Resource Constraints and Management Options in Mountain Watersheds of the Himalayas

Proceedings of a Regional Workshop held 8-9 December, 2003 in Kathmandu, Nepal

Editors
Rodger White
Sanjeev Kumar Bhuchar

About ICIMOD

The **International Centre for Integrated Mountain Development** (ICIMOD) is an independent 'Mountain Learning and Knowledge Centre' serving the eight countries of the Hindu Kush-Himalayas – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and the global mountain community. Founded in 1983, ICIMOD is based in Kathmandu, Nepal, and brings together a partnership of regional member countries, partner institutions, and donors with a commitment for development action to secure a better future for the people and environment of the Himalayan region. The primary objective of the Centre is to promote the development of an economically and environmentally sound mountain ecosystem and to improve the living standards of mountain populations.

The **People and Resource Dynamics of Mountain Watersheds in the Hindu Kush-Himalayas Project** (PARDYP) is a regional research for development project funded by the Swiss Agency for Development and Cooperation (SDC), the International Development Research Centre (IDRC) of Canada, and the International Centre for Integrated Mountain Development (ICIMOD) and active in watershed and natural resources management in five watersheds in China, India, Nepal, and Pakistan. PARDYP's aim is to contribute to balanced, sustainable, and equitable development of mountain communities and families in the Hindu Kush-Himalayan region. To achieve this, it is focusing on data collection, processing, exchange, and dissemination in major areas such as the understanding of community institutions, determination of reasons for social and gender inequity, investigation of the status and dynamics of natural resources, and the potential for improvement of the livelihoods of mountain communities.

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International Centre for Integrated Mountain Development
Kathmandu, Nepal
September 2005

ISBN 92 9115 143 2

Cover photos

Published by
International Centre for Integrated Mountain Development
G.P.O. Box 3226
Kathmandu, Nepal

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Printed and bound in Nepal by
Hill Side Press (P) Ltd.
Kathmandu, Nepal

Foreword

The middle mountains of the Hindu Kush-Himalayas are intensively used and highly populated. Conventional wisdom considers these areas as suffering from significant environmental degradation with increasing shortages of water, declining forest cover, increasing soil erosion and reducing water quality. The reality is more complicated – and less pessimistic.

The importance of addressing these critical mountain issues led ICIMOD to amalgamate earlier projects on the rehabilitation of degraded land and mountain natural resources into the People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP). Based on research undertaken by these previous projects in the middle mountains of Nepal, and to some extent in other countries of the region, PARDYP was conceptualised in 1996. In 2003 PARDYP entered its third three-year phase with regional collaboration throughout the Hindu Kush-Himalayan region as the basis for its operations and research. The Swiss Agency for Development and Cooperation (SDC) and the International Development Research Centre (IDRC) of Canada continue to provide funding and intellectual support.

The primary objectives of PARDYP are to carry out research for development to better understand the processes of natural resource degradation and to recommend sustainable community and farm-based options to promote the rehabilitation of degraded lands and make sustainable increases in on-farm productivity. It examines the impact of natural and man-made interventions on soil fertility and the linkages of these natural factors with the socioeconomic environment in which they are found. The human factor is perceived as the critical basis for future improvements; hence, the project is implemented through a participatory research process in mountain communities.

PARDYP is also an example of the collaborative regional approach taken by ICIMOD in carrying out its mandate for the Hindu Kush-Himalayan region. Research and the daily management of project sites are undertaken by the collaborating focal institutions in China, India, Pakistan, and Nepal. The participating scientists from these countries are the project's researchers and the source of its strength. As the central executing agency, ICIMOD is also extremely fortunate in having the help of specialists from the universities of British Columbia (Canada), Zurich, and Bern (Switzerland). We are confident that the work carried out by PARDYP will contribute to the better management of mountain natural resources and help reduce the poverty in agricultural communities throughout the greater Himalayan region.

Dr. J. Gabriel Campbell
Director General
ICIMOD

Acknowledgements

This work was carried out with the aid of grants from the Swiss Agency for Development and Cooperation and the International Development Research Centre, Ottawa, Canada.

PARDYP's pioneering research work on watershed management and resource dynamics in the Himalaya region is a team effort that draws on the contributions of many people. PARDYP thanks and gratefully acknowledges:

- the financial support and strategic guidance provided by the Swiss Agency for Development and Cooperation (SDC), the International Development Research Centre (IDRC), and the International Centre for Integrated Mountain Development (ICIMOD);
- the invaluable technical inputs of researchers Professor Rolf Weingartner and Dr Juerg Merz from the University of Berne, and Dr Hans Schreier and Dr Sandra Brown from the University of British Columbia;
- the facilities and support provided by the directors and staff of the regional partner institutions: the G.B. Pant Institute of Himalayan Environment and Development, the Pakistan Forest Institute, the Center for Biodiversity and Indigenous Knowledge (Kunming), the Kunming Institute of Botany, and ICIMOD;
- the dedication and hard work of the four PARDYP country teams that have been ably led by Hakim Shah (Pakistan), B.P. Kothyari (India), Bhuban Shrestha and P.B. Shah (Nepal), and Xu Jianchu (China);
- the authors of the papers in this publication and the people who assisted in improving drafts of the papers;
- the diligence of the local PARDYP observers and field staff in the study watersheds in their daily data collection work;
- the office support provided by Samma Shakya;
- the cooperation of the local people in the study watershed for giving freely of their time and allowing their land to be used for trials and demonstrations;
- the cooperation of NGOs and line agencies in the PARDYP watersheds for extending help to conduct trials and demonstrations and for helping in disseminating PARDYP's findings;
- the ICIMOD Publications’ Unit, in particular Dharma R. Maharjan and Asha Kaji Thaku who prepared the figures and diagrams and the layout;
- and especially Stephen Keeling who edited the contributions, liaised with the authors, coordinated the compilation, and supervised the layout of this volume.

The successes and lessons learned during Phase 2 are due to the hard work and cooperation of all these (and other) people. Many thanks!

Executive Summary

This document is a compilation of the papers presented at the wrap-up workshop for Phase 2 of the People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP), held in Kathmandu in December 2003. This project is funded by the Swiss Agency for Development and Cooperation (SDC), the International Development Research Centre (IDRC, Canada), and the International Centre for Integrated Mountain Development (ICIMOD). PARDYP Phase 2 began in October 1999 and ended in December 2002, and has been active at the watershed scale in the four ICIMOD countries of China, India, Nepal, and Pakistan.

PARDYP is a research for development project that evolved out of previous IDRC-funded projects that were concerned with natural resource dynamics and the rehabilitation of degraded areas in the middle mountains of the Hindu Kush-Himalayas (HKH). These field studies provided much experience and a number of important lessons. Their main findings were that 1) geographical generalisations should only be made based of the results of long term replicated tests and trials, 2) water is as important as soils in terms of both dynamics and sustainability, 3) institutional and policy settings must be supportive in order to obtain sustainable development, and 4) common methodologies and scientific rigour are crucial for monitoring biophysical parameters and change. The PARDYP project was developed at a 1996 workshop and was based on these findings and the need for longer term data generation and field study, and the need to work more closely with watershed communities. The second phase of the project was worked out at a 1999 workshop following the presentation of the Phase 1 findings at a workshop in Baoshan, China in May 1999 (see Allen, R.; Schreier, H.; Brown, S. and Shah P.B. eds (2000) The People and Resource Dynamics Project: the First Three Years, 1996-1999. Kathmandu: ICIMOD.)

PARDYP's primary objectives are to provide a basic understanding of natural resource degradation processes, to recommend proven strategies and programmes for community and farm-based prevention of degradation, and to promote the rehabilitation and improved management of natural resources in five watersheds of the Hindu Kush-Himalayas region.

ICIMOD is the central executive agency. The project is implemented in partnership with many collaborators. Specialists from the universities of British Columbia (Canada) and Berne (Switzerland) have provided technical back-up. The Kunming Institute of Botany in China, the GB Pant Institute of Himalayan Environment and Development in India, and the Pakistan Forest Institute are the focal institutions and have undertaken the day-to-day management of the project in the watersheds. Each of these institutions identified their own national partners from other government offices, NGOs, and grassroots organisations. Project staff at ICIMOD have managed and undertaken the activities in Nepal along with a number of local partners.

PARDYP has covered substantial ground in its second phase by establishing benchmark watersheds. In some of the fields of study, for example the hydrological and erosion plot studies, standard methodologies for all five watersheds have been developed. In other areas a variety of study foci and methods have been followed to reflect the differing conditions and local traditions of particular watershed societies. In all aspects, the emphasis has been on participatory research and management.

The work carried out up to the end of the Phase 2 workshop identified the major common issues as:

- population issues leading to land use intensification and consequent soil nutrient deficiencies;
- drinking and irrigation water shortages in the dry season; and
- water quality problems due to the improper use of fertilisers and widespread very high levels of faecal coliforms.

The widely perceived high levels of soil erosion have been found to be not as widespread, or as significant, as previously thought. In fact soil erosion rates from agricultural land have been found to be generally low in all of PARDYP's watersheds. Degraded land has shown high rates of erosion. PARDYP has been able to successfully demonstrate techniques for rehabilitating land and has turned some areas of degraded land into productive land. Although the techniques for rehabilitating land degradation are well understood, more work is needed on the key elements of ensuring community management and overcoming social and gender equity concerns to maintain improvements.

Forest degradation has been found to be not so significant. In all five PARDYP watersheds, forest cover has been maintained or is increasing. In Nepal, community management has helped stabilise forest cover. But in China, Pakistan and India there continues to be a major focus on centralised forest management.

While poor agricultural productivity is still a very significant issue, PARDYP has shown the many opportunities for increasing farm productivity. This has been demonstrated successfully in all the watersheds. Initial results indicate that a proper mix of simple technologies and institutional linkages can substantially increase agriculture productivity.

PARDYP has carried out many studies to identify potential interventions to combat some of the key resource problems that affect the watersheds. This publication assembles the results of three years of painstaking research by the country teams. More time is needed to ensure that these options are adequately demonstrated and promoted by farmers. These proceedings should serve as a valuable resource for researchers, development workers, policy makers, and students of natural resource management working in the HKH.

The many findings from PARDYP Phase 2 are documented in the 21 papers in this volume. An introductory paper explains the background to PARDYP and summaries the main Phase 2 achievements. The papers are grouped together under the three main workshop themes of on-farm activities, water and erosion, and common property resources. The papers by Gafur, Acharya et al., Biggs and Messcherschmidt, and Rai are not reporting on PARDYP work but were included in the workshop, and in these proceedings, to give an appropriate forum and for the PARDYP teams to hear of similar innovative work.

A planning workshop for Phase 3 was held in September 2002, and the three major donors approved the funding of a further three-year phase to the end of 2005. Phase 3 is already well underway elaborating options open to farmers and developing them through action research.

Acronyms and Abbreviations

BGC	Bheta Gad-Garur Ganga Catchment, India
BGW	Bheta Gad-Garur Ganga watershed, India
CHT	Chittagong Hill Tracts
CIMMYT	the International Maize and Wheat Improvement Centre
Danida	Danish International Development Agency
DAP	diammonium phosphate fertiliser
DFID	UK Department for International Development
FAO	Food and Agriculture Organization
GIS	geographical information system
hh	household
HKC	Hilkot catchment, Pakistan
HKW	Hilkot watershed, Pakistan,
HKH	Hindu Kush-Himalayas
HMGN	His Majesty's Government of Nepal
ICIMOD	International Centre for Integrated Mountain Development
IDRC	International Development Research Centre
JKC	Jhikhu Khola catchment, Nepal
JKW	Jhikhu Khola watershed, Nepal
masl	metres above sea level
NARC	National Agricultural Research Council
NARMSAP	Natural Resource Management Sector Assistance Programme (Nepal)
NGO	non-governmental organisation
NWFP	Northwest Frontier Provinces
PARDYP	People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project
SDC	Swiss Agency for Development and Cooperation
SLCP	Sloping Land Conversion Program
SRI	system of rice intensification
SSMP	Sustainable Soil Management Program
TM	traditionally managed (rice cultivation)
VAM	vesicular arbuscular mycorrhiza
VDC	village development committee

WOCAT	World Overview of Conservation Approaches and Technologies
XIC	Xizhuang catchment, China
XIW	Xizhuang watershed, China
YKC	Yarsha Khola catchment, Nepal
YKW	Yarsha Khola watershed, Nepal

Non-standard units and exchange rates (as of 2004) used in papers

IR	Indian rupees (exchange rate of US$1: IR 46)
mu	Chinese local unit for land size (1 ha = 15 mu)
NR	Nepali rupees (exchange rate of US$1:NR 74)
PR	Pakistani rupees (exchange rate of US$1: PR 59)
yuan	Chinese currency (US$1: 8.3 yuan)

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Overview of PARDYP Research: Promising Approaches to Watershed Management

Roger White

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with an

Overview of the PARDYP Watersheds and Components

by the PARDYP Teams

Abstract

Over the last seven years PARDYP has carried out research on watershed management in the Midhills of the Hindu Kush-Himalaya region. The research has been carried out by national research institutions in five watersheds of between 60 and 100 km^2 in area. This work has improved the understanding of impacts of hydrometeorology on the land, land use dynamics, the community management of natural resources, and hydro-meteorological patterns. In this introduction chapter, we summarise the major learning from PARDYP Phase 2, based on the findings presented at a wrap-up workshop held in December, 2003. Ten of the options for development that have been tested, demonstrated, and promoted by PARDYP are proving popular with farmers across the region and are described. Some of the broad research findings that need further investigation and clarification during PARDYP Phase 3 (2003-2005) are presented.

