedlings, cuttings, and saplings (grafted and non-grafted), are needed. These planting materials come from various sources.

Seeds are obtained from local forests, the District Forest Office (DFO), local NGOs, the Nepal Agricultural Research Council, the Royal Nepal Botanical Garden, China, Pakistan, and The Philippines.

Seedlings are mainly obtained from the ICIMOD nursery in Godavari. Some also come from the DFOs in Godavari, Banska, and Kavre.

Saplings of fruit trees come mainly from horticultural stations in Dhankuta and Kirtipur in Nepal; many come from India, Pakistan, and China.

To meet the requirements for plantation seedlings from outside is impossible, so a standard nursery was established in Godavari, on an area of 0.3 ha, in February, 1993. Within two years (1993-1994) more than 60,000 seedlings were raised, most of which were planted in Godavari and Kavre.

Technology for Raising Seedlings

To raise the standards of existing hill nurseries, strong and sufficient seedlings are required. Based on two years' practice, the following technical points were seen to be necessary for nursery management.

1. The seed bed should be carefully prepared and soil collected preferably from a nearby forest. If the soil is not fertile, 10-20 per cent organic fertiliser should be mixed with the soil in a proportion of 10-20 per cent to provide enough nutrients for young seedlings.
2. Watering is important for seed beds, especially in the crucial early stages. A plastic net cover, semi-pervious to light, has been used for covering seed beds. It has proved to be very effective for retaining moisture and providing enough sunlight to young seedlings.
3. Pre-treatment of seeds is a must. More than 40 species of plants were tried at the Godavari nursery, of which about 75 per cent belonged to the legume family and had a lower germination rate when sown in beds without pre-treatment. In order to increase the germination rate, all seeds should be soaked in water for two to 72 hours. Soaking increases the germination rate by 10-50 per cent. Tables 1 and 2 show the results of some experimental plants and their features. From these two tables we can see that the germination rates of most of the plants are from 30-90 per cent. The germination rate of plants such

as *Albizia, Leucaena, Flemingia, Acacia,* and *Tephrosia* could not be increased even after soaking the seeds for many days. Careful observation showed that the seeds had very hard coats which prevented them from absorbing water. When scoured with abrasive paper the germination rate increased by 90-100 per cent.

Table 1: Experimental Plants and Their Basic Features
Godavari, Kathmandu

Names of Plant	Seed Weight (gramme/100pc)	Germination Rate (%)	Collected Places
Hedgerow species			
Acacia decurrens var. dealbata	1.90	20.0	Yunnan, China
Acacia mearnsii	1.40	5.0	Yunnan, China
Acacia auriculaeformis	2.50	5.0	Yunnan, China
Amorpha fruticosa	0.93	10.0	Pakistan
Alnus nepalensis	0.07	25.0	Nepal
Albizia lebbeck	3.10	50.0	Nepal
Albizia esticulate	3.25	60.0	Nepal
Calliandra calothyrsus	5.00	55.0	Philippines
Cassia siamea	2.14	3.0	Yunnan, China
Caesalpinia sappan	65.70	30.0	Yunnan, China
Delonix regia	56.50	20.0	Yunnan, China
Desmondium rensonii	0.22	98.0	Philippines
Desmondium sp.	0.24	95.0	Nepal
Flemingia macrophylla	1.80	80.0	Nepal
Flemingia macrophylla	2.02	85.0	Philippines
Hippophae salicifolia	1.05	70.0	Nepal
Indigofera dosua	1.02	60.0	Nepal
Leucaena leucacephala	6.00	30.0	Philippines
Leucaena leucacephala	7.00	90.0	Nepal
Leucaena pallida	4.80	50.0	Nepal
Leucaena diversifolia	1.20	70.0	Nepal
Robinia pseudoacacia	2.12	35.0	Pakistan
Tephrosia candida	2.30	48.0	Yunnan, China

Table 2: Experimental Plants and Their Basic Features
Godavari, Kathmandu

Names of Plant	Seed Weight (gramme/100pc)	Germination Rate (%)	Collected Places
Fodder Bush Species			
Bauhinia variegata	32.60	80.0	Nepal
Cajanus cajan	8.45	75.0	Yunnan, China
Crotalaria pallida	2.40	60.0	Yunnan, China
Canavalia ensiformis	120.00	85.0	Nepal
Mucuna pruriens	110.00	86.0	Nepal
Sesbania rostrata	1.08	38.0	Nepal
Sesbania cannabina	1.85	75.0	Nepal
Fodder Grass Species			
Astragalus sinicus	2.05	80.0	Sichuan, China
Amaranthus caudatus	0.10	90.0	Sichuan, China
Lolium multiflorum	0.28	30.0	Sichuan, China
Trifolium repens	0.05	95.0	Sichuan, China
Tree Species			
Camellia sinensis	58.30	9.8	Yunnan, China
Juglans regia	-	70.0	Shaanxi, China
Pinus armandii	8.50	40.0	Shaanxi, China
Paulownia tomentosa	0.04	0.5	Shaanxi, China

Performance of Plantations

Establishment of Hedgerows

Hedgerows are the main component in the establishment of plantations; they play a multifunctional role. Hedgerow functions are broadly: minimising runoff and reducing soil erosion; enhancing soil fertility to improve productivity; conserving soil moisture within the cropping alleys and making them conducive to plant growth; and providing biomass for fodder, green manure, and mulching materials.

The characteristics necessary for good hedgerow species are fast growth, strong root systems, nitrogen-fixing ability, tolerance to lopping and quick coppicing, and resistance to diseases and pests.

Keeping these requirements in mind, 23 plant species have been introduced at the Godavari nursery for raising seedlings (see Table 1).

Of these species, half are local and the rest are exotic. All seedlings of the 23 species grew when they were in the nursery, but they performed differently when they were transplanted in the fields. After one growing season's observation, it could be seen that three species of *Acacia*, two of *Leucaena*, one of *Calliandra*, and one of *Cassia* did not perform well in Godavari; their growth was slow and they were intolerant to frost. In 1994, 11 species of hedgerow were found to grow well and they were placed under observation. Table 3 shows the growth rate of 11 hedgerow species in Godavari.

Table 3: Growth Rate of Hedgerow Species
Godavari, Kathmandu

Species	Seedlings status and Growing Date			First Measurement June 22-July 5, 1994			Second Measurement Oct. 5-25, 1994		
	Growing Date	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)	Branches (pec)	Height (cm)	Diameter (cm)	Branches (pec)
Albizia lebbeck	July 13, 1993	18.5	0.41	128.9	1.15	23	184.1	2.40	20
Alnus nepalensis	July 5, 1993	15.5	0.35	185.8	2.04	22	356.6	3.49	18
Desmondium rensonii	July 6, 1994	10.0	0.30	110.5	20.95	20	245.0	1.53	21
Desmondium spp.	July 20, 1993	15.5	0.55	98.5	1.05	19	124.5	1.66	22
Flemingia macrophylla	July 20, 1994	19.0	0.38	121.0	1.13	16	196.4	1.82	14
Indigofera dosua	July 21, 1993	20.5	0.52	74.9	1.14	11	149.8	1.56	14
Tephrosia candida	July 7, 1993	17.5	0.41	102.9	1.18	17	180.3	1.53	10
Acacia mearnsii	July 25, 1993	12.5	0.31	59.0	0.53	8	86.7	0.76	8
Amorpha fruticosa	July 25, 1993	15.5	0.31	113.8	1.10	9	130.3	1.30	9
Dalbergia sissoo	July 14, 1993	20.0	0.65	30.4	0.99	9	52.0	1.15	9
Leucaena leucocephala	July 12, 1993	15.5	0.35	33.3	0.56	8	42.3	0.99	7

From Table 3 it can be seen that there were no great differences among the species when they were growing. After 15 months, big differences could be seen among the 11 species. *Acacia mearnsii, Dalbergia sissoo,* and *Leucaena leucocephala* had poor growth rates. The other eight species grew well, with average heights of 130.3cm to 356.6cm and average diameters of 1.30 to 3.49cm. Among the eight species the best was *Alnus nepalensis* in terms of growth and diameter; the second was *Albizia lebbeck*; the third, *Flemingia macrophylla*; the fourth, *Tephrosia candida*; and the fifth, *Indigofera dosua*.