PARDYP Research

It is generally accepted that environmentally sound land use practices are needed in upper catchments to maintain downstream water quality and quantity. In turn, secure livelihoods for upland farmers are essential to maintain these environmental services for downstream users. This can best be promoted by fully involving those who live in the upstream catchments in measures to improve environmental conditions and local livelihoods. In this way, between 1997 and 2003, the People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP), has developed approaches in its five watersheds that reflect local priorities, practices and norms (see p.11 below for a description of the project and its watersheds).

External evaluations carried out by the project's donors in 1999 and 2002 found PARDYP's success to have been due to:

- its long term commitment to working with communities and building up relations with them with no great rush to get results;
- it placing young staff in the watersheds who have been willing to learn from local farmers; and
- the low expectations of the communities as PARDYP is recognised as a research project and not a development project.

Testing options with communities – PARDYP's success has been largely due to the way it has built up the credibility of its research teams with local people so that local people have become willing to trust the teams' recommendations and try out the new ideas and methods being promoted. PARDYP's approach has led to farmers and researchers working together to try out these new ideas.

Understanding the environmental context – In the middle mountains of the Hindu Kush-Himalayas (HKH), with its predominantly monsoonal climate, farmers have to deal with excess water in the monsoon and water shortages during the dry season. The area's increasing population and intensifying farming practices have made it crucially important to manage the area's water supplies more efficiently. PARDYP has worked on developing and demonstrating water management techniques to overcome the problems of excess and deficient water for domestic and cropping needs. It has promoted water harvesting, pond tanks, cisterns, groundwater recharge, drip irrigation, and micro-sprinklers as options to improve water availability and the more efficient use of water.

What then has PARDYP achieved in Phase 2?

Impacts of Hydrometeorology

In Phase 2 PARDYP has given much attention to collecting information on the hydrology and meteorology of its study areas. The resulting hydro-meteorological data sets provide a long-term baseline against which the impact of changes in land use and land management on water quality and quantity can be measured. This is an important source of information for understanding the impact of processes and of changes in these processes. This information reinforces much of the knowledge already available on the intensity and distribution of rainfall. Such information is useful for other researchers, in particular for understanding issues to do with global climate change.

In addition PARDYP has drawn together the data from its five watersheds to analyse parameters such as soil erosion, rainfall intensity, and high flows. The data collected on rainfall, runoff intensities, variability, seasonality, and other facets has been published in yearbooks. This information is useful and unique. As a final product PARDYP will produce a consolidated yearbook containing all the hydro-meteorological data from its watersheds.

PARDYP has not been able to detect changes in hydrology regimes, such as reduced low flows or increased incidence of floods, probably because its network has not been sensitive enough to detect this, or, where it has been sensitive enough, the changes have not been large enough to detect over the relatively short observation periods. However, the baseline should prove useful for future researchers on climate change in mountain areas. Its findings have led PARDYP to conclude that water shortage is a more important issue than floods.

A second strand of PARDYP's research on water has been on the management of water resources. The work in each watershed has reflected the different conditions, available skills, and local priorities. For example PARDYP China has developed a cascade system of underground tanks for domestic and irrigation water with help from government agencies (see Li Zhinan 2005 in this volume) These tanks are fed by perennial springs. PARDYP has also supported farmers to build smaller surface tanks for irrigating maize crops.

The same approach has generally not been possible in Nepal's Jhikhu Khola watershed where most perennial springs and streams are already used to capacity. Some water tanks have been installed by the water supply board at Bela in this watershed, and communities tap streams by diverting spring and streamwater from the sources with plastic pipes. Therefore, the work on water management options in Nepal has concentrated on the better use of water through sprinklers and drip systems and by enhancing domestic water supplies by collecting rainwater from roofs and by channelling runoff into underground tanks for irrigating dry season crops. In India water from perennial streams and springs has been channelled into plastic lined ponds. Some of these have been used to raise fish. This has been very successful and there are over 70 fish ponds in the PARDYP India watershed.

Nearly all households in the Pakistan watershed have day-long access to piped water. This gives enough water for kitchen gardening and so little need is felt to improve either water management or to expand irrigation into the dry season. No water harvesting structures are planned for this area, but trout farming is being tested with the poor Gujar communities in the upper watershed.

The monitoring of spring and river sources has highlighted problems with drinking water quality. Water quality studies found faecal coliform contamination in most spring sources in all watersheds, often at many times the maximum World Health Organisation limits. New piped water supply schemes have benefited many villagers in the watersheds; but this has often led to the old springwater sources being abandoned and the user groups ceasing to function. The problem with this is that when the new supply systems fail there is no alternative source to fall back on.

PARDYP has recognised the importance of reacting to results arising from its research. The development of options for improving water quality is one example of how research findings have helped change PARDYP's research priorities.

Land use research

PARDYP has supported studies to understand how changes in land use and husbandry innovations are impacting the local hydrology in terms of water quality and quantity at sub-catchment level and for seasonal flows. The most important types of changes in land use to record are in the balance between forest, dry land agriculture, and irrigated agriculture.

The studies have found that existing systems are far more resilient that previously thought. Trials are underway to look at the hydrological impact of converting grasslands to hybrid poplar and vegetables in Hilkot watershed, Pakistan. Such changes may lead to detectable increases or decreases in seasonal water discharge at the sub-catchment level (20 ha in this case), but may not have an effect at the watershed level (in this case 1600 ha).

All visitors to the Nepal watersheds are interested to see how local farmers continually transport litter and fodder from the forests to the households, and the subsequent movement of compost to the fields. In the Jhikhu Khola valley bottoms, up to 50 tonnes of farmyard manure are commonly added to each hectare of agricultural fields each year.

An early PARDYP finding was the problem of acid soils. Much work was carried out to look at acidification processes including the contribution of pine needles in compost and livestock bedding. Trials carried out in 2003 on liming rainfed fields showed promising results. However, it would appear that acid soils are not really such a big problem in the other watersheds and certainly not in the Chinese watershed with its karstic limestone. Soil results from Pakistan indicate that soils there need to be acidified if tea is to be grown successfully. It would appear that the very intensive nutrient management manifest in the heavy workloads of compost making and additions in Nepal has developed to overcome the problem of acid soils. This hypothesis needs further testing and in 2004 the Nepal team will try to find out if land management methods differ on the soils derived from limestone within the Jhikhu Khola. The results of project studies on soil fertility dynamics in the Nepal watersheds are presented later in this volume by Shah (2005).

PARDYP'S research on farming systems and cropping intensities has recorded the great intensification of cropping on the best quality valley bottom lands. Some marginal areas have become less intensively cultivated because of out-migration. There been no extensification of land use.

Integrating research findings from land and water

PARDYP has looked at the interactions between land use and climate parameters, and at the levels of soil erosion and sedimentation. PARDYP and other studies have found that rates of soil erosion have been lower than expected in all the PARDYP watersheds. Soil erosion from agricultural land tends to be low, whilst degraded land consistently shows much higher rates. This indicates the effectiveness of measures taken by farmers to conserve soil and shows that most attention needs to be given to reducing soil erosion on degraded lands, most of which is common property land. The findings that soil erosion occurs mostly on degraded land reinforce PARDYP's earlier findings from Jhikhu Khola.

The analysis of soil erosion data is beginning to give very interesting results although PARDYP is reluctant to make concrete statements based on only a few seasons' findings from its erosion plot studies. However, the Jhikhu Khola research has now reached a stage – with 44 plot-years of data, and other results from China, Pakistan and India, and from other studies carried out by the Lumle Agricultural Research Station, Nepal – where concrete statements can be made. These studies indicate that soil erosion from rainfed land, in terms of volume of transported soil, is not a significant problem. This directly contradicts the problem and situation analysis produced during PARDYP's planning and replanning exercises. It also goes against the widely held views that soil erosion is a significant problem in the middle mountains of the Himalayas. This analysis clearly shows that farmers' land management practices are very effective in minimising soil erosion. The erosion rates in the PARDYP watersheds have been found to be low compared to the rates reported from Asia by the International Board for Soil Research and Management's (IBSRAM – Bangkok) research.

Jehangir (2005) in this volume presents the results of the climate-soil erosion links for the PARDYP watersheds. This has been a difficult job as the work started without a clear hypothesis which meant that erosion rates from different land uses cannot be compared. The results focus on rainfall amount, its erosivity, and its timing. The broader implications for land managers are not so clear.

Developing Options for Farmers

Water management

For improved water management PARDYP recommends:

- protecting spring sources, promoting local management rules by strengthening user groups, and planting vetiver grass to filter overland flow;

- treating water at the household level through the SODIS solar distillation method using one litre discarded plastic water bottles, and treatment with chlorine where contamination remains;
- installing plastic-lined ponds for harvesting rainwater and perennial water sources;
- installing 500 litre tanks for harvesting rainwater from roofs for domestic supplies throughout and following the monsoon; and
- installing simple, locally available, cheap drip irrigation sets (with or without plastic mulches) to cut water needed to grow some crops by up to 60%.

An important area that PARDYP has identified is the amount of leaching of nutrients from soils in farmers' fields. This seems to be significant and can have a large impact on farmer's costs and groundwater quality. From 2004 PARDYP plans to look at ways of improving the time and rates of fertiliser application through lysimeter studies of nutrient movements.

On-farm research

PARDYP seeks to identify sustainable farming practices that reduce negative environmental impacts and increase farmers' incomes without increasing women's workloads.

On-farm trials in Pakistan, India, and Nepal have raised many questions. The few failures have helped to provide a broader understanding of issues of adoption and scaling-up. In Pakistan the responses from the local community have been excellent and this has led to high credibility and the consequent adoption of many practices promoted by the project including vegetable seed production, line planting maize, and intercropping.

One of PARDYP's greatest successes has been encouraging farmers to learn about new techniques from each other. For a number of years the PARDYP network has wanted to try out the planting of hybrid maize in rows. Maize was already planted in rows in the Xizhuang watershed in China, but in a very intensive way that was not really replicable elsewhere. Following successes with improved maize varieties in Hilkot in 2001, the Pakistan team started to look at composite and synthetic types of hybrid maize. The high cost of the seed meant that the traditional practice of broadcasting seed and later thinning out the plants was not appropriate. The Pakistan team has been able to double yields and grow other crops in between the rows of maize, whilst also, probably, improving the use of fertilisers.

These successes have prompted the Nepal team to try out this new practice. They plan to start work in 2004 with the International Maize and Wheat Improvement Centre (CIMMYT) and the Swiss Agency for Development and Cooperation-funded Hill Maize Project. Although maize is less important to farmers in the India Bheta Gad watershed, hybrid maize could be usefully demonstrated to farmers there.

PARDYP needs to also learn from outside initiatives. Work on improved composting has not been a success in Nepal partly due to the lack of follow-up by PARDYP's local partners. However, the Swiss-funded Sustainable Soil Management Program (SSMP) is promoting the use of black plastic sheet covers to improve compost quality. This will be tried by PARDYP Nepal in 2004.

PARDYP has had some clear successes but now needs to clarify and consolidate these results and decide what to do next. One approach would be to get each country team to consider the five or so best options, pieces of information, or advice that has come out of their work; then describe them and plan the next steps including perhaps more research and testing, and then consider how to get more farmers to adopt the new techniques.

The following PARDYP-tested measures show great promise for farmers of the HKH region:

- line planting, incorporation of legumes, and improved fertilisation to improve maize yields;
- improved terracing;
- fish ponds in areas with perennial watersources using three species of carp to exploit different niches within ponds and provide income and nutritious food;
- the application of biofertilisers such as rhizobium and azotobacter to improve crop yields;
- planting crops in mixtures to lessen the risk of complete crop failures and to diversify incomes;
- drip irrigation to reduce water demand and labour inputs; and
- using the system of rice intensification technique of planting rice to increase yields.

The demonstration of alternative pest management with bio-pesticides has shown promise but has not been adopted because it is too time consuming and is less effective than the cheap readily available pesticides. Work on the application of lime to acid soils needs elaborating.

Soil fertility

PARDYP has documented soil fertility dynamics on intensively-used land since 1989 in various publications and has linked these dynamics to changing land use and land use practices in the Jhikhu Khola watershed. It has become clear that farmers are able to detect change and come up with solutions faster than researchers. The details of this work are detailed by Shah in this volume (2005).

Common property resources

The rehabilitation and management of common property resources has been an important theme in PARDYP's research. One of the main conclusions has been that the handing over of management responsibilities for common property to user groups often improves management. The research has also shown how developing community responsibility by forming user groups and applying a range of technical options including recommended species for planting will most often lead to the rehabilitation of degraded land.

Land use dynamics

PARDYP has mapped the land use in its five watersheds and either by repeating these surveys over time or by using historical data has been able to see land use dynamics. Further work is needed and repeat surveys will be carried out in 2004 using new satellite data. The main finding so far has been that all of the watersheds have either stable or increasing forest cover. These findings cannot be generalised as different approaches to land management in the watersheds have different impacts. However, in Nepal there appears to be a reduction in the quality of forest cover probably due to the on-going insurgency. Separate analyses and country studies need carrying out to quantify change.

PARDYP's studies of common property resources have found that the degraded parts of forests in its watersheds, although they make up about only five percent of the total area, contribute about 50% of the river-transported sediment that leaves the watersheds. The lasting rehabilitation of these areas will only happen if local users benefit. In Nepal, forests provide fodder for livestock and litter for bedding that end up as compost to fertilise arable land.

Technical solutions to biomass production (planting fodder trees and grasses, improving forest management) and reducing soil erosion (by plugging gullies and reducing surface flows) are relatively easy to put in place. The challenge is more in terms of the institutional arrangements needed for the long-term sustainable management of these areas.
But ideas cannot be merely transplanted from area to another. For example, Nepal's community forestry approach needs modifying to fit different national conditions for use in other countries.

Adoption of options

PARDYP has found that the adoption of innovations it has promoted relies on it:
- establishing the credibility of its research teams with local farmers;
- having sensible and workable options for improvements to be tested and demonstrated; and
- involving farmers as research partners.

The basket of sensible and workable options considered suitable for research farmers to test and adapt consists of many well-know technologies and practices. As research continues many of the possible options are dropped by farmers for being judged unsuitable for local conditions. Local farmers have tried green manuring and growing button mushrooms but have not wanted to adopt them. However, these options may be suitable for other conditions. Combinations of options can have a significant impact such as improved composting combined with line planting, water harvesting, and drip irrigation. Simple changes can have dramatic results.

Some examples of transfer of innovations from one area to another have been:
- broom grass from northeast India to Uttaranchal;
- large cardamom from Sikkim to Nepal; and
- fish ponds from Pithoragarh to the Bheta Gad watershed in India.

Some examples of transfer of innovations between PARDYP watersheds have been:
- the system of rice intensification from Nepal to Bheta Gad, India and Hilkot, Pakistan;
- fish ponds from Bheta Gad to Hilkot; and
- broom grass and large cardamom from Nepal to Bheta Gad and Pakistan.

Popular Options

PARDYP's research has found the following ten options to be the most popular as they lead to significant improvements in farmers' livelihoods.

1. Biofertilisers – Trials in India, Pakistan, Nepal and China have shown that the application of certain microorganisms has consistently increased yields by around 25% for beans and wheat. Phosphorous mobilising bacteria and *Azotobacter* species have shown the most promise. Also, yield increases of 40% have happened when legumes have been inoculated with the right strain of rhizobium.

2. Improved seed – Good quality seed makes a large difference. In 1999 maize farmers in the PARDYP Pakistan watershed doubled their yields by planting improved varieties. In 2002 farmers planted hybrid maize and doubled their yields again. In India wheat yields doubled when improved varieties were planted. However, improvements in one area may lead to other kinds of problems emerging. For example, using more demanding improved varieties may lead to shortages in micronutrients. Farmers too recognise that it is crucial to maintain soil fertility and hence techniques for improving the quality and quantity of compost are very popular.

3. Napier grass – The growing of Napier grass is spreading through farmer-to-farmer diffusion. Napier grass for fodder grown on field margins and terrace risers has been promoted by NGOs, projects, and line agencies for many years. PARDYP Nepal is promoting 11 grasses and fodders suited to a range of altitudes and soil types and a wide range of farmers' needs.

4. System of rice intensification – Rice farmers can increase their yields by up to 50% by adopting aspects of the system of rice intensification (SRI) such as early transplanting using 7-10 day old rice plants. This doubled the number of tillers over traditional practices in all farmers' trials in the Pakistan and Nepal watersheds. But so far trials in the PARDYP-India watershed have been unsuccessful. In 2003, 10 farmers in the Nepal watershed tested SRI. All of them selected small blocks of their poorest paddy land as they were not convinced it would work, but they went ahead because of their previous successes with PARDYP's recommendations. In all cases farmers reported that their highest yields came from their SRI plots. PARDYP is planning to try the same approach in 2004 in India and Pakistan. It looks like it is the stress caused to the plants by the early transplanting that leads to quadrupling the number of tillers per plant and yield increases. The significantly more labour needed for weeding has not dissuaded small farmers from adopting this technique as their primary concern is to increase yields.

5. Fish farming – Another success has been with fish ponds in the Bheta Gad watershed, Uttaranchal. What started as one trial with a water harvesting pond fed by a small perennial water source for irrigating vegetables has been developed and adopted by many farmers. There are now more than 70 fish ponds in this watershed. This backyard fish culture has been modified and adopted by farmers. Ninety percent of fish pond owners are poor scheduled caste people. PARDYP is receiving many requests from watershed management practitioners to know how to set up and run these ponds.

6. Off-season vegetables – It is important that mountain farmers take advantage of their 'niche' climatic conditions. This is often their only comparative advantage over agricultural enterprises in the plains. If market access is good, off-season vegetables and temperate fruits can give very good returns. While some farmers in Nepal have been quick to intensify the valley bottom production of irrigated vegetable crops, there has been virtually no improvement in crops like papaya and lychee which are both seen as crops for home consumption and the surplus for giving away to friends and neighbours. In Pakistan, the raising of grafted fruit trees for sale to meet increasing local demand, and the growing for sale of improved pears (sold at 10-20 rupees per 25 kg) and walnuts in Uttaranchal may also prove to be successful enterprises.

7. 'New crops' – In some areas it may be possible to grow fruit commercially or semi-commercially. Fruit can also improve family nutrition. The introduction of new fruits such as 'low-chilling' apples that do not need low temperatures to fruit, and kiwi fruit for October/November harvesting extends the period when fruit is available. This spreads both the labour requirements and the income through the year. Marginal degraded land is often the only land available for expanding agricultural activities. The establishment of fruit trees on this

land is difficult but not impossible. New approaches used in Pakistan have combined the use of eyebrow terracing and porous pitchers to establish apple trees on stony dry areas. Fortunately rainfall is quite evenly spread throughout the year in the Pakistan watershed and so, by concentrating on collecting water from the small but frequent rainfall events, it has been possible to achieve good establishment.
Other promising new crops include shitake mushrooms grown on alder logs for selling to East Asian markets, and asparagus for sale to urban markets and for export.

8. Improved composting – The adoption of new practices often leads to agricultural intensification and more demand for nutrients. The imposition of the stall-feeding of livestock following the introduction of community forest management has significantly increased the availability of farmyard manure in Nepal. The use of improved forages can also increase the amount of farmyard manure. Improved composting can also make significant improvements in soil fertility management. Significant improvements in quality (10%) and rates of composting (40% faster) by covering compost heaps with black plastic sheets have been demonstrated in Nepal and is proving popular.

9. Degraded land rehabilitation – In the Bheta Gad watershed in India, the out-migration of young people from farming families has led to a large area of agricultural land being abandoned. This land is now being used for open gazing and is threatened by degradation. PARDYP has promoted the rehabilitation of these sites by mobilising families to informally consolidate their individual plots. It has promoted the rehabilitation of these degraded lands by increasing green cover through planting fodder trees and grasses, by improving forest management, and by reducing soil erosion by plugging gullies and reducing surface flows.

This has led to farmers in four other villages doing the same to overcome their fodder and timber shortages. An important reason for the success of this has been the testing and demonstration of new technologies and species by the PARDYP researchers including both native local and exotic species and techniques. The challenge is now to establish the institutional arrangements for community management that will lead to access and benefit sharing to promote long term sustainable management of these areas.

10. Drip irrigation – In areas of water scarcity the use of locally available and inexpensive drip irrigation systems enable farmers to grow off-season vegetable crops; the use of eyebrow terraces and pitcher irrigation enable farmers to establish fruit tree orchards; and the use of water harvesting in ponds can significantly increase income. Small mud-lined farm ponds of 10 m^3 size are providing income of $100 or more per year in PARDYP India's watershed.

Conclusions

In summary PARDYP's research findings have found that:

- although there are many good options for farmers, many are not being adopted because farmers are unaware of them;
- on and off-farm demonstrations, with many options at one location serving as a kind of 'beacon' for farmers, can greatly increase adoption by farmers. However, for up-scaling local extension staff need to well-trained and to have established their credibility and trust with farmers;
- working with farmers to develop ideas can be rewarding and lead to good results;
- natural systems seem to be more resilient than generally thought to changes in land use and farming practices. But there may be a strong 'buffering' effect where changes in

environmental parameters such as increasing nitrogen levels in water or increasing soil acidity only become visible later;
- the health of the five research watersheds over the last 10 years has at least been maintained or has improved significantly in terms of tree cover;
- the rates of soil erosion from agricultural land are much lower than originally thought, while soil erosion from degraded land may be the source of most river-transported sediment
- the most important hydrological issues are the low flows in watercourses during dry periods and how to improve water management, rather than about floods and how to reduce peak flows; and
- new unforeseen problems are arising in farmers fields including new nutrient deficiencies resulting from more intensive cropping.

An important lesson that PARDYP has learnt is the importance of tailoring its recommendations to meet farmers' preferences. Unsuitable options will be ignored. An example of this came from the PARDYP-Pakistan area. Here, the bulk of agricultural land is owned by the Swati ethnic group, but it is farmed by the Gujars who keep livestock. They operate a sharecropping system with the landlords. Crop residues are a very important source of fodder for the tenant farmers. Consequently PARDYP's attempts to introduce high yielding, short-straw varieties failed. The doubling of grain yield was very attractive to the landlords, but the new varieties were not adopted by the Gujar farmers because of the poor fodder straw yields. PARDYP is now searching for high yielding long-straw varieties. This was a good lesson for the project.

As PARDYP conducts more research and gains more credibility new avenues of funding have opened up. It seems that government agencies, NGOs, and projects are willing to make money available for development activities in all the PARDYP watersheds. What seem to be missing are new promising ideas from all development actors. One problem is that projects often have an intervention cycle that is too short for the PARDYP process of building up credibility, understanding communities' needs, and identifying credible solutions. PARDYP has taken seven years to gain credibility. Many large projects such as the Bagmati and Wang watershed management projects are only five-years long. Success can be very difficult to achieve in such short time horizons.

All projects have strengths and weaknesses. Only when PARDYP networks in an honest and frank way can it learn from other projects in terms of successes and failures. PARDYP and other projects need to give more attention to this.

PARDYP's Five Watersheds and Six Components

The PARDYP Teams

1

PARDYP is a research for development project, funded by the Swiss Agency for Development and Cooperation (SDC), the International Development Research Centre (IDRC) of Canada, and the International Centre for Integrated Mountain Development (ICIMOD). It operates in five middle mountain watersheds across the Hindu Kush-Himalayas (HKH) with two in Nepal and one each in China, India, and Pakistan. The location, drainage pattern and basic characteristics of the watersheds are given in Figure 1 and Table 1.

PARDYP is coordinated and managed by ICIMOD and implemented by the following partner institutes:

- Kunming Botanical Institute and the Centre for Biodiversity and Indigenous Knowledge (CBIK) in China;
- G.B. Pant Institute of Himalayan Environment and Development (Almora) in India;
- Pakistan Forestry Institute (Peshawar) in Pakistan; and
- ICIMOD in Nepal.

PARDYP Phase 1 ran from October 1996 to September 1999, Phase 2 from October 1999 to December 2002, and Phase 3 runs from January 2003 to December 2005. These workshop proceedings show the progress made in Phase 2.