In Dhaireni, four species of hedgerow were tested and the results can be seen in Table 4. The growth rate was expected to be better than that of Godavari because of Dhaireni's sufficient warmth and longer growing season. The data in Table 4 show the best species to be *Tephrosia candida* which reached 14.8cm in height and 1.68cm in diameter, the second was *Dalbergia sissoo* which reached 132.8cm in height and 1.25cm in diameter, and the third and fourth were *Leucaena leucocephala* and *Albizia lebbeck* respectively. It should be emphasised that Dhaireni is a typically degraded area with an arid climate and very poor soil conditions. In this environment, *Tephrosia candida* grew very well, resisting long periods of drought and producing more biomass than any other plants grown on the same site. The biggest *Tephrosia,* 172cm in height and 2.58 in diameter, bore fruit (35 pods) after only 16 months of growth. This is important as it signifies that the seeds can be produced locally instead of importing from outside the area.

Table 4: Growth Rate of Hedgerow Species
Dhaireni, Kavrepalanchok Dis.

Species	Seedlings status and Growing Date			First Measurement July 5, 1994		Second Measurement Nov. 30, 1994	
	Growing Date	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)
Albizia lebbeck	July 25, '93	17.5	0.45	42.3	0.71	90.0	1.43
Dalbergia sissoo	July 25, '93	21.6	0.60	58.6	0.83	132.8	1.25
Leucaena leucocephala	July 25, '93	15.8	0.32	62.8	0.59	117.7	0.81
Tephrosia candida	July 25, '93	16.5	0.35	77.4	0.72	148.0	1.68

As seen in Table 3, the height of eight hedgerow species of reached 100cm or more by July 1994. Since then, pruning experiments have been carried out on three plots ((plantations) in Godavari and the results are shown in Table 5. The results show that the biomass production of six hedgerow species varied from 5.41kg./100m to 86.36kg/100m at the first pruning. Two months later a second pruning was carried out and the biomass production from eight hedgerow species varied from 11.51kg/100m to 96.84kg/100m. *Amorpha fruticosa* and *Desmodium rensonii* in plot I were not high enough, so they were not pruned the first time.

In terms of biomass production, the hedgerow species, *Alnus nepalensis,* which produced 48.38-183.20kg/100m within the growing season, ranks first; *Albizia lebbeck,* with 48.24-58.88kg/100m, ranks second; *Indigofera dosua,* with 25.03-43.24kg/100m, ranks third; *Tephrosia candida,* with 31.31-36.83kg/100m (it can only be pruned once), ranks fourth; *Desmondium* (local), with 27.03kg/100m, ranks fifth; *Desmondium rensonii,* with 5.41-22.57kg/100m, ranks sixth; *Flemingia macrophylla,* with 15.57kg/100m, ranks seventh; and *Amorpha fruticosa,* with 11.51kg/100m, ranks eighth.

To summarise this result, six hedegrow species (*Alnus nepalensis, Albizia lebbeck, Indigofera dosua, Tephrosia candida, Desmondium* (local), and *Flemingia macrophylla)* can be recommended for hedgerow species in areas at altitudes of 1,500-1,800masl. Out of these six, *Alnus nepalensis* is the best in terms of fast growth, nitrogen- fixing ability, tolerance to lopping, and resistance to pests and diseases. All the fresh biomass (leaves and tender branches) pruned from the eight hedgerow species were fed to goats in Godavari.

Table 5: Biomass Production of Hedgerow Species

Godavari, Kathmandu

Plots	Name of Species	First Pruning* (June 30-July 3, 1994)			Second Pruning* (August 23 - Sept. 12, 1994)			Total Amount of Pruning (within a growing season)		
		Length of hedgerow (m)	Fresh weight of biomass (kg)	Fresh weight/ hedgerow length (kg/100m)	Length of hedgerow (m)	Fresh weight of biomass (kg)	Fresh weight/ hedgerow length (kg/100m)	Length of hedgerow (m)	Fresh weight of biomass (kg)	Fresh weight/ hedgerow length (kg/100m)
I	*Alnus nepalensis*	-	-	-	89.3	43.2	48.38	89.3	43.2	48.38
	Amorpha fruticosa	-	-	-	60.8	7.0	11.51	60.8	7.0	11.51
	Desmondium rensonii	-	-	-	113.4	25.6	22.57	113.4	25.6	22.57
	Flemingia macrophylla	-	-	-	406.4	62.6	15.40	406.4	62.6	15.40
	Indigofera dosua	-	-	-	91.9	23.0	25.03	91.9	23.0	25.03
	Tephrosia candida	-	-	-	49.5	15.5	31.31	49.5	15.5	31.31
II	*Albizia lebbeck*	223.9	16.0	7.15	223.9	92.0	41.09	223.9	108.0	48.24
	Alnus nepalensis	405.3	350.0	86.36	405.3	392.5	96.84	405.3	742.5	183.20
	Desmondium rensonii	120.2	6.5	5.41	-	-	-	120.2	6.5	5.41
	Indigofera dosua	161.4	28.0	17.35	161.4	29.5	18.28	161.4	57.6	35.69
	Tephrosia dosua	112.0	34.1	30.45	112.0	36.8	32.88	112.0	70.9	63.30
III	*Albizia lebbeck*	182.2	44.0	24.14	182.2	63.1	34.63	182.2	107.1	58.88
	Alnus nepalensis	448.3	212.8	47.47	448.3	161.8	36.09	448.3	334.6	83.56
	Desmondium (Local)	18.5	1.5	8.10	18.5	3.5	18.91	18.5	5.0	27.03
	Indigofera dosua	18.5	3.8	34.05	18.5	4.2	45.95	18.5	8.0	43.24
	Tephrosia candida	31.5	11.6	36.83	-	-	-	31.5	11.6	36.83

* Pruning height: 50cm above the ground.

Horticulture

Growing Fruit Trees

Horticulture is an important component of mountain farming systems because they have a special role in generating cash income for farmer households. In Godavari, the area above 1,600m has a temperate climate that is suitable for various temperate fruit trees. In April 1993, 10 species of temperate fruit saplings were introduced into Godavari. Through two growing seasons (1993-1994) 10 species of temperate fruit trees adapted to the climatic conditions in Godavari and most of them grew well.

Table 6 shows the growth rates of six species of temperate fruit trees. It shows that three varieties of apricot, three of plum, three of peach, and three of pear grew from 118-186.6cm in height and 2.00-3.75cm in diameter; this means that all varieties had normal, standard growth rates. In addition, one-third of the fruit trees have blossomed and many trees are expected to bear fruit next spring.