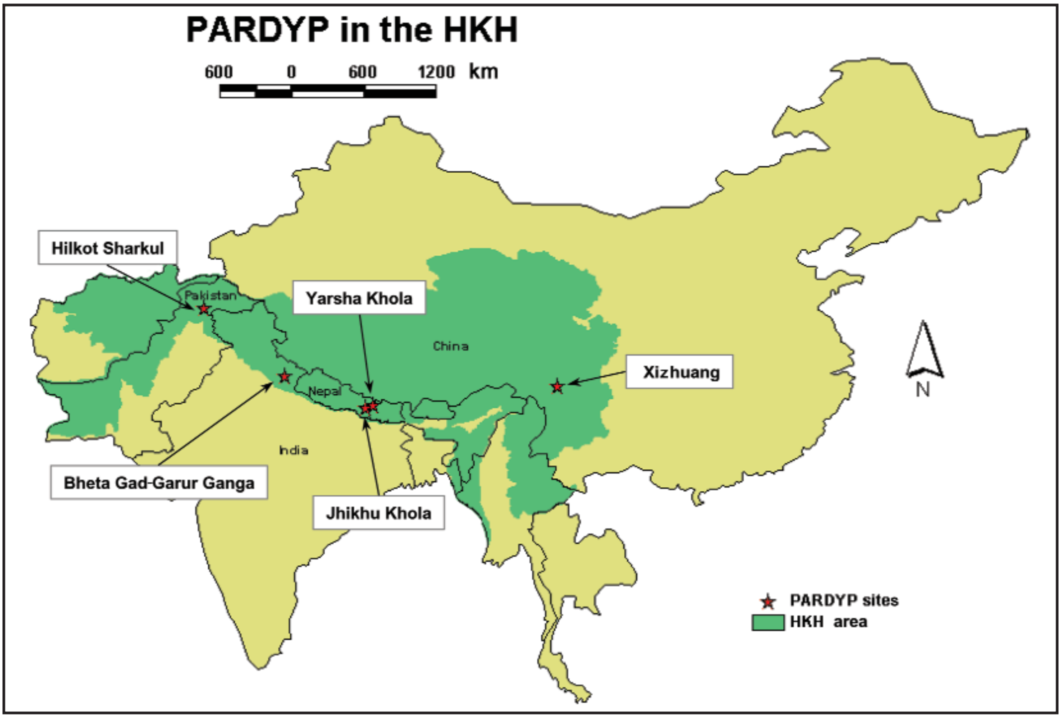


Figure 1: **Location of PARDYP watersheds**

Table 1: **Characteristics of the PARDYP watersheds**

					
	Xizhuang	**Bheta Gad-Garur Ganga**	**Jhikhu Khola**	**Yarsha Khola**	**Hilkot- Sharkul**
	China	**India**	**Nepal**	**Nepal**	**Pakistan**
Physiography	Xizhuang	Bheta Gad-Garur Ganga	Jhikhu Khola	Yarsha Khola	Hilkot-Sharkul
Total area	3,456 ha	8,481 ha	11,141 ha	5,338 ha	5,230 ha
Elevation range (masl)	1700-3075m	1090-2520m	800-2200m	1000-3030m	1448-2911m
Climate	Wet and dry seasonal variations	Sharp wet and dry seasonal variations	Humid sub-tropical to warm temperatures	Humid sub-tropical to warm temperatures	Humid sub-tropical to cool temperatures
Average rainfall (mm/yr)	1413 mm	1291 mm	1316 mm	2276 mm	911 mm
Dominant geology	Limestone and sandstone	Schists and gneiss	Mica schist and limestone	Gneiss and slate and graphitic schist	Micaceous schist, and slates
Population	4016 (1997)	14,524 (1998)	48,728 (1996)	20,620 (1996)	11,322 (1998)
Population density (people/km^2)	116 (128 in 2002)	171	437 (587 in 2001)	386	243
Average family size	4	7	6	5	8
Dominant ethnicity	Han Chinese	Brahmin, Rajputs, scheduled castes	Brahmin, Chhetri, Tamang, Danuwar	Brahmin, Chhetri, Tamang	Gujar, Swati, Syed
Major cash crops	Tea, tobacco, fruit	Winter vegetables, fruit, tea, fodder	Potatoes, tomatoes, rice, fruit, vegetables	Seed potatoes, fruits	Fruit, fodder
Main staple crops	Maize, wheat, beans, potatoes, rice	Mixed cereal grains, rice, wheat	Rice, maize, wheat, potatoes, millet	Maize, rice, millet, potatoes, wheat	Wheat, maize, rice

PARDYP evolved from the following IDRC-funded initiatives:

- the three-year long Soil Fertility and Erosion Project and the follow-on four-year Mountain Resource Management Project (1989-1996) that undertook resource dynamic studies in the Jhikhu Khola watershed, Nepal; and
- the Rehabilitation of Degraded Lands in Mountain Ecosystems Project (1992-1996), undertaken by research institutes in China, India, Nepal and Pakistan involving the rehabilitation and regreening of patches of degraded and denuded land on HKH valley slopes.

The project was launched in response to concerns about the pressures on the resources and people in the HKH middle mountains. Issues of particular concern were the marginalisation of the mountain farmer, the declining availability of water and land, forest degradation, declining soil fertility, declining carrying capacities of the resource base, the lack of natural regeneration, and the challenges to providing for the needs of the increasing population.

PARDYP is carrying out research for development in hydrology and meteorology, farming systems, land cover, water availability and management, soil erosion and fertility, on- and off-farm conservation, land rehabilitation, community forestry, agronomic and horticultural initiatives, and social, economic, gender and marketing issues.

Three international institutions have provided advice, support, and consultancy services to PARDYP since its inception. The University of British Columbia provides inputs mainly in Nepal on soil fertility management and productivity through periodic visits by its staff. The University of Berne provides expert advice on hydrology through periodic visits and a permanent research hydrologist based in Kathmandu. Inputs from the University of Berne cover all five watersheds. From January 2003, the Geography Department of the University of Zurich has been assisting PARDYP with issues relating to access to natural resources and by providing broad backstopping in the social sciences. Representatives from these three institutes are members of PARDYP's Technical Advisory Committee.

In Phase 2 project activities were organised around the six components of 1) community institutions, 2) gender and equity, 3) water resources, 4) common property resources, 5) on-farm activities, and 6) livelihood potentials. The highlights of the Phase 2 work were as follow.

Community institutions

PARDYP has reviewed natural resource policies and decentralisation and accountability in watershed management through:

- carrying out work on decentralisation in China;
- making an inventory of community based organisations in the PARDYP Nepal watersheds;
- carrying out studies in India on the impact of resource dynamics on people's occupations, drinking water, community forestry, and joint forest management; and by
- looking at watershed management issues in Pakistan concerning ethnic groups, land tenure, and conflicts, and by trying out joint forest management.

Gender and equity

PARDYP's Phase 2 work on gender and equality has included:

- in China, running activities to build the gender awareness of government staff that has encouraged them to use gender equality indicators to evaluate the work of government leaders and staff;

- in India, by organising meetings and motivational activities to empower women and women's groups, and by promoting off-season vegetable production, improved composting, and small-scale nurseries;
- in Nepal, by mainstreaming gender issues into most of its activities including in the water, common property resource, on-farm resources, livelihood potentials, research studies, and field action programmes. These programmes have concentrated on the role of women in managing natural resources and have highlighted their central role in managing and harvesting these resources; and
- in Pakistan, by appointing female social mobilisers and a female horticulturalist to support savings and credit and kitchen gardening activities though the project's women's groups, and also by holding women's farmer's days.

Water resources

The daily monitoring of PARDYP's network of 44 meteorological stations, 27 hydro-stations, and 23 erosion plots continued in the four countries. Data has been analysed and published in annual yearbooks for all the watersheds and provides valuable information on climatic conditions, stream flows, and sediment transport. This unique data series is comparable between sites and is extremely valuable for designing hydropower stations, improving irrigation, preventing storm destruction, and other uses.

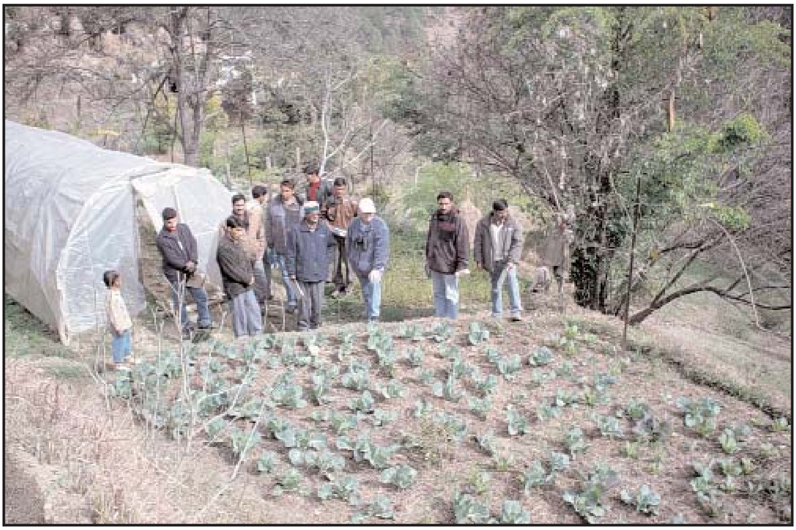
A PARDYP station, Nepal

Common property resources

PARDYP's common resources programme has focussed on community forests in Nepal, village forest panchayats in India, community owned gujara forests in Pakistan, and the central role of women in this work. The rehabilitation of heavily degraded sites is one of the most challenging tasks in these forests. The PARDYP Nepal team has carried out a successful six-year long programme with a user group to rehabilitate such an area. The condition of this area has greatly improved with soil erosion reduced and soil fertility improved. It is now producing much fodder and serving as a demonstration site for other user groups to see the potential of degraded areas.

On-farm activities

- In China, on-farm trials have been carried out to introduce new crops and varieties; experiments have been run on agroforestry, reforestation, and water harvesting; and local farmers have been trained in growing tree seedlings and fruit tree grafting.
- In India, the introduction and piloting by farmers of biofertilisers has led to significant increases in grain crop yields.
- In Nepal, many on-farm demonstrations and species performance trials have been carried out. Results look promising for the wider dissemination of alternative pest management, improved rice varieties, the growing of grasses and hedgerow species for fodder and composting, the growing of new cash crops, and the use of drip irrigation.
- In Pakistan over 140 on-farm trials have been conducted including on the effects of organic fertilisers, biofertilisers, intercropping, and cover crops; the performance of new varieties of maize and rice; and on tea growing. Initial results have been promising and farmers have started to adopt many of these new technologies.



Innovations to increase productivity

Livelihood potentials

- In China, PARDYP has supported the establishment of nurseries that are growing forest and agroforestry tree species and tea plants.
- In India, the project has successfully introduced small-scale fish farming and improved bee-keeping using an indigenous species of bee.
- The PARDYP Nepal team has identified a set of strategies for improving livelihoods and has found that increasing cash crop production, although generally beneficial, comes with health hazards due to the overuse of chemicals.
- PARDYP Pakistan has collected data on medicinal plants, trained farmers on keeping local honey bees, promoted the planting of thousands of fruit trees, trained farmers in mushroom production, and run farmer-to-farmer visits to observe alternative ways of farming.

Phase 3 approaches

New approaches are being adopted in Phase 3 (2003-2005) with research activities being carried out in the following four 'expected result areas' through 20 sub-projects.

- Options for improved farming systems productivity developed and tested (ER1 – 7 sub-projects).
- Options to increase productivity of agricultural land tested and disseminated (ER2 – 6 sub-projects).
- Water management options for equitable access identified, tested and disseminated (ER3 – 2 sub-projects).
- Options and approaches to impact sustainable and equitable access to water land and forests are identified and disseminated (ER4 – 5 sub-projects).

More information on PARDYP is available at www.pardyp.org

Part One

On-farm Activities

2

Consolidation of Farming Options Developed in Earlier Phases of PARDYP

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2

Abstract

The Hindu Kush-Himalayan region's diverse social, cultural and agro-climatic conditions and its unique geography and geology mean that a single development approach cannot be applied for the area's sustainable development. PARDYP (the People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project) is a research for development project working in the hills of India, China, Nepal and Pakistan on natural resource management. It identifies and recommends practical solutions to local people's problems relating to food, fodder and water. It highlights the potential for increasing farm incomes through the use of appropriate technologies such as drip irrigation, polyhouses, biofertilisers, and high yielding varieties and the growing of off-season vegetables. PARDYP also promotes multipurpose tree and grass species for rehabilitating degraded land. Such interventions can significantly increase production. Drip irrigation is an effective technique for overcoming water scarcity during the dry season. The introduction of fodder trees and grasses has great potential for the ecological rehabilitation of degraded sites. This paper provides a synthesis of the options tested by PARDYP between 1996 and 2002 and discusses their potentials and constraints.

Introduction

The Hindu Kush-Himalayan (HKH) region occupies approximately 4.3 million km^2, and is home to about 140 million people. It is a unique geographical and geological entity with diverse social, cultural, and agro-economic environments. Consequently, a single developmental approach cannot be applied uniformly to the entire region. The People and Resource Dynamics Project, (PARDYP) is looking at the interrelationships between factors responsible for the degradation of the area's resource base. PARDYP is also examining the way communities manage their natural resources. It is taking new technologies and integrating them with traditional knowledge on agriculture and forestry to restore the natural resource base. This paper provides a synthesis of the options tested by PARDYP between 1996 and 2002. The five PARDYP watersheds, with two in Nepal and one each in India, Pakistan and China are described in the introductory paper in this volume.

PARDYP has used participatory rural appraisal and informal meetings with villager and farmer groups to identify the major problems in its watersheds. The PARDYP team members then suggested and tested potential interventions. Technological interventions were made through participatory action research and were aimed at reducing workloads, increasing on-farm productivity, and the overall uplifting of mountain communities.

Technologies to Increase Soil Fertility

Biofertilisers

Biofertilisers are microorganisms that can improve the availability of key soil nutrients either by fixing nitrogen or releasing important nutrients. Biofertilisers are either fungal or bacterial. Only a few are commercially available and many are at the research and testing stages.

Vesicular arbuscular mycorrhiza (VAM) are fungi that live in a harmonious relationship with plant roots. In this symbiosis the fungi provide the plant with extra nutrients from the soil, especially phosphorus and zinc, in exchange for sugars from the plants. These biofertilisers are cost effective, environmentally friendly, and help to naturally maintain soil fertility. Biological nitrogen fixation, a microbial process that converts atmospheric di-nitrogen into a usable form, helps to maintain soil nitrogen reserves. Biofertilisers are particularly important in mountain areas as they can be easily transported. A small packet weighing a few hundred grams can provide the same amount of nutrients for crops as inorganic fertiliser weighing hundreds of kilograms. The limited availability of these biofertilisers to farmers is the major constraint for their wider use.

In India the application to the soil of the biofertiliser *A. chroococcum*, strain:

- W5 increased wheat production by around 14% over a series of 250 trials in four years;
- CBD-15 increased paddy production by around 18%;
- A41 increased finger millet (Madua) production by between 38% and 43%;
- M4 increased maize production by between 21% and 28%; and
- W5 increased production the production of in the vegetable crops tomato, brinjal, pumpkin and capsicum by around 18%.

In India different rhizobium strains also led to up to 42% increased production in bean varieties and leguminous crops. There was an increase in production of between 10 and 42% by applying biofertilisers. The effect differed by place and season. Paddy production increased by around 17% after applying VAM. Rhizobium on leguminous crops showed the best responses of a 43% increase while *A. chroococcum* on cereal crops showed increases of between 11% and 43% (Table 2.1).