The growth rate of persimmon (three varieties) and Chinese dates (two varieties) were not as good as expected. This could be due to the temperature in Godavari in summer not being high enough to meet the requirements of these two species. This point still has to be proven through further investigations.

As mentioned before, in the hill areas (1,000-1,500m) of Nepal, subtropical fruits, especially citrus, have potential for domestic and international markets. But the citrus produce sold in the markets is not as good as expected in terms of size, shape, and quality. For example, seedless navel oranges with high quality juice are predominant in international markets but they are not available in Nepal. In order to improve this situation, several varities of seedless orange and other high quality citrus fruits have been introduced in Godavari. This can be seen in Table 7. The Table shows that all citrus varieties grow well but the Pakistani varieties performed best with growth rates, in terms of height, diameter, and crown, much higher than other citrus varieties. This could be due to the large size of the saplings introduced from Pakistan. Many Pakistani plant varieties are expected to bear fruit next spring. It should be mentioned that there is a lot of concern about citrus virus diseases and that all citrus plants have been strictly controlled by the quarantine office of the Nepalese Government. After a minimum of three to five years, when the plants are confirmed as being free from any viruses, the good varieties will be propagated for farming.

The growth rates of guava, avocado, and macadamia seem good. Several guavas have been seen on the branches of the guava tree and it is expected that more trees will bear fruit in the coming spring. The temperature in Godavari may not be high enough for the avocado and macadamia, this still has to be proved.

Fodder and Green Manure

Fodder shortages are always a big problem and growing fodder is very important for plantation establishment. Soil nutrients on degraded land are very poor but can be improved through growing green manure (most species of legume are grown for both fodder and green manure). In the spring of 1993, a series of fodder species were introduced experimentally in Godavari and Dhaireni.

Table 8 shows the biomass and pod production of bush fodder species in Godavari. It shows that four species of legume (*Cajanus cajan, Sesbania cannabina, Sesbania rostrata,* and *Crotalaria pallida*) produced more than one kg/sq.m. of biomass. Of these, two species of *Sesbania* produced from 2.7-5.5kg/sq.m., which is more than *Cajanus cajan* and *Crotalaria pallida* produced. It can also be seen that biomass and pod production decreased with an increase in altitude. The temperature in Godavari may be too low for *Cajanus cajan* that could not bear flowers until the end of November, 1994. These four legume species originated from tropical areas. They are worth growing for fodder and manure because they are fast growing, nitrogen-fixing plants. They also provide a mass of forage to cover exposed land, reducing soil erosion during the monsoon season.

Table 6: Growth Rate of Temperate Fruit Trees

Godavari, Kathmandu

Species and Varieties	Saplings Status and Growing Date			First Measurement (October 16, 1993)				Second Measurement (October 15, 1994)			
	Growing Date	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)	Crown		Height (cm)	Diameter (cm)	Crown	
						N-S (cm)	E-W (cm)			N-S (cm)	E-W (cm)
Apricot											
Meixin (1-1)	May 22, 1993	35.3	0.50	72.5	1.12	25.4	22.5	118.4	2.00	52.8	57.8
Xinli (1-2)	"	30.4	0.45	52.5	1.16	24.5	24.4	129.6	2.15	79.4	77.0
Erzhaunzhi (1-3)	"	36.2	0.65	72.3	1.22	26.0	44.8	120.9	2.50	76.5	80.2
Plum											
Li - 3 (2-1)	May 22, 1993	32.3	0.65	59.3	1.32	23.5	20.7	145.8	2.76	82.6	97.8
Gaili (2-2)	"	35.4	0.70	70.3	1.35	35.9	34.6	146.6	3.73	110.8	112.2
Huahuanli (2-3)	"	31.5	0.55	56.8	1.04	40.0	32.8	130.5	2.50	81.5	95.3
Peach											
Yuhualu (3-1)	May 22, 1993	38.5	0.46	76.1	1.29	35.0	30.9	141.0	3.12	96.4	103.2
Youtao (3-2)	"	40.6	0.55	77.7	1.53	46.6	44.9	186.6	3.41	128.6	113.2
Beijing 8 (3-3)	"	40.2	0.60	72.6	1.57	36.7	33.0	139.5	3.50	95.4	102.1
Pear											
Suli (4-3)	May 22, 1993	55.3	0.61	70.0	1.26	20.5	20.5	152.0	2.43	38.8	62.6
Xueli (4-2)	"	52.1	0.65	56.0	1.24	20.8	14.8	142.6	3.20	43.6	51.4
Changxlli (4-3)	"	48.5	0.59	52.0	0.96	15.3	15.8	149.8	2.10	55.5	61.0
Persimmon											
Songbenzhaosheng (5-1)	May 23, 1993	30.5	0.32	44.7	0.78	7.2	6.1	95.0	1.78	15.8	18.2
Quianchuancilang (5-2)	"	35.1	0.35	38.6	0.76	10.7	11.8	61.8	1.85	31.2	31.6
Cilang (5-3)	"	32.6	0.40	44.1	1.00	11.0	12.1	98.0	2.15	29.0	35.6
Chinese Date (*Ziziphus jujuba*)											
Jingzhao (6-1)	May 23, 1993	35.5	0.55	52.7	1.03	16.0	14.1	87.4	1.66	36.4	42.0
Cuizhao (6-2)	"	37.2	0.51	54.0	0.96	20.3	18.2	101.4	1.82	64.6	51.6

Table 7: Growth Rate of Subtropical Fruit Trees

Godavari, Kathmandu

Species and Varieties	Saplings Status and Growing Date			First Measurement (October 16, 1993)				Second Measurement (October 15, 1994)			
	Growing Date	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)	Crown		Height (cm)	Diamet er (cm)	Crown	
						N-S (cm)	E-W (cm)			N-S (cm)	E-W (cm)
Citrus from Nepal											
Lime - *Kagati* lime	July 18, 1993	20.1	0.30	30.5	0.55	29.0	24.3	24.3	51.5	1.45	39.0
Mandarin - *Dhancuta suntala*	"	22.5	0.40	40.4	0.60	12.8	11.5	11.5	57.0	1.23	22.8
Sweet orange *Dhancuta junar*	"	25.0	0.42	29.0	0.63	9.8	14.5	14.5	38.3	1.26	19.8
Citrus from Pakistan											
Lime - *Kagati* lime	May 1, 1993	65.3	1.04	83.0	1.35	51.5	52.3	140.3	4.10	114.3	116.8
Sweet orange - Blood red	"	64.0	0.57	74.8	0.89	39.8	40.5	114.5	3.34	64.8	88.0
Sweet orange - Succari	"	62.0	0.92	93.2	1.47	37.4	37.4	103.0	3.66	85.2	69.2
Grapefruit - Shamber	"	68.3	1.35	109.8	1.63	47.5	41.8	151.8	3.82	102.5	90.0
Mandarin - Kinnow	"	53.4	1.22	86.3	1.55	35.3	35.3	126.5	3.46	98.8	93.3
Citrus from China											
Mandarin - Ponggan	Nov. 21, 1993	25.5	0.45	-	-	-	-	32.5	1.30	14.7	15.5
Sweet orange - Meishan	"	30.0	0.52	-	-	-	-	38.2	1.39	17.0	20.3
Sweet orange - New hall	"	30.2	0.55	-	-	-	-	33.5	1.52	19.5	19.3
Sweet orange - Skages Bonanza	"	31.5	0.60	-	-	-	-	48.0	1.78	18.2	19.8
Sweet orange - Delicious seedless	"	32.1	0.65	-	-	-	-	47.7	1.52	22.6	22.2
Guava (*Psidium guajava*)											
Allahab ad Sufeda seedless	Oct. 22, 1993	25.0	0.52	-	-	-	-	76.6	1.69	56.0	51.1
Avacado (*Persea americana*)											
Ethhinger	Oct. 22, 1993	28.6	0.65	-	-	-	-	84.4	1.77	61.1	60.0
Macadamia (*Macadamia integrifolia*)											
Keauhou	Oct. 22, 1993	18.5	0.35	-	-	-	-	44.9	1.28	40.4	32

Table 8: Biomass and Pod Production of Bush Fodder Species

Godavari, Kathmandu

Species	Altitude of Growing (metre)	Date of Sowing	Date of Harvesting	Area of Sowing (m^2)	Biomass Production		Pod Production	
					Total Fresh Weight (kg)	Yield per unit area (kg/m^2)	Fresh Pod Weight (kg)	Yield per unit Area (g/m^2)
Cajanus cajan	1550	Apr. 15, '94	Nov. 20, '94	30.5	61.3	2.01	-	-
Cajanus cajan	1615	Apr. 15, '94	"	31.0	51.2	1.65	-	-
Sesbania cannabina	1550	May 18, '94	Nov. 18, '94	15.0	64.5	4.30	12.9	860.0
Sesbania cannabina	1615	"	"	13.0	35.1	2.70	7.0	540.0
Sesbania rostrata	1550	"	"	10.0	55.0	5.50	10.0	1000.0
Crotalaria pallida	1615	"	Nov. 22, '94	30.0	30.3	1.01	9.0	300.0
Amaranthus caudatus	1615	Apr. 15, '94	Sept. 20, '94	22.5	19.6	0.87	-	88.8 (seeds)

Table 9 shows the biomass and pod production of Jack beans (*Canavalia ensiformis)* and Velvet beans (*Mucuna pruriens*)in Godavari. These two species are strongly recommended by World Neighbours and some tropical countries as very good cover crops for fodder and green manure. From Table 9 it can be seen that Jack beans produced 1.88-3.95kg/sq.m. of fresh materials (biomass and pods). The yield of Velvet beans seems to be a little higher than that of Jack beans but the yields of both decrease as altitude increases. Fortunately, the pods of both species can mature in the climatic conditions of Godavari. This means that the seeds can be produced locally. In addition, throughout two years' cultivation, these two bean species provided a dense forage which closely covered the land they grew on without any soil erosion. There were hardly any weeds under the plants. We may conclude that Jack beans and Velvet beans are worth growing for fodder and green manure in Godavari.

Table 10 shows the biomass production of fodder grasses in Godavari and Dhaireni. From Table 10 it can be seen that four species of fodder grass, namely, rye grass (*Lolium multiflorum*), *Symphytum peregrinum*, white clover (*Trifolium repens),* and Napier grass (*Pennisetum purpureum*) produced 1.01-8.45kg/sq.m. of biomass which may not be impressive but is significant. For example, rye grass was harvested during April-June when very little fresh fodder could be collected for the animals (many wild animals such as deer and rabbits came to the rye grass fields to graze). The fodder grass *Symphytum* grows rapidly and regenerates. From April to October it can be harvested every two months. It is a highly productive fodder grass which can be harvested for several years without replanting. White clover is a nitrogen-fixing fodder grass which can be harvested three times every growing season. Because its dense forage closely covers the land, it not only protects soil from erosion but also improves soil fertility. Napier grass is a fast-growing fodder grass which has been proven to grow well and propagate easily in adverse places, so farmers accept it as a good fodder. From Table 10 it can be seen that Napier grass can be harvested twice in Godavari and three times in Dhaireni (the yield being much more than in Godavari because the Dhaireni site has sufficient heat and a longer growing season).

Table 9: Biomass and Pod Production of Jack Beans and Velvet Beans
Godavari, Kathmandu

Species	Altitude of Growing (metre)	Area of Sowing (m^2)	Biomass Production			Pod Production		
			Total Fresh Weight (kg)	Yield per unit area (kg/m^2)	Maximum Plant Weight (kg)	Total Fresh Pod Weight (kg)	Yield per unit Area (g/m^2)	Maximum Pod Yield per Plant (kg)
Jack Beans	1550	15.0	31.4	2.09	2.00	27.9	1.86	2.20
(Canavalia ensiformis)	1615	40.5	52.3	1.29	0.40	23.9	0.59	0.24
Velvet Bean	1550	15.0	24.9	1.66	1.70	35.6	2.37	2.40
(Mucuna pruriens)	1615	35.0	27.3	0.78	0.60	40.6	1.16	0.98

Table 10: Biomass Production of Fodder Grasses
Godavari, Kathmandu
Dhaireni, Kavrepalanchok

Species	Date of Sowing	Area of Sowing (m^2)	Yield per unit area (kg/m^2)	First Harvesting (June 26, 1994)		Second Harvesting (August 25, 1994)		Third Harvesting (October 4, 1994)	
				Total Fresh Weight (kg)	Yield per unit area (kg/m^2)	Total fresh weight (kg)	Yield per unit area (kg/m^2)	Total fresh weight (kg)	Yield per unit area (kg/m^2)
Rye Grass *(Lolium multiflorum)*	May 25, '93	28.0	1.01	28.2	1.01	-	-	-	-
Symphytum *(Symphytum peregrinum)*	May 20, '93	7.0	8.40	13.1	1.87	27.0	3.86	19.0	2.71
White Clover *(Trifolium repens)*	Jan. 10, '94	25.0	3.50	27.5	1.10	38.0	1.52	22.7	0.91
Napier Grass *(Pennisetum purpureum)*	May 25, '93	110.0	2.71	-	-	94.8	0.86	203.0	1.85
Napier Grass (Kavri, 1000m)	Jun. 30, '93	8.0	8.75	18.0	2.25	27.8	3.48	24.20	3.03

Paulownia elongata is a very well-known fast growing tree. In April 1993, 107 stump roots (10-15cm in length and 2-4cm in diameter) of *Paulownia* were introduced in the Godavari area. These stump roots were grown in three different places at altitudes of 1,400m, 1,550m, and 1,650m in order to investigate the difference in growth rate at different altitudes. The results have been shown in Table 11 where it can be seen that the average growth rate of *Paulownia* reached 197.5-644.0cm in height and 9.02-11.43cm in diameter after 18 months' growth.

Table 11: Growth Rate of Paulownia (*Paulownia elongata*)

Godavari, Kathmandu

Altitude of Growing (meter)	Date of Growing	Average Growth Rate in 1993		Average Growth Rate in 1994		Minimum Growth by Nov. 22, 1994		Maximum Growth by Nov. 22, 1994	
		Dia-meter (cm)	Height (cm)	Dia-meter (cm)	Height (cm)	Dia-meter (cm)	Height (cm)	Dia-meter (cm)	Height (cm)
1400	April 28, '93	3.22	233.5	11.43	522.8	8.59	490.0	13.68	651.0
1550	April 25, '93	2.81	116.1	9.02	644.0	7.15	510.0	12.90	800.0
1650	May 9, '93	2.90	114.5	10.66	197.9	8.30	138.0	13.60	360.0

The maximum growth rate of Paulownia was 800cm in height and 13.68cm in diameter. Lower altitudes were seen to be conducive to an increase in diameter of the tree but not to an increase in height. In general, all data from different altitudes show that *Paulownia* is a fast-growing tree species.