In Pakistan, good germination and increased yields came from rhizobium-treated leguminous plants. Improved germination was a feature of rhizobium-treated seeds increasing yield by between 13 and 17% for soyabean (*Glycine max*), and 46.5 to 100% for mung (*Vigna radiata*) (Table 2.1). In the Chinese trials, tea and maize yields increased after inoculating the soil with the biofertiliser Haio. The increases were 22% for tea and 4% for maize (Table 2.1).

The beneficial effect of biofertilisers on plant growth and yield has been reported from other parts of the world on various crops (Pandey and Kumar 1989; Fulchieri and Frioni 1994; Daramola et al. 1994; Pandey et al. 1998; Daly and Stewart 1999). The main challenge remains of how to provide biofertilisers to farmers. Local government and non-government organisations could play a vital role in its distribution.

Bio-composting

The steep slopes and rugged terrain of the Hindu Kush-Himalayas mean that only limited areas are suitable for agriculture. Farmers have developed ways to make the most of this cultivable land based on their local innovations. Amongst their traditional agricultural practices

Table 2.1: **Results of biofertiliser research trials in PARDYP phases 1 and 2**

Country	Research trial crops	Biofertiliser applied	Yield increase (%)	Length of trials	No. of trials
India	Wheat, local VL-616, 738	*Azotobacter chroococcum* strain W_5	+11.5 to 17.6	4 yrs	65
	Paddy, local, VL-221	*Azotobacter chroococcum* strain CBD-15	+15.6 to 21.4	1 yr	5
	Paddy, local, Vl-81	Nutrilink (VAM)	+15.9 to 19.8	3 yrs	7
	Madua, local, Vl-149	*Azotobacter chroococcum* strain A_{41}	+38 to 42.9	2 yrs	7
	Bean VL-1 Contender	Rhizobium	+14.2 to 25	3 yrs	20
	Soyabean VL-2	Rhizobium	+21.6 to 38.5	3 yrs	10
	Rajma, VL-63	Rhizobium	+42.8	1 yr	2
	Urad, local	Rhizobium	+11.1	1 yr	3
	Mung, local	Rhizobium	+22.2	1 yr	3
	Maize local, popcorn var.	*Azotobacter chroococcum* M_4	+21.1 to 28.2	1 yr	8
	Tomato	*Azotobacter chroococcum* W_5	+18.5 to 20	4 yrs	75
	Capsicum	*Azotobacter chroococcum* W_5	+17.8 to 22.5	4 yrs	75
	Brinjal	*Azotobacter chroococcum* W_5	+16.2 to 18.5	4 yrs	75
	Pumpkin	*Azotobacter chroococcum* W_5	+12.4 to 14.3	3 yrs	100
Pakistan	Mung	Rhizobium	+42.5-100	1 yr	2
	Soyabean	Rhizobium	+13-17	1 yr	2
China	Maize	Haio	+4	1 yr	3
	Tea	Haio	+22	1 yr	3

Note: trials were carried out with both farmers and groups of farmers

the preparation and use of farmyard manure is very important. Farmers depend on manure from their livestock to maintain and increase soil fertility for crop production. But there is only a limited use of crop rotation and nitrogen fixing species to augment soil fertility.

Compost is well-rotted organic matter. Composting is largely a biological process in which aerobic (needing oxygen) and anaerobic (not needing air or free oxygen) microorganisms decompose organic matter and lower the carbon-to-nitrogen ratio. The final product is well-rotted manure or compost. Compost is prepared from vegetable refuse, weeds, rice husks, and sugarcane and animal waste.

Traditional farmyard manure is a mixture of cattle dung, urine, plant residues, and leaf litter that is put as cattle bedding. Farmers remove it every few days and dump it in the open to decompose. Many of their nutrients are washed away as these piles are exposed to rain. It is often applied to farmer's fields when only partially decomposed as it can take more than six months to decompose.

PARDYP has been promoting a simple and cheap technology to improve the quality of farm compost. It involves simply placing the material in a pit and covering it with black polythene sheet. This is particularly beneficial for farmers with limited livestock. It helps to maintain soil fertility and improve soil physical and chemical properties and reduces the composting period and the loss of nutrients.

In India, improved pit farmyard manure was tried for vegetable production. In Pakistan, an onion crop was grown with decomposed pine needles composted in a pit and was compared with other traditional types of compost manure and inorganic fertiliser. At the Indian site, the use of this improved compost led to an 8-12% increase in yields and a reduction in the incidence of diseases (especially cutworms). A 78% increase in the onion crop was recorded at the Pakistan site after applying improved compost (Table 2.2). Swift and Palmer (1995), Stewart et al. (1998), Murugappan et al. (2001), and Ojha et al. (2002) have reported beneficial effects of improved compost on different crops and agro-ecosystems in other areas.

Table 2.2: **Improved compost and vermiculture research trials, PARDYP phases 1 and 2**

Country	Trial crops	Intervention	Yield increase (%)	Length of trials	No. of trials
India	Vegetable	Pit compost	8-12	2 yrs	10
Nepal	Bitter gourd	Bokashi	33	2 yrs	1
Pakistan	Onion	Animal, poultry, pine needles, various plant leaves, chemical fertiliser	77.7% increase with pine needles	1 yr	1
China	Maize	Earthworms	5.7	1 yr	3
	Tea	Earthworms	15.6	1 yr	3
India	Vegetables	Earthworms	Positive	1 yr	1

Organic fertiliser

Organic matter takes a long time to decompose and is often applied to fields before fully decomposed which can cause pest and disease problems. Bokashi is an organic manure that can be prepared within about 10 days in summer and 30 days in winter. It is prepared by combining the following ingredients in the following proportions:

- rich organic soil (47%)
- rice husks (13%)
- mustard oil cake (13%)
- chicken manure (10%)
- wood ash (7%)
- rice bran (7%)
- rotten bamboo leaves (0.6%)
- artemisia leaves (2.4%).

The materials are mixed thoroughly and stored under shade to ferment away from direct rainfall or sunlight. Water is added regularly to help decomposition. In Nepal, bitter gourd grown on Bokashi-treated soils gave 33% more yield (Table 2.2).

Vermicompost

Vermicompost is produced by using earthworms to convert biodegradable wastes into compost. Earthworms are vital for soil health and plant growth. The beneficial effect is because earthworms eat up plant material and soil, grinding it down in their digestive tracts and excreting it as small granular pieces. It normally has a black or dark brown colour. The chemical composition of vermicompost is superior to compost made in pits or by bacterial decomposition.

This technology was demonstrated in a few farmers' field in the Indian PARDYP watershed. In China experiments were conducted by applying vermicompost to tea and maize crops. There was a reported 5.7% yield increase for the maize and 15.6% for the tea crop (Table 2.2). Atlavingte and Vanagas (1982), Kale and Bano (1986), Radha et al. (1992), and Clive and Johan (1992) have reported beneficial effects from applying vermicompost to crops.

Technologies to Increase Yields

Improved seed varieties

High yielding crop varieties give higher yields and in some cases are more resistant to diseases than traditional varieties. Farmers often realise more profits from high yielding varieties of grain and vegetable crops compared to local varieties. PARDYP provided the seed of new varieties to farmers in its watersheds. This led to many farmers replacing their old varieties with the new ones.

In India the high yielding wheat varieties VL-738, 616, finger millet (Madua) VL-149); paddy VL-81; maize (Amber Popcorn); and pea (Azad-p1 and Arkil varieties), were distributed to farmers to test. In Nepal, seeds of high yielding varieties of maize (Khumal, Yellow, Rampur Composite, Arun-2, Bioseed), paddy (Pant-10, Sabiti) and 13 pigeon pea varieties were tested for their performance in farmers' field and experimental stations. In Pakistan different varieties of maize (Pahari, Kissan, Azam, Super 3025), wheat (Suleman, Inqilab, Tatara, Gaznavi, Nowshera-96), rice (Jp-5, Basmati-385, Dilrosh-97, Swati-1), cabbage (Golden Axe, Stand-by, Atlas, Darby day, and First of June varieties), tomato (Roma and Condon varieties) and potato (Cardinal variety) have been tested for yield, disease resistance, and early maturing qualities.

Many farmers are adopting these varieties as they are often suited to local conditions and give up to double the yield of local varieties. In India the VL-738 variety of wheat, the VL-149 variety of finger millet (Madua), and Azad-p1 of pea have become popular yielding 14% to 90% more than the traditional varieties (Table 2.3).

Farmers participating in PARDYP's trials in Pakistan preferred Azam and Super 3025 maize varieties. The production of Azam has reached 7.5 t/ha compared to less than 2 t/ha for traditional varieties. Super 3025 gave 243% more yield than local varieties. The Inqilab variety of wheat has given three times the yield, the JP-5 variety of paddy twice the yield, the Swat-1 onion 36% more, and the Roma tomato 69% more than local varieties. They are all becoming popular among Hilkot farmers.

In Nepal four maize varieties have been tested. The Bioseed hybrid variety performed best giving a maximum yield of 7.6 t/ha and a biomass of 9.2 t/ha with a medium crop duration of 105 days. The Arun-2 variety matured rapidly in only 93 days but gave the least yield at

Table 2.3: **High yielding variety research trials in PARDYP phases 1 and 2**

Country	Trial crops	Variety	% yield increase over local variety, or other finding	Length of trials	No. of trials
India	Wheat	VL-616, VL-738	91.6 to 125%	4 yrs	250
	Madua	VL-149	110%	2 yrs	8
	Paddy	VL-221	Matured in 110 days, tastes good	1 yr	2
	Paddy	VL-81	14.2 to 20%	3 yrs	6
	Maize	Amber Popcorn	50.4%	1 yr	2
	Pea	Azad-p1, Arkil	40 to 60%	3 yrs	40
Nepal	Maize	Khumal Yellow, Rampur Composite, Arun-2, Bioseed	Bioseed, 7.6t/ha	1 yr	2
	Paddy	Pant-10	5.4 t/ha	2 yrs	12
	Paddy	Sabiti	3.9 to 5.6 t/ha	2 yrs	10
	Pigeon pea	1 perennial and 7 dwarf varieties	Icp-13055 best	1 yr	2
Pakistan	Maize	Pahari, Kissan and Azam	Azam, 7.5 t/ha	3 yrs	26
	Maize	Super 3025	243% than local	1 yr	8
	Tomato	Roma	69%	1 yr	1
	Potato	Cardinal	4.6-10 t/ha	1 yr	1
	Wheat	Suleman, Inqilab, Tatara, Gaznavi, Nowshera-96, local	Inqilab, 3116 kg/ha, +123.2% than local	3 yrs	50
	Rice	JP-5, Basmati-385, Dilrosh-97, Swat-1 and local	JP-5 +110.7 % more yield than local	3 yrs	12
	Onion	Swat-1 and Desi	Swat-1 +36%	2 yrs	3
	Cabbage	Atlas, Standby, Darby Day, Golden Acre, First of June	Atlas 47 day maturity, 2418 kg/ha production	2 yrs	3

2.8 ton/ha and a biomass yield of 4.7 t/ha. Khumal Yellow and Rampur Composite were medium in yield but took longer to mature and so farmers preferred them least. The farmers accepted the Pant-10 and Sabiti varieties of paddy as they have proved to be high yielding under high inputs suitable for intensive farming. Only seven of the 13 pigeon pea lines flowered. Pea Icp-13055 variety was found the best (Table 2.3). Tandon and Shah 1982, Shah 1997, Singh *et al.* 1997 have all concluded that using improved crop varieties is necessary to fulfil the food demands of people in the Indian PARDYP areas.

Intercropping, multi-cropping, cover crops and crop rotations

PARDYP has worked on intercropping and multi-cropping to increase the productivity of cropping land. It has also tried out alternatives to the traditional winter wheat-summer paddy rotation. One of the benefits of new crop rotations is to prevent the build up of disease and pests and, if a legume crop is incorporated into the rotation, their may also be improved fertility.

In PARDYP's India watershed, some farmers tried growing vegetable crops instead of the traditional winter wheat crop after the paddy had been harvested. In the Pakistan watershed, farmers tried intercropping combinations of leguminous crops amongst their traditional crops with maize grown with mung bean, mash bean (*Vigna mungo*), and soyabean. Off-season pea has been grown with onion, and mung bean with potatoes. In Nepal, maize was intercropped with bush bean, and the system of rice intensification (SRI) practice was tested (Table 2.4). This innovative technique of transplanting single, very young rice seedlings at wide planting intervals – as opposed to the traditional more mature *bunches* of seedlings per closer interval – has given significant yield increases.

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Table 2.4: **Results of intercropping research trials in PARDYP phases 1 and 2**

Country	Research Trial Crops	Intercrop	Change	Length of trials	No. of trials
India	pea	tomato, radish	positive	1 yr	2
Pakistan	maize	mung or mash bean or soyabean	> PR 2100-9600/ha when either of these 3 intercropped	1 yr	3
	pea, onion	onion + Vas Pea or onion alone	+ PR 44,725 to 90,550/ha when pea + onion	1 yr	3
	potato	bean	+ 46.7% income	1 yr	2
	wheat or maize	wheat + maize + tomato, wheat + maize + radish , maize + tomato + radish	maize + tomato + radish best	2 yrs	30
Nepal	yellow maize	bush bean	Up to + 42.3% income	1 yr	17
	paddy	SRI practice	+58%	1 yr	1

In India some farmers who planted peas and then tomato before paddy reported increased incomes compared with growing wheat after the paddy. In Pakistan, maize with intercropped legumes yielded between Pakistani rupees (PR) 2,100 and 9,600/ha increased income (US$1:PR 58). Peas grown in a mixture with onions gave an income of PR 190,550/ha against the previous PR 100,000 to 145,825/ha when these crops were grown alone. The farmers reported an income of PR 2700 from a 450m^2 plot, when maize was intercropped with mung beans, against an income of PR 1,840 and 1,200 from a single cropping of potato or maize. The maize (Azam variety)-tomato-radish cropping sequence gave the best yields amongst those tried (Table 2.4).

In Nepal, farmers who followed PARDYP's suggestion to grow maize with beans earned more than Nepalese rupees (NR) 25,000/ha per season (US$1:NR 74 in December 2003). Growing these crops singly realised only NR 4600/ha for maize and NR 10,380/ha for beans. The application of SRI rice cultivation increased paddy yields by up to 58% (Table 2.4). Robert (1985), Pilbeam et al. (1999), Sabirin and Hamdan (2000), Zhardhari (2000), and Ojha et al. (2002) have also reported how crop rotations and intercropping have increased yields and soil fertility management in indigenous agriculture systems.

Disease control

Crop diseases are a major problem for most farmers causing reduced production and reduced incomes. Borers and cutworms are major pests in India in all seasons. In Pakistan, defoliating beetles and borers are major problems. For farmers in Nepal's Jhikhu Khola watershed the main problems are plant borer, late blight of tomato, and potato wilt.

In India, well-decomposed farmyard manure checked the problem of cutworms and a 1% solution of the pesticide Sevin greatly reduced borer and cutworm infestations (Table 2.5). In Pakistan, a 1% solution of Sevin was effective against cutworms, and light traps helped control cocciferous beetles (*Anomola dimediata*).

Table 2.5: **Results of disease control research in PARDYP phases 1 and 2**

Country	Trial crop	Disease control application	Change	Length of trials	No. of trials
India	borer	Sevin	1% solu. effective	3 yrs	10
Nepal	tomato, fruit borer	10% solution of titep ati (*Artemisia vulgaris*), andil (*Ricinus communis*), bakaina (*Melia azaderach*), *Vintex negundo* (simali)	+ 58-112% better result compared to control	2 yrs	2
	late blight of tomato	lemon grass, 1:5 & kantakari, 1:25	+65%, and +95% disease control respectiv ely	2 yrs	2
	potato wilt	Ketuki (*Agave americana*) 1:5, kantakari 1:25	kantakari best	2 yr	2
	late blight	plastic tunnel	+ 17% protection	2 yr	2
Pakistan	cockchafer beetles	light traps	useful	1 yr	1
	borers	1% Sevin	100% control	2 yrs	10
	wheat grain	Phostoxin	100% control	2 yrs	10

In Nepal a 1% solution of titepati (*Artemisia vulgaris*), andil (*Ricinus communis*), bakina (*Vintex vigundo*), and simali (*Melia azedarach*) were separately tested against tomato fruit borer. Andil extract was the most effective. For late blight of tomato, lemon grass (*Cymbopogon flexuosus*), kantakari (*Solanum xanthocarpus*), and plastic cloches were tried and kantakari gave the best protection. Potato wilt was successfully checked using a 1:25 solution of kantakari (Table 2.5). Other researchers have reported plant extracts and microorganisms controlling plant diseases (Dubey et al. 1984, Mishra et al. 1988, El-Abyad et al. 1993, Kothyari et al. 1993, and Kothyari 1997).

The use of extracts from locally available plants to control crop pests shows promise. However, it has not been adopted by farmers as the process is time consuming and technical. Pesticides like Sevin are more attractive as they are readily available, cheap, easy to use, and apparently non-toxic.

Income Generating Activities

Low temperatures in the winter in hill areas mean that few vegetables are produced. The low temperatures and frost delay seed germination, slow down growth, and lead to high plant mortality. Associated problems include poor plant quality and lack of uniform plant size.

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Many of these problems can be overcome by covering the crops with polythene in pits, trenches, and polyhouses. Polypits are made by digging pits – usually at least 2.5 ft deep – and covering with a polythene sheet supported on a frame. During warm days the polythene is partly or completely removed to allow sunlight in and maximise photosynthesis. The pits are covered and sealed at night.

PARDYP has also encouraged farmers to use polyhouses for growing winter vegetables. In the Indian watershed, off-season vegetable production was introduced by using polyhouses, polypits, and poly trenches. Vegetable seedlings are raised in the protected structures during winter and then transplanted to the fields as temperatures rise in the spring. This means that the crops are ready for harvesting two to three week earlier than if raised by planting seeds in the open. In Pakistan turnip and in Nepal bitter gourd have been raised as off-season vegetables.

These techniques are gaining popularity in PARDYP's Indian watershed as some farmers are earning more than Indian rupees (IR) 10,000/year by selling seedlings and produce like tomato, capsicum, pumpkins, and brinjal in the off-season when there is a shortage of vegetables (US$1:IR 46) In Pakistan the introduction of turnip as an off-season vegetable has meant that farmers get eight times more income from the same piece of land compared to growing the traditional wheat crop. In Nepal, the introduction of bitter gourd as an off-season vegetable has provided more than NR 9,000/ha from one crop (Table 2.6). Dass et al. (2002) have reported vegetable production as a way of improving livelihoods amongst tribal people in India.

Table 2.6: **Results of off -season vegetable research trials in PARDYP phases 1 and 2**

Country	Trial crops	Product	Change	Length of trials	No. of trials
India	tomato, capsicum etc.	seedling and fruits	>IR 10,000/yr	4 yrs	25
Pakistan	turnip	leaf	> 8 times	2 yrs	2
Nepal	bitter gourd	fruit	> NR 9,000	2 yrs	3

Value Addition and Other Supporting Activities

Water harvesting technology and drip irrigation

Water shortages caused by fluctuations in rainfall can seriously damage crops and reduce yields. Long dry spells lead to root and stem wilting and can lead to plant death. Farmers need to irrigate their crops to supplement the often inadequate rainfall. PARDYP has promoted drip irrigation. It is a simple technology that helps overcome water shortages. Its application ensures a uniform water supply to plant roots resulting in better growth and higher yields. An upland farmer using drip irrigation fed from a small water source can easily produce off-season vegetable in lean periods. The drip system typically uses only 60% of the water used by irrigating with buckets. In Pakistan and Nepal this technology has been tested with off-season production of tomatoes, bitter gourd, and cauliflower.

It has shown positive result in all tested plots leading to a doubling of profits for some farmers in Nepal (Table 2.7). Smajstrla and Locasio (1990) and Marr et al. (1993) reported increased vegetable production from using drip irrigation in the USA.

Table 2.7: **Results of drip research trials in PARDYP phases 1 and 2**

Participating country	Research trial crops	Intervention	Change	Length of trials	No. of trials
Pakistan	tomato	drip irrigation	positive	1 yr	1
Nepal	bitter gourd	drip irrigation	> 2x profit	2 yrs	3
	cauliflower	drip irrigation	> NR 250-300/ha	1 yr	1

Management and improvement of wasteland

Large areas of land in the hills of the Hindu Kush-Himalayas have become low output grazing and wasteland. Such areas are generally used to produce grass during the monsoon season (mid-June to September) and are left open for grazing during the rest of the year. This land is not being used to its full potential. It is the lack of technical know-how that prevents improvement of these mismanaged lands. These areas could be better used to increase production and minimise environmental degradation.

In PARDYP's Indian watershed, a number of types of fodder trees and grasses were tried out on degraded community land by villagers as demonstrations. Tea cultivation, vegetable seed production and the production, of fruit trees have been tried out in the Pakistan watershed. In the Nepal watershed a number of species have been tested on degraded sites and nutrient poor degraded red soils for biomass production and improving soil nutrient status.

In India, all tested species performed well. Among the tree species *Dalbergia sissoo* performed the best with *Grewia oppositifolia* and *Bauhinia retusa* as the next best. Among the grass species *Thysanolanea maxima* was the best followed by Napier grass. These produced significant amounts of biomass and increased the fertility of soil and reduced the workloads of women.

In Pakistan in 2000, tea was planted over four hectares in the PARDYP watershed with the help of the Lever Brothers Company and tea growing experts. It is performing well. In other areas farmers are earning good money from vegetable seed and fruit tree plant production on previously barren lands.

In Nepal, the long-term rehabilitation experiments on degraded lands are giving interesting results. The growing of sunflower (*Helianthus annuus*), sunhemp (*Crotolaria juncia*) and pigeon peas (*Cajanus cajan*) in carbon-deficit soils has helped increase the soil carbon pool. Lemon grass (*Cymopogan citrates*), stylo (*Stylosanthes guianensis*), Guatemala and Thailand creeper grass have performed well on red soils under different conditions (Table 2.8). Aronson et al., (1993), Babu et al. (1993), Kothyari et al. (1996a, 1996b, Rebafka et al. (1993), and Muller et al. (1998) have worked on similar lines with restoring degraded lands with many benefits realised.

Table 2.8: **Results of rehabilitation research trials in PARDYP phases 1 and 2**					
Country	**Trial**	**Species planted**	**Effects**	**Length of trials**	**No. of trials**
India	rehabilitation	*Dalbergia* sp., *Grewia* sp, Oak sp., *Alnus* sp., *Bauhinia* sp.	*Dalbergia* sp. performs best.	4 yrs	20
	grass	*Thysanolanea maxima* , Napier, *Pennisetum* sp.	*T. maxima* best	4 yrs	20
Nepal	rehabilitation	sunflower, sun hemp, pigeon pea	carbon increased	4 yrs	1
	red soil	lemon, *Setaria*, Stylo, Thailand creeper	lemon grass best	4 yrs	1
	grass trial	11 types of grass	Guatemala best	4 yrs	1
	fodder trial	7 grasses for fodder & composting	Napier, molasses best	4 yrs	1
Pakistan	tea		positive	1 yr	2
	seed production	onions, vegetables	positive	4 yrs	3
	fruit nurseries	apples, peaches, nuts, etc.	good earning	2 yrs	5

Constraints

There are no local dealers within the PARDYP watersheds or nearby where farmers can purchase biofertilisers, high yielding varieties of seeds, or drip irrigation systems. Farmers depend upon the PARDYP teams to get hold of these items. The process of preparing plant extracts for disease control has proved to be too time consuming to be adopted. A further problem is that the plants may not be available at the time of disease incidence and farmers do not know how to preserve them for out-of-season use.

Conclusions

The sustainable management of cropland, forests and barren land can contribute much to improving natural mountain ecosystems. Many traditional management practices are centuries old and well-established. Good people's participation is needed to successfully introducing new practices. Also, technologies may return promising trial results, but success depends upon the willingness of farmers to use them. Routine demonstrations and on-site training on their use is necessary to increase farmers' confidence and help wider acceptance. Providing integrated training programmes on soil, water and, crop, and pest management are needed to enhance cash crop production among the upland cultivators of the Hindu Kush-Himalayas.

Acknowledgements

The authors are grateful to the villagers and line agencies in their watersheds for providing their land and extending other help to conduct trials and demonstrations. Thanks are also due to the heads of the institutions where the team members are located for providing space and facilities. We also thank IDRC, SDC and ICIMOD for providing funds.

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On-farm Research with and for Farmers: Experience from PARDYP in Nepal

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Abstract

Farmers with good access to markets are increasing their incomes by diversifying their farming systems to produce food for the growing markets. This is resulting in agricultural intensification in areas with access to irrigation. This intensification is creating problems in Nepal's middle mountains with soil fertility depletion, the increased use of external inputs, and very high demands for irrigation water. The People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project's Nepal initiative (PARDYP Nepal) has initiated several on-farm activities to address these issues in the Jhikhu Khola watershed. This watershed lies to the east of Kathmandu in Kabhre Palanchok and Sindhupalchowk districts. Promising options are being demonstrated and disseminated to local communities. The present paper discusses the approaches taken to involve farmers to adapt, demonstrate, and participate in the research. It then illustrates how the dissemination of the adapted technologies has been carried out.

Introduction

The rapidly growing population pressures in the Jhikhu Khola watershed are leading to an increased demand for food. To meet this demand and to increase farm incomes farmers with access to markets and favourable climatic conditions have been increasing their cropping intensities. One example from the Jhikhu Khola watershed shows that the rate of population growth increased from 1.8% per annum between 1947 and 1990 to 2.6% from 1990 to 1996 (Shrestha et al. 2003). Food production has kept pace with the increasing population. The average number of crop rotations have increased from 1.3 to 2.5 per year between 1980 and 1994 (Schreier and Shah 2000) and by 2001 had reached 2.8 rotations per year. Some farmers have started to grow four crops per year on prime irrigated land in valley bottoms (Von Westarp 2002). The consequences of this are depleted soil fertility and increased agrochemical inputs and irrigation water demand.

Schreier and Shah (2000) say that soil fertility is decreasing because of this intensification. The carbon and available phosphorus have dropped to well below desirable levels and soil pH values have become inadequate with pHs of less than 5.0 in about 80 per cent of soil samples taken by these authors. The same authors further report particular concerns about red soils as many of them have pH values below 4.3. These levels favour the solubility of aluminium and iron which can result in aluminium toxicity and create problems with phosphorous availability. Available phosphorous can react with iron and aluminium to make phosphate insoluble.