The Progress of Recovering Vegetation in Dhaireni

Dhaireni is a typically degraded area with barren land, poor soil fertility, and harsh climatic conditions. There are no water resources apart from the limited rainfall during the monsoon season. Before starting plantation, the average vegetation coverage was estimated at about 10-15 per cent, consisting of less useful species such as *Heteropogon contortus, Eupatorium odenophorum, Solanum khasianum, Euphorbia spp.*, and *Sonchus* spp. For the quick recovery of degraded land, the following measures have been adapted on the site

1. The land users' group made regulations for protecting the areas from open grazing and illegal encroachment on any kind of land for fodder, fuelwood, or timber.
2. *Agave sisalana*, a hardy, thorny, and drought resistant plant, was grown along the border of the protected area as a biological fence. It has been proven that this plant can keep buffaloes and cows away from the plantation area.
3. Twenty-two lines of hedgerows, with a length of 134.5 metres, have been established. Four species of bushes were selected for hedgerows of which *Tephrosia candida* and *Dalbergia sissoo* are very promising.
4. Since Napier grass can adapt to harsh climatic conditions and poor soil conditions it has been abundantly grown between hedgerows and in gullies. Most of it has grown well and has begun to reduce soil erosion.
5. Tree plantations were established on the site. Local farmers are very keen to grow some useful trees on degraded land, so eight species of these have been tried in Dhaireni. The results have been shown in Table 12. From Table 12 it can be seen that of eight species the growth rates of Jackfruit, *Lapsi, Mashala, Bakaino*, and Guava seem impressive in terms of height (61.3cm - 166.3cm) and diameter (1.12cm - 2.15cm). *Tanki, Kangiyo*, and Mulberry can survive but do not grow well. Taking into consideration the conditions, this progress is not so bad.

Table 12: Growth Rate of Tree Species
Dhaireni, Kavrepalanchok Dis.

Species	Seedlings Status and Growing Date			First Measurement (July 5, 1994)		Second Measurement (Nov. 30, 1994)	
	Growing Date	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)
Artocarpus Lakoocha (Jackfruit)	July 24, '93	25.0	0.50	79.2	0.94	101.0	1.31
Bauhinia purpurea (Tanki)	July 25, '93	18.3	0.35	41.1	0.52	37.9	0.64
Choerospondia axilliaris (Lapsi)	July 25, '93	22.4	0.41	61.1	1.04	90.0	1.67
Eucalyptus camaldulensis (Mashala)	July 26, '93	23.5	0.38	81.5	1.03	113.2	1.53
Grevillea robusta (Kangiyo)	July 20, '93	15.0	0.30	29.4	0.46	28.6	0.86
Melia azedarach (Bakaino)	July 27, '93	30.5	0.45	101.1	1.48	166.3	2.15
Morus alba (Mulberry)	July 30, '93	14.5	0.32	65.0	0.65	68.6	1.08
Psidium guajava (Guava)	July 28, '93	25.0	0.52	49.5	0.80	61.3	1.12

Through two years' effort the degraded land in Dhaireni site has been improved. The most obvious change is the increase in vegetation coverage from 10-15 per cent to 85-90 per cent. This is due to the planting of hedgerows, trees, Napier grass, and naturally regenerated native grass (*Heteropogon contortus*). This newly-increased vegetation coverage has laid an important foundation which is useful for further plantation. It is thought that this degraded land will be rehabilitated in three to five years and will become productive enough to meet farmers' demands for fodder, fuelwood, and cash income.

Discussions on Plantations

Functions of Hedgerows

As described earlier, the Godavari Watershed Area is very rich in vegetation. Unfortunately, during the past decades, most of the forests were destroyed, especially on the gentle slopes. This was through the excessive removal of the most useful species for fodder, fuel, timber, and other needs. With the increase in population, not only the people who live nearby but also those who live 10-20 kilometres away now come to Godavari to collect fodder or fuelwood. Such activities are greatly changing the composition of the forest which is gradually being dominated by less useful species. This trend will continue if proper measures are not adopted. This typical degraded forest land can be seen not only in Nepal but also throughout the Hindu Kush-Himalayan Region.

If human intervention on forests is stopped, the degraded forestland may recover naturally, but it will take many years. Under recent circumstances, this is not possible. One of the alternatives is to make degraded forestland more productive land, e.g., through establishing various plantations. Hedgerows play a multifunctional role in establishing plantations. As mentioned before, about 79 per cent of the forest species are less useful on the Godavari site. Among the useful species (21 per cent), most have less nutritional value and slow growth rates (see Table 13). From Table 13 it can be seen that nine natural tree species are typical and representative of the Godavari site and are usually used as fodder by local farmers. The crude protein contents of these tree species are much lower than those of planted tree species (*Castanopsis indica* excepted). From the nutritional point of view planted tree species (in this case, hedgerow species) are much better than the natural species, being richer in nutrition, fast growing, and nitrogen-fixing. Once the hedgerows are established (normally it takes two to three years) they can serve as soil erosion binders, fodder, green manure, and fuelwood resources. But if farmers are determined to carry out afforestation with these natural forest tree species it will take more than 10-20 years to achieve this which, moreover, might not be possible under present circumstances.

Table 13: Comparison of Nutrient Compositions between Planted Tree Species and Natural Tree Species

Species Name	Dry Matter (%)	Chemical Composition on Dry Matter Basis (%)					Phosphorus (%)	Calcium (%)
		Crude Protein	Crude Fat	Crude Fibre	Nitrogen free extract	Total Ash		
<u>Planted Tree Species</u>								
Alnus cremastogyne	82	17.6	-	-	-	-	-	-
Albizia lebbeck	64	21.7	3.7	31.4	36.1	9.3	0.20	1.85
Amorpha fruticosa	88	24.3	14.6	10.0	45.8	5.3	0.28	1.31
Desmodium elegans	92	22.1	3.1	16.7	44.6	6.5	0.21	2.30
Flemingia macrophylla	91	13.4	2.0	46.9	27.3	10.6	0.18	2.78
Indigofera esquirolii	90	21.6	2.7	29.4	39.4	6.9	0.30	1.83
Leucaena leucocephala	89	23.8	4.3	20.2	43.1	8.6	0.17	3.14
Robinia pseudoacacia	88	26.9	3.0	17.7	44.6	7.8	-	-
Tephrosia candida	90	21.2	3.1	29.4	36.8	9.5	0.20	3.01
<u>Natural Tree Species</u>								
Castanopsis indica	35	14.8	2.6	29.4	47.9	5.3	0.12	0.43
Eugenia jambolana	37	7.9	2.6	20.7	61.7	7.1	-	-
Eurya acuminata	40	7.4	2.3	11.4	62.5	4.4	-	-
Machilus gamblei	35	10.9	2.9	26.9	55.4	3.9	0.67	0.31
Prunus cerasoides	48	6.4	3.7	13.0	60.7	4.2	-	-
Quercus glauca	50	8.6	2.6	29.8	42.7	4.3	-	-
Quercus lamellosa	51	10.0	3.8	26.2	42.9	5.1	-	-
Quercus incana	50	7.1	4.6	28.7	44.2	2.3	-	-
Schima wallichi	-	9.7	-	-	-	3.4	-	-

Source:
1. Compilatory Committee of "Fodder Plants in China", 1989.
2. Kong Qingfu et al. Chemical Compositions and Nutrients of The Fodder Plants in China, 1990.
3. K.k. Panday. Fodder Trees and Tree Fodder in Nepal, 1988.
4. K.G. Tejwani. Agroforestry in India, 1994.