Farmers try to compensate for reduced soil fertility by applying high doses of mineral fertilisers. Merz et al. (2003) reports farmers in the Jhikhu Khola watershed applying up to 400 kg urea (46% nitrogen), 800 kg diammonium phosphate (18% nitrogen, 46% phosphorus), and 800 kg of complex fertiliser (20% nitrogen, 20% phosphorus) per hectare to their main cash crop of potatoes. An additional 200 kg/ha per annum of other fertilisers are applied to some other crops. A large portion of this applied fertiliser gets washed through the soil into the river system adversely affecting water quality. Farmers are growing more cash crops such as vegetables. To avoid the danger of pest damage farmers are using pesticides in much higher doses than recommended (Shrestha and Neupane 2002).

The main cropping pattern in irrigated land *(khet)* in this watershed's valley bottoms is rice during the monsoon season followed by potato, tomato, or other vegetables. Around a third of farmers do not have enough irrigation water (Merz 2003). An inadequate supply of irrigation water for dry season cropping is the main constraint for these farmers. The average rainfall in the watershed was 1200 mm between 1993 and 2000. More than 80% of precipitation falls during the monsoon months of June to September. The watershed does not have any rainfall-rich area to fulfil dry season irrigation water demands (Merz et. al. 2000). Diesel or kerosene pumps are used during dry seasons to pump water from springs or streams into fields for irrigating winter cash crops. The diversion of water sources to irrigate winter crops is resulting in the drying out of some streams during the winter and is reducing the ground watertable (Nakarmi and Neupane 2000).

Maize is the main monsoon crop on rainfed land *(bari)*. It is followed by wheat, barley, mustard, or the land is left fallow. Farmers grow winter cash crops only in a few small plots where irrigation water is accessible. The watershed's 38% of its agricultural land that is rainfed is mostly left fallow during the dry months due to water shortages. According to Postel et al. (2001), in developing countries irrigated land generally yields twice as much food as rainfed land. Extending irrigation to rainfed areas thus seems to be a good possibility for increasing food production without having to intensify cropping of irrigated land.

PARDYP Nepal has started the following interventions to improve the livelihoods of farmers in the Jhikhu Khola watershed:
- drip and micro sprinkler irrigation system for dry season irrigation;
- demonstrating the system of rice intensification (SRI) to improve yields of monsoon rice;
- demonstrating plastic lined water-harvesting ponds on rainfed land to collect monsoon rainwater for irrigating dry season crops;
- incorporating lime in red soils on rainfed land to enhance soil pH and productivity; and
- introducing alternative pest management using extracts from local plants.

The project has also worked on improving household incomes. Nutrition rich fodder grasses and hedgerow species were introduced to the milk producing farmer groups to increase milk production. This intervention is also increasing farmyard manure production for composting. The project offered farmers the following 11 species: stylo (*Stylosanthes hamata*), molasses (*Melinis minutiflora*), dinanath (*Pennisetum pedecellatum*), vetiver (*Vetiveria lawsoni*), flamengia (*Flemingia microphylla*), tephrosia (*Tephrosia candida*), sunhemp (*Crotalaria juncea*), Guatemala grass (*Tripsacum laxum*), Napier grass (*Pennisetum purpureum*), broom grass (*Melinis minutiflora*), and sunflower (*Tithonia diversifolia*).

The present paper mainly discusses the approaches taken by the project to introduce and adapt these technologies to local conditions and to involve farmers in on-farm research.

Project Approaches

The project has taken different approaches for the adaptation, demonstration, participatory research, and dissemination of new farming practices. The approaches have varied depending on the nature of the technology. The project has mainly worked through implementing:

- research trials and demonstration;
- on-farm participatory research trials and demonstrations;
- farmer to farmer visits;
- networking with different organisations; and
- demand-driven programmes.

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Research trials and demonstration

Many of the technologies tested and promoted by PARDYP are new to farmers. The project has therefore taken the approach of first testing and demonstrating these technologies, mostly at the Ministry of Agriculture's Paanchkhal Horticulture Centre and later at the other four main sites shown on Figure 3.1. This allows the project to get scientific data and experience on how to use and adopt technologies to the local environment. It also gives farmers the chance to observe them before trying it out. Firstly, trials for demonstrating and monitoring activities are established at Paanchkhal Horticulture Centre to allow farmers to observe the effectiveness of new technologies. The second phase will implement participatory trials and demonstrations in farmers' fields.

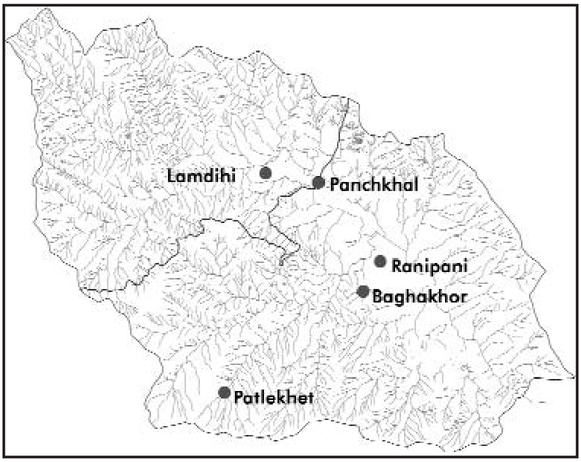

Figure 3.1: **Jhikhu Khola Watershed showing main PARDYP research sites**

In the first phase farmers, as they visit the horticulture centre to obtain seeds, seedlings, and information, observe the new technologies being tested. The project team discusses these technologies with them and explores the possibility of establishing trials on their farms. The project has taken this approach with drip irrigation, SRI, grass and hedgerow species for fodder and composting, and organic pest management.

On-farm research trials and demonstrations

Some technologies tested and promoted by PARDYP are not new to farmers. For these the project team directly approaches farmers to carry out trials without prior research demonstrations. The issues are discussed with farmers and the farmers' concerns and questions addressed. Farmers who are convinced of the technology's promise then go ahead and establish trials in their fields. The farmers select the trial sites in collaboration with the PARDYP team. Fellow farmers are encouraged to contribute to the trials. The project has followed this approach for demonstrating the plastic lining of water harvesting ponds and the incorporation of lime into red soils on rainfed land to enhance soil pH and productivity.

Farmer to farmer visits

Farmer to farmer visits are an effective way of disseminating technologies. Before starting work with a new group of farmers, the project team discusses the problems they are facing in their farming systems. Probable causes and possible solutions are identified. A number of farmers are then taken to the PARDYP demonstration sites where other farmers are already tackling these types of problems using simple technologies. Sometimes, before starting to set up demonstration trials, interested farmers are taken to the demonstration site in the horticulture centre to discuss issues of concern.

Demand driven programmes

In the course of PARDYP's interactions with farmers, many of them have asked for support for income generating activities that do not come within PARDYP's research agenda. PARDYP has supported the following activities to encourage farmer participation in its research activities:

- mushroom cultivation, vegetable nursery management, and seed production training;
- a farmers field school on growing potatoes;
- fruit tree seedling distribution;
- demonstration of solar dryers; and
- soil nutrient analysis.

Trial Results

The results from the trials carried out by PARDYP Nepal in the Jhikhu Khola watershed in PARDYP phases 1 and 2 are summarised and discussed below.

Drip irrigation

Drip irrigation has been described by Postel et al. (2001), Katz (2001), and Haile et al. (2003) as water-efficient irrigation systems. Standard drip irrigation systems are expensive sophisticated systems designed to serve large areas of commercial cash crop horticulture. They are not suitable to be broken down to fit small plots such as farmer's fields in Nepal. In recent years the South Asian NGO, International Development Enterprises (IDE) has been marketing locally fabricated, low-cost drip irrigation systems mostly in the west of the Nepal. The system includes a plastic container and weatherproof lateral pipes with discharge holes at intervals along the pipes (Figure 3.2). Each hole is baffled to ensure that water regularly reaches the plant root zones. Lateral pipes are connected to the container. The systems are simple to use and available in capacities to irrigate areas of between $40m^2$ to $500m^2$. The initial investment is low at about US$20 to irrigate 60 to 120 sq^2 of land depending upon the crop.

The Phase 1 trials with drip irrigation were carried out at Paanchkhal Horticulture Centre to grow bitter gourd vegetables. It was set up with one drip-irrigated plot and another plot where the crop was irrigated with a bucket. The drip system used 50% to 60% less water than the bucket system for the same yield. The 2001 trial at the centre produced about 640 kg of bitter gourds from the drip and bucket-irrigated plots, corresponding to about 44 t/ha. Figure 3.3 shows water use and crop production on the $144m^2$ sized drip and bucket irrigated plots in 2001. The trials also showed that the drip irrigation needed much less labour. The labour demand for the application of irrigation water was six times less for the drip than the bucket system (Prajapati-Merz et al. 2002).

Figure 3.2: **A simple drip irrigation system**

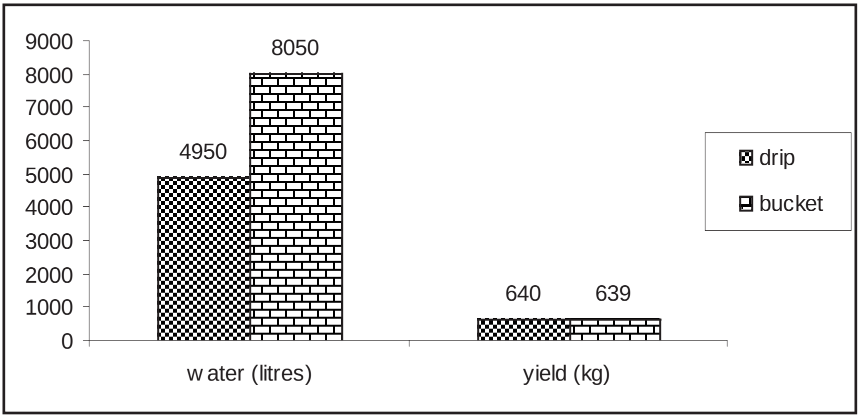

Figure 3.3: **Water use and crop production from drip and bucket irrigated plots at Paanchkhal Horticulture Centre**

In the second phase, a trial was started with a farmer on a rainfed plot in Lamdihi (Figure 3.1). Lamdihi is a low-lying area in the Paanchkhal valley with good access to the nearby Araniko highway. Local farmers started to grow cash crops for the nearby markets of Banepa and Kathmandu after this highway was built and malaria was eradicated. In the valley bottoms farmers grow two to three crop of vegetable in addition to a crop of monsoon rice. The area is only a few minutes walk from the road in the valley bottom, but farmers still concentrate on growing monsoon maize and winter wheat. The Rayale irrigation canal runs through Lamdihi and provides plenty of irrigation water until October each year. From then on the water supply gets scarcer until by the end of January to early February it dries up completely. From February to the onset of the monsoon farmers face serious shortages of irrigation water.

Participating farmers proposed growing bitter gourd as a trial crop and using a smaller plot for the bucket irrigation control. Plots of 144m^2 were put under drip irrigation and 80 bitter gourd plants were planted at 1.2m intervals plant-to-plant and 1.5m between rows. A plot of only 18m^2 with 10 bitter gourd plants at the same spacing was prepared for bucket irrigation. Fertiliser input was the same for both plots with 33 t/ha of organic matter, 170 kg/ha of diammonium phosphate, 450 kg/ha of urea, and 100 kg/ha of potash applied. The fertilisers were applied in split doses for efficient uptake. In this trial the farmers managed to save 45% of water whilst getting 14% more yield from their drip plots. They reported yield figures of 44 t/ha on the drip irrigation plots and 39 t/ha on the bucket-irrigated plots. The results from the bucket-irrigated plot were extrapolated to give the comparison in Figure 3.4. The average market price for bitter gourd was around NR 17/kg at the time, thus giving a gross income of NR 10,000 from the drip-irrigated plots.

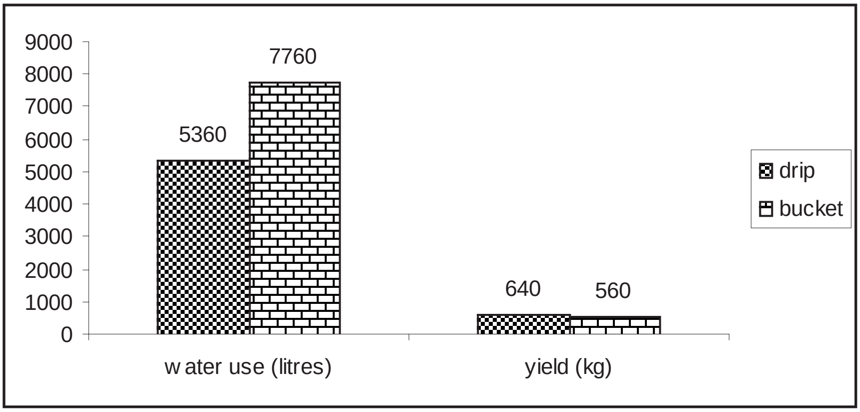

Figure 3.4: **Water use and production from drip and bucket irrigated plots at Lamdihi**

These successful results led to five more local farmers adopting the system in 2003. Their gross income from their drip plots has been NR 9,000 to 12,000 per plot growing the same crop.

PARDYP organised the dissemination of this new technology through farmer to farmer visits. Many farmers visited the Paanchkhal Horticulture Centre and Lamdihi sites to observe drip irrigation in action. Along with promotion by local NGO Ranipani Gram Sewa Kendra, these demonstrations have led to about 70 farmers starting to use drip irrigation.