Alnus cremastogyne can be taken as an example from a study of China. Its leaves contain 2.5 per cent of nitrogen, 0.1 per cent of phosphorus, and 0.54 per cent of potassium. Traditionally, Chinese farmers collect the fresh leaves of *Alnus* and put them onto crop fields for green manure. By some statistics, 100kg of *Alnus* leaves have the equivalent of 5.4kg of urea, 0.70kg of calcium superphosphate, and 0.99kg of potassium chloride. A field study showed the use of *Alnus* leaves as green manure by 7,500kg, 9,750kg, and 14,062kg per hectare. Consequently, the crop yields increased by 15.9, 20.4, and 28.7 per cent, respectively.

From Table 5 we can see that, among the six hedgerow species, *Alnus nepalensis* grew the most within a growing season, producing 48.38-183.20kg of biomass per 100m. On an average, the biomass is 115.79kg/100m. If the leaves account for 80 per cent, it means 100m. of *Alnus nepalensis* hedgerow can produce 92.63kg of leaves which contain the equivalent of 5.0kg of urea, 0.65kg of calcium superphosphate, and 0.92kg of potassium chloride.

Alnus nepalensis is a local tree species and is found all over Nepal. From the results of the experiment in Godavari it can be recommended as the best hedgerow species for similar conditions in the Hindu Kush-Himalayan Region. Other species like *Albizia lebbeck, Amorpha fruticosa, Desmondium* spp (local), *Indigofera dosua, Tephrosia candida*, and *Flemingia macrophylla* can also be used as hedgerow species or even for afforestation because of their fast growth, nitrogen-fixing ability, and rich nutrition. All the leaves and tender branches of these species have proved to be good fodder; they have been fed to goats and rabbits in Godavari.

Fodder and Green Manure

Poor soil fertility on the Godavari and Dhaireni sites is the major constraint to improving the productivity of degraded land. According to soil survey reports, the nitrogen content of the soil is about 0.033-0.60 per cent on the Godavari site and about 0.02-0.12 per cent on the Dhaireni site. By any standards, these nitrogen contents are too poor for crop cultivation. To prove this point, in 1993, some crops were cultivated in the alleys between hedgerows when the experimental plots had just been established in Godavari. These crops were cabbage, cauliflower, radish, mustard, broad beans, and peas. None of them performed well unless they were provided with additional fertiliser.

Even the yields of leguminous crops like broad beans and peas were not impressive. Therefore, the improvement of soil fertility should be given priority when degraded land is cultivated. The effective and cheap way of improving soil fertility is through cultivating various leguminous plants.

From Tables 8 and 9 we can see that five leguminous bush and grass species have been tested on the Godavari site. *Crotalaria pallida, Cajanus cajan, Mucuna pruriens*, and *Canavalia ensiformis* produced biomass from 0.78-2.01kg/sq.m. Their nitrogen content is about 2.3 - 2.5 per cent indicating that they can produce 195-396kg nitrogen per hectare. *Sesbania cannabina* and *Sesbania rostrata* produced biomass from 2.7-5.5kg/sq.m. indicating that they can produce 918-1,870kg of nitrogen per hectare (nitrogen content is 3.4 per cent). White clover (*Trifolium repens*) can be harvested three times and its biomass production is 3.5kg/sq.m. per year indicating that white clover can produce 980kg of nitrogen per hectare (nitrogen content is 2.8 per cent). [These experiments have been conducted on small plots that need to be determined again in future]. All these results are encouraging. These five species are nitrogen-fixing plants which can serve as both green manure and fodder. Table 14 shows the data of some fodder bushes and grasses from which it can be seen that all leguminous species are very rich in nutrients and have been widely used by farming systems throughout the world. All species of fodder bushes and grasses have been fed to goats and rabbits in Godavari and they have proved to be good fodder for these animals.

How to Harness a Buffer Zone

There is a vast area between cultivated land and forest land in the Hindu Kush-Himalayan Region. We could call this area a buffer zone characterised by degraded forestland or bush land in which the resource bases are declining and soil erosion is increasing. This buffer zone will expand with the increase in both human and animal populations. Farmers or villagers are greatly relying on this buffer zone from where they have to collect fodder, fuelwood, and other materials. It is estimated that this buffer zone extends over more than millions of hectares?. How to harness this buffer zone is a big challenge and task for policy makers, government officers, and scientists. Ownership of land should be first thought out. In China, for example, bare land is given to the farmers by responsibility contract systems for more than 50 years; the farmers are then interested in investment, afforestation, or other farming activities. Some districts of Nepal have carried out a release system by giving community or buffer land to users' groups.

Table 14: Nutrient Compositions of Some Fodder Bushes and Fodder Grasses.

Species Name	Dry Matter (%)	Chemical Composition on Dry Matter Basis (%)					Phosphorus (%)	Calcium (%)
		Crude Protein	Crude Fat	Crude Fibre	Nitrogen free extract	Total Ash		
Amaranthus paniculata	93.1	12.7	2.6	31.3	41.4	12.1	0.22	3.24
Cajanus cajan	-	17.3	6.0	28.1	39.7	6.7	0.23	-
Crotalaria juncea	-	15.6	-	-	-	-	-	-
Lolium multiflorum	81.7	13.7	3.8	21.3	46.4	14.7	0.32	0.49
Pennisetum purpureum	91.8	10.5	2.0	33.0	44.7	9.6	0.04	0.07
Symphytum peregrinum	10.5	30.0	6.0	13.2	34.0	17.1	-	-
Sesbania gradiflora	-	34.8	4.2	7.5	48.7	12.5	0.33	2.33
Trifolium repens	20.0	24.7	2.7	12.5	47.1	13.0	0.34	1.72

Source: 1. Su Jiakai et al. Cultivation Technology of Improved Fodder Grass, 1983.
2. Kong Qingfu et al. Chemical Compositions and Nutrients of Chinese Fodder Plants, 1990.
3. Gan Shulong et al. Economic Animal and Plant Resources in Sichuan, China, 1988.
4. IRRI. Green Manure in Rice Farming, 1988.

Another issue would be the kind of technologies that could be transferred to farmers in order to gain more benefits when land is released to them. Five plantation models established on the Godavari and Dhaireni sites could provide some examples of how to make degraded land more useful and productive. Some of these experiments are successful, some cannot be copied by other areas, and some need to be further tested and modified.

Bibliography (not cited in the text)

Compilatory Committee of "Fodder Plants in China", 1989. *Fodder Plants in China*. Beijing: Agriculture Press.

Kong Qingfu, 1990. *Chemical Compositions and Nutrients of Fodder Plants in China*. Beijing: Agriculture Press.

Gang Shulong, 1990. *Economic Animal and Plant Resources in Sichuan, China*. Sichuan: Publishing House of Sichuan Academy of Social Sciences.

IRRI, 1991. *Sustainable Agriculture: Green Manure in Rice Farming*. Philippines: IRRI.

ICIMOD, 1993. *ICIMOD Methodology Workshop on Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayan Region, May 29 to June 3, 1993*. Kathmandu: ICIMOD.

K.k. Panday, 1988. *Fodder Trees and Tree Fodder in Nepal*.

Su Jiakai, 1987. *Cultivation Technology of Improved Fodder Grass*. Beijing: Agriculture Press.

K.G. Tejwani, 1994. *Agroforestry in India*. New Delhi: Oxford and IBH Publishing Co. Pvt. Ltd.

Zhang Xianwan, 1983. *A Study on Agro-Ecosystems in the Middle Hill Areas of Sichuan*, China: Chengdu Branch, Chinese Academy of Science.

D.P. Joshi, 1994. 'An Inventory of Flora and Fauna and A Biomass Study of ICIMOD Complex Site, Godavari, Nepal'. (unpublished).

G.B. Juwa, 1994. 'Soil Survey of ICIMOD Complex Site, Godavari, Nepal'. (unpublished).

M.N. Subedi, 1994. 'A Baseline Vegetation Survey of Bajrapareko and Dhaireni at Kavre Palanchok District, Nepal'. (unpublished).

Chapter 12

ABSTRACTS

Alternative Approaches to Rehabilitating Degraded Lands in Mountain Ecosystems of Nepal and the Hindu Kush-Himalayas

Damodar Parajuli

Abstract

This paper enumerates the different categories of land use in Nepal. It outlines the principal causes for the widespread forest degradation that the country is facing. These include encroachment, settlement programmes, shifting cultivation, and logging. The main effects of this degradation are: loss of biodiversity, soil and gully erosion, landslides, and debris torrents. The problems of forest degradation and,hence, environmental change could be reversed by adopting alternative approaches to rehabilitating degraded lands. These approaches include alternative ways of fulfilling daily requirements for forest products; reforestation of degraded lands; and encouraging people to undertake forestry activities. The paper also discusses some of the long- and short-term plans undertaken by HMG/Nepal. However, the main constraints in this respect have been the lack of sufficient finances, restrictive legislation, and the lack of appropriate technology. With the enactment of forest legislation (1992), various NGOs,INGOs,donor agencies, and research organisations are making significant contributions to halting forest degradation in the Nepal Himalayas.

Mapping of Watershed Afforestation by Means of the Global Positioning System: Land Ownership, Tenancy Systems, Ethnic Composition, and Problems in the Tarbela Watershed Project Area

Bashir A. Wani

Abstract

This paper presents an outline of the Tarbela Watershed Management Programme in the catchment area of the Tarbela dam. It describes the impacts on the project's various target groups in relation to attitudes, employment, and so on. It details the organisational, technical, and social problems faced by the project. The Monitoring and Evaluation System adopted by the project has succeeded in maintaining accurate information about and assessment of the project outcomes.

The second part of the paper summarises the boundary survey and mapping of afforestation undertaken by the project by using the Global Positioning System. Part three discusses the land ownership and tenancy systems in the project area which are: share cropping, fixed amount of produce, quarter share cropping, mortgage, land rent in cash,and *kalang* (nominal compensation for land/rangeland).

The nomads visiting the alpine pastures of the project area are described, categorised, and the damage to watersheds that their movement causes outlined. In conclusion, a description of the major ethnic groups in the project area is given.

Rehabilitation of Vegetation under Various Geological Conditions in the Hill Areas of the Dry, Hot Valleys of Yuanmou , China

Yang Zhong
and **Zhang Xin Bao**

Abstract

This paper discusses the rehabilitation of vegetation under various geological conditions in the dry and hot valleys of the hill area of Yuanmouin, China. It describes the physical conditions of the area, i.e.,the soil types (haplic and red soil), bedrock (soft mudstone, siltstone, sandstone, metamorphic rocks, and granite), nature of the terrain (gentle slopes, steep gully slopes, and valley plains), climate, and the various degrees of soil erosion under different land conditions. The types of vegetation found in the area at different altitudes are mentioned. The paper describes the relationship between bedrock types and recommends revegetation models that would be appropriate for the Yuanmou area.

A Preliminary Study of the Key Techniques in the Restoration and Rehabilitation of Degraded Mountain Ecosystems

Qui Xuezhong
Zhao Xuenong
and **Tang Jianwei**

Abstract

In order to restore and rehabilitate the degraded ecosystem of Nanjian county, various experiments were undertaken which established a number of key factors. The first of these was the choice of three kinds of suitable plant species, namely, plant species for water regulation and fuelwood;plant species for biological fences and checkdams;and plant species for herbage. The second was soil preparation along with a combination of plant community structures. The third was the building of suitable engineering structures to store water and regulate its flow.

The second part of the paper discusses the measures for lessening water loss and soil erosion, and these are: plant platforms, biological fences, biological checkdams,water pits, water ditches, and water caves. Therefore, according to the topography, landform and rainfall, and soil characteristics, these systems can be pursued to regulate and minimise the erosive processes that lead to the degradation of mountain ecosystems.

SWEET (Sloping Watershed Environmental Engineering Technology) Package for Regeneration of Degraded Lands in the Indian Himalayas

P.P. Dhyani
and **B.P. Kothyari**

Abstract

This paper discusses the SWEET package developed by the G.B. Pant Institute of Himalayan Environment and Development, Almora, U.P., India, for regenerating degraded land in the Himalayan region of India and restoring lands in and around the shrines (e.g., Badrinath, Kedarnath, Yamunotri, and Gangotri) of the Indian Himalayas. It briefly describes the scope of this methodology; its target areas (degraded lands, including

abandoned agricultural land owned by individual farmers and degraded community lands owned by villagers); and the elements of the technology package (protection, waste water harvesting, green fodder plantation, crop diversity, and value addition to raw materials, selection of tree species, nurseries, and plantation and soil management).

Rehabilitation of degraded land in and around Badrinath has already commenced under the Badrinath Restoration Programme which is described at some length in the paper.

Water Harvesting and Its Impact on Development of the Central Himalayas

B.P. Kothyari
and **P.P. Dhyani**

Abstract

This paper discusses the low cost water harvesting technology developed by the G.B. Pant Institute of Himalayan Environment and Development in Almora, Uttar Pradesh, India, and its impact on the restoration and rehabilitaion of degraded land and the sustainable development of rural ecosystems in the Hindu Kush-Himalayan Region.

It gives a brief account of the methodology and materials used by the technology and the trial results from six, diverse agroclimatic regions (production of biomass, production of seasonal vegetables, rehabilitation of degraded land, and comparative cost construction for the most affordable water harvesting tanks for villagers). It recommends the appropriate management and use of existing water, both rainwater and spring (surface) water, as a possible and feasible alternative for mitigating the water crisis in the Central Himalayas. The paper also points out the possible limitations to a wide acceptance of this technology.

Rehabilitation of Degraded Lands in Mountain Ecosystems of the Hindu Kush-Himalayan Region

Keshar Man Sthapit

Abstract

This paper presents a description of two of the main efforts carried out to assess the status of land degradation in Nepal: the Reconnaissance Inventory of the Major Ecological Land Units and Their Watershed Condition and the Land Resources' Mapping Project. An outline of the main types of land degradation in Nepal is also given.

The second part of the paper deals with the principal factors causing degradation, namely, rapid population growth and use of the land beyond its capabilities. The role of the Department of Soil Conservation is also described.

Part Three discusses the soil conservation and watershed management programmes implemented by the Department of Soil Conservation. These include land use planning, land productivity conservation, development infrastructure protection, natural hazard prevention, and the community soil conservation programme. The paper then gives three examples of rehabilitation work accomplished by the Department. These are the Landslide Treatment at Labok, Biring Watershed in Ilam district; the Sarbang Burrow Pit Demonstration Site, Kulekhani Watershed, and terrace improvement in the Bagmati Watershed. In conclusion, the factors on which the success of rehabilitation depends are enumerated. These are: complete treatment of the area, people's participation, a process-oriented approach, and regenerative conservation packages.

Annex 1
Workshop Programme

First Day - 19 December, 1995 (Monday)

8:30 Participants arrive in Baoshan
10:30 Registration (Yingdu Hotel meeting hall)

11:00 **SESSION ONE**

<u>**Opening Session**</u>

Chairperson: Egbert Pelinck

- Rapporteur: Sameer Karki
- Remarks from the Director General of ICIMOD
- Welcome remarks from the Representative of CAS: Zhao Yong Ren
- Remarks from the Representative of IDRC: Steven Tyler
- Welcome remarks from the Governor of Baoshan

12:30-14:00 Lunch Break

14:00-15:30 **SESSION TWO**

<u>**Country Report**</u>

Chairperson: Steven Tyler
Rapporteur: Sameer Karki

- Brief report from ICIMOD Project Coordinator for an Eco-regional Approach to Rehabilitation of Degraded Lands in Mountain Ecosystems of HKH *Pei Shengji*
- Country report from India - *B.P. Kothyari*
- (G.B. Pant Institute of Himalayan Environment and Development)
- Country report from Pakistan - *B.H. Shah*, (Pakistan Forest Institute, Pakistan)

15:30-16:00 Tea Break

16:00-17:30 **SESSION TWO continued**

Chairperson: Egbert Pelinck
Rapporteur: Sameer Karki

- Country report from Nepal - Site I - *B.R. Bhatta* (ICIMOD)
- Country report from Nepal - Site II - *S.R. Chalise* (ICIMOD)
- Country report from China - *Xu Jian-chu* (Kunming Institute of Botany, CAS)

18:30 Reception and Dinner by ICIMOD

Second Day - 20 December, 1995 (Tuesday)

8:30-10:00 **SESSION THREE**

Chairperson: B.A. Wani
Rapporteur: Sameer Karki

Technology and Socioeconomic Aspects of Rehabilitation of Degraded Lands in Mountain Ecosystems

- Understanding Degradation Processes in the Middle Mountains of Nepal - Hans Schreier and P.B. Shah
- Soil Fertility Issues under Irrigated and Rain-fed Agriculture in the Middle Mountains of Nepal - P.B. Shah
- Alternative Approaches to Rehabilitating Degraded Lands in Mountain Ecosystems of Nepal and the Hindu Kush-Himalayas - D.P. Parajuli

10:00-10:30 Tea Break

10:30-12:00 **SESSION THREE continued**

Chairperson: D.P. Parajuli
Rapporteur: Sameer Karki

- SWEET Package for Regeneration of Degraded Lands in the Indian Himalayas -B.P. Dhyani and B.P. Kothyari
- Living Terrace Edge: An Effective Method of Slope Utilisation in the Upper Reaches of the Yangtze River - Li Xiubin
- Rehabilitation of Vegatation under Various Geological Conditions in the Hill Area of the Dry, Hot Valleys of Yuanmou, China - Yang Zhong and Zhang Xin Bao
- Mapping of Watershed Afforestation by Means of the Global Positioning System: Land Ownership, Tenancy Systems, Ethnic Composition, and Problems in the Tarbela Watershed Project Area - B.A. Wani

12:30-14:00 Lunch Break

14:00-15:30 **SESSION THREE continued**

Chairperson: Pei Shengji
Rapporteur: Sameer Karki

- A Matter of Relativity: Design for Low-cost Soil Erosion Monitoring under Differing Land-use Regimes - R.D Hill
- Use of Native Plant Species and Indigenous Knowledge for Rehabilitation of Degraded Mountain Ecosystems - Xu Jianchu, Tong Shaoquan, Yang Qixiu, and Qiu Xuezhong
- A Preliminary Study of the Key Techniques in the Restoration and Rehabilitation of Degraded Mountain Ecosystems - Qui Xue-Zhong, Zhao Xuenong, and Tang Jian Wei

15:40-16:00 Tea Break

16:00-17:30 **SESSION THREE continued**

Chairperson: Ronald Hill
Rapporteur: Sameer Karki

- A Study on Species' Screening and Techniques for Afforestation in the Hot and Dry Valley of the Jinsha River - Shi Pei-Li, Diao Yangguang, Wei Taichang, Cheng Keming & Xi Yourong
- Rehabilitation of Degraded Lands in Mountain Ecosystems: A Technical Report of Plantation Establishment in Nepal - Lu Rongsen
- Water Harvesting Technology and Its Impact on Development of the Central Himalayas - B.P. Kothyari and B.P. Dhyani

18:30 Dinner

Third Day - 21 December, 1995 (Wednesday)

Field Trip Organiser: Tongshaoquan & Yan Qixiu

8:30 Depart for field site of ICIMOD Project on Rehabilitation of Degraded Lands in Mountain Ecosystems in Damay Village (one hour drive).

13:00 Lunch

14:30 Depart from village for Baoshan town

16:00-18:00 **SESSION FOUR**

Group discussion

Chairperson: Pei Shengji
Rapporteur: P.B. Shah, Li Xiubin, Sameer Karki

Proposed topics for discussion:

- Priority programme activities for the future along with the need for and the desirability of the next phase of the project.
- The type of training materials that could be prepared by collaborating institutions, including future follow-up activities in rehabilitating degraded lands in mountain ecosystems.
- Detailed work plan for project implementation in 1995.

18:30 Dinner

Fouth Day - 22, December, 1995 (Thursday)

8:30-10:00 **SESSION FOUR: Group Discussion continued**

Chairperson: Pei Shengji
Rapporteur: P.B. Shah, Li Xiu-bin, Sameer Karki

10:00-10:30 Tea Break

10:30-12:30 **SESSION FIVE**

Reports from Group Discussions and Consolidation of the Discussions

Chairperson: Pei Shengji
Rapporteur: P.B. Shah, Sameer Karki, Li Xiu-bin

12:30-14:30 Lunch Break

14:00-15:00 **SESSION SIX**

Closing of the Workshop

Chairperson: Zhao Yong Ren
Rapporteur: Sameer Karki
Concluding remarks: B.A. Wani
D.P. Parajuli
Pei Shengji

15:00-18:00 Visit to Baoshan city area

16:00-18:30 Tea Break

18:30 Dinner hosted by Baoshan City Government

Fifth Day - 23 December, 1995 (Friday)

8:30 Participants depart from Baoshan by bus for Mongshi airport which is about 140km from Baoshan.

Note: The arrangement of chapters in the text does not conform to the Programme. The sequence of the papers for the document was subsequently determined by the editors.

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Note:

PFI	:	Pakistan Forest Institute
IDRC	:	International Development Research Centre Canada
KIB	:	Kunming Institute of Botany
KIE	:	Kunming Institute of Ecology
CIB	:	Chengdu Institute of Biology
CIMDE	:	Chengdu Institute of Mountain Disasters and Environment
CAS	:	Chinese Academy of Sciences

ICIMOD

Founded out of widespread recognition of degradation of mountain environments and the increasing poverty of mountain communities, ICIMOD is concerned with the search for more effective development responses to promote the sustained well being of mountain people.

The Centre was established in 1983 and commenced professional activities in 1984. Though international in its concerns, ICIMOD focusses on the specific, complex, and practical problems of the Hindu Kush-Himalayan Region which covers all or part of eight Sovereign States.

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- India
- Nepal
- Bangladesh
- China
- Myanmar
- Pakistan

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