PARDYP is continuing to support the NGO with technical advice. For example, PARDYP facilitated a field visit programme for farmers from Ranipani to observe the drip irrigation sites at Lamdihi. The visiting farmers asked practical questions about growing crops with drip irrigation.

System of rice intensification

The system of rice intensification (SRI) involves changing certain standard management practices to get higher rice yields. It was developed in Madagascar and has been tested in several Asian countries. The results from a number of trials are given in Uphoff and Fernandes (2002). The practice involves transplanting two-leaf rice seedlings singly within 15 to 30 minutes of taking them from the nursery bed, planting them in a widely spaced square pattern, and keeping the soil moist but not flooded during the vegetative stages (Figure 3.5).

Figure 3.5: **SRI rice ready to harvest showing wide spacing**

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The first PARDYP Nepal SRI trial was carried out in the Paanchkhal Horticulture Centre in 2002 alongside a control plot of the same size of 140m^2 where rice was grown traditionally. Single two-leafed 12-days-old seedlings were transplanted at distances of 25 x 25 cm in the SRI plot. In the traditionally managed (TM) plot 30-days-old seedlings were transplanted at an average distance of 10 x 10 cm with bunches of three seedlings planted at each point. The same amount of fertiliser was applied to both plots (50 kg N/ha, 30 kg P/ha, and 30 kg K/ha). The SRI plot was irrigated weekly during its vegetative growth phase and flooded only during the reproductive phase while the traditionally managed plot was kept flooded throughout. Both plots were drained 20 days before harvest.

The harvested yield was 20% more in the SRI plot. The main drawback of the SRI system is that it is very labour intensive, especially at planting time when it needs skilled labour for line planting and weeding. Also, weed growth was more in the SRI trial as the soil was only kept saturated and not flooded. The SRI plot needed nearly three times more labour than the traditionally managed plot for planting and weeding and overall needed twice the time for crop management (Table 3.1).

Table 3.1: **Comparison of labour requirement for SRI and traditionally managed plots**

	SRI (hrs)	Traditionally managed (hrs)
Plot preparing	3	3
Planting	7	2
First weeding	7	0
Second weeding	14	7
Harvesting	3	3
Total	34	15

A survey on SRI adoption has shown that the extra labour involved makes it less suitable for small holding farmers. Thus PARDYP in 2003 investigated how to reduce the labour involved.

The requirements of the SRI system were discussed with interested farmers before the monsoon rice season began in 2003. The problems they identified were:

- the difficulty of getting the young seedlings from the nursery and transplanted into the field within 15-30 minutes; and
- excessive weed growth.

These problems were reviewed and the following solutions suggested.

- Raise seedlings on a dry seed bed in a field with good soil and a reliable water supply. When the seedlings are ready for transplanting at the two-leaf stage after eight days, remove patches of 5-10 cm^2 of seedbed with soil attached to a depth of up to 5 cm to protect the roots. Transport these seedling patches to the site for transplanting and keep them in a corner of the field in a moist condition. Take them out from the patches just before transplanting. The seedlings can be kept in the fields in this way for up to 10 hours.
- Use a type of hand weeder developed by farmers in Sri Lanka to make SRI less labour intensive (Uphoff and Fernandes 2002). This weeder is manufactured in Nepal by the National Agricultural Research Council (NARC) in collaboration with the International Maize and Wheat Improvement Centre (CIMMYT). It is pushed along and clears the areas in between the widely spaced rows of rice plants.

In 2003, SRI experimental plots were established at the Paanchkhal Horticultural Centre. Four different treatments, three for SRI and one for traditional management were established over 140m^2 plots. Plot SRI 1 was irrigated once a week and weeded manually. In the SRI 2 plot soybeans were planted in-between the rice rows to study what effect this had on reducing weed growth and its effect on rice yield. In plot SRI 3 no supplementary irrigation was applied during the period of vegetative growth and the crop was left to be irrigated only by the monsoon rains. This was done to test whether the monsoon rain alone provides sufficient moisture. Climatological data shows that the longest period without rain during the monsoon season in the Paanchkhal area is only 10 days. Also in this plot the seedlings were planted using seedlings removed from the nursery bed in clumps with soil attached, as suggested above. The mechanical weeder was used for weeding. Fertiliser input was the same for all plots (N: 50 kg, P: 30, K: 30 kg/ha).

Table 3.2: **Average number of tillers, fertile tillers, and plant height in SRI trials at Paanchkhal**

Plots	Tillers	Fertile tillers	Height (cm)
SRI 1	22	18	104
SRI 2	20	15	108
SRI 3	24	19	106
TM	11	9	102

The rice plants in the SRI 3 plot produced the most tillers with an average of 24 per plant (Table 3.2). The plants in the traditionally managed plot had the least with 11 per plant. The average number of fertile tillers was also highest in SRI 3 and the least in the traditionally managed plot. Average plant height was greatest in the SRI 2 soybean plot and the least in the traditionally managed plot (Table 3.2).

The three SRI treatments gave similar grain and biomass yields (Figure 3.6). In plot SRI 2 an additional yield of 666 kg/ha of dry soybeans was harvested The grain yield of the SRI plots was on average 21% higher and the biomass yield 12% higher than in the traditionally managed plot.

Using the weeder reduced the time needed for weeding to a tenth of that in the standard SRI plot (SRI 1). SRI plots 1 and 3 were weeded twice while SRI plot 2 only needed weeding once

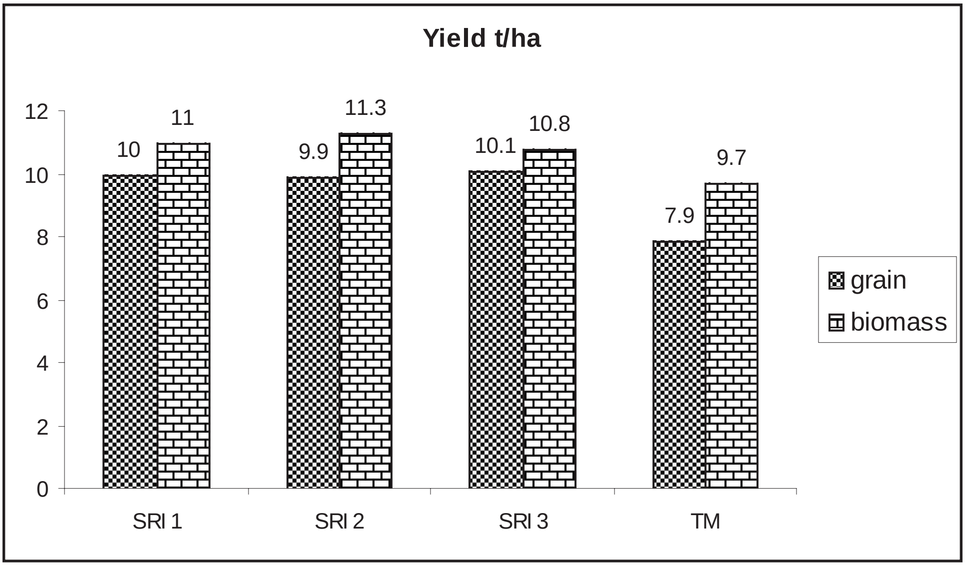

Figure 3.6: **Comparisons of grain and biomass yield of different SRI and traditional treatments**

as the soybean plants suppressed weed growth. Intercropping soybean reduced the weeding time to nearly a half compared to the traditionally managed plot (Table 3.3). Planting seedlings from patches had no affect on the survival rate of the planted seedlings and on yield.

Table 3.3: **Comparisons of labour needed (hr/plot) for different SRI treatments**

	TM	SRI 1	SRI 2	SRI 3
First weeding	0	7	4	1
Second weeding	7	14	0	1
Total	7	21	4	2

These trials suggest that farmers would benefit most by using SRI practices under rainfed conditions and by planting soybean in between rows. These results need replicating over a few years before any definitive recommendations can be made to farmers.

Before these SRI trials began a number of Paanchkhal farmers visited Sitapaila, Kathmandu to see the fields of a farmer who had been practicing SRI for two years. The same farmers also visited the SRI demonstration plot at the Paanchkhal centre to familiarise themselves with the technology. Their observations and other farmer-to-farmer interactions have helped to promote this new technology.

In 2003 six Jhikhu watershed farmers tested SRI in plots of between 20 and 80m^2 on three types of irrigated terraces and two different soil textures. The terraces were *kanle khet* (well-irrigated land), *tari* khet (irrigated), and *pakho khet* (unirrigated former bari land). The soil textures were loamy (black) and clayey (red). The rice varieties Makawanpur 1, Naya Parwanipur, Malika, and Panta 10 were tested (Table 3.4). The rice variety and the fields were selected by the farmers. Most farmers selected their lower yielding fields.

For all six farmers the grain and biomass yields were significantly higher in their SRI plots than in their traditionally managed plots irrespective of khet type and variety used. The grain yield was between 20% and 50% more and the biomass between 2% and 40% more in the SRI plots (Figures 3.7 and 3.8). These first year results produced good yields on marginal khet lands without permanent irrigation systems, but need further testing in different rainfall conditions before firm recommendations can be made.

Neighbouring farmers observed these trials and helped with harvesting and calculating the final yields. Their interest suggests that more farmers will try out SRI.

Table 3.4: **Characteristics of six 2003 SRI trial sites in the Jhikhu Khola watershed**

Farmer No.	Khet type	Soil texture/colour	Rice variety	Remarks
1	Kanle	Loamy/dark grey	Makawanpur 1	Good irrigated site
2	Kanle	Loamy/dark grey	Naya Parawanipur	Shaded irrigated site
3	Kanle	Clayey/reddish brown	Naya Parwanipur	Irrigated
4	Tari	Clayey/red	Malika	Former unirrigated bari
5	Tari	Clayey/red	Malika	Former irrigated bari
6	Pakho	Clayey/red	Panta 10	Former rainfed bari (unirrigated)

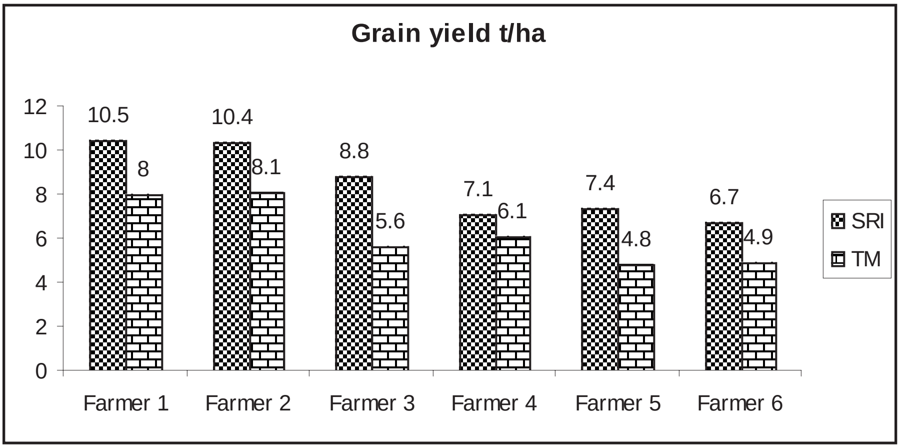

Figure 3.7: **Grain yield differences between SRI and traditionally managed rice**

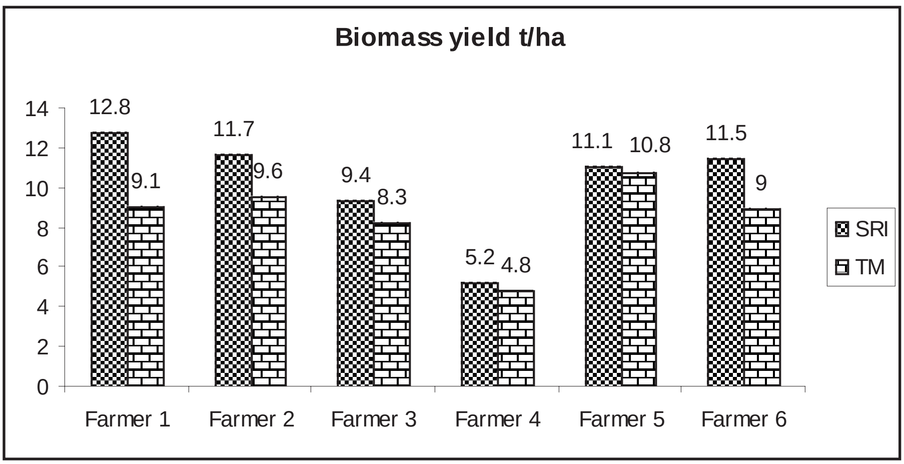

Figure 3.8: **Dry biomass differences between SRI and traditionally managed rice**

Organic pest management

Most farmers in the Jhikhu Khola watershed are involved in commercial vegetable production. They use increasing amounts of chemical pesticides often in higher than recommended doses. Apart from being harmful to human health this may lead to the build up of resistance among pests, ecosystem destruction, and environmental pollution. PARDYP has therefore been investigating the potential or organic pest management.

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Experimental trials were first carried out in 1999 at Paanchkhal Horticulture Centre to test the pesticidal value of local plant extracts. The plants used were bakaina (*Melia azaderach*), titepati (*Artemisia vulgaris*), simali (*Vintex negundo*), nimtel (*Eclipta prostata*), lemon grass (*Cymbopogon citrates*) and kantakari (*Solanum xanthocarpus*). The initial results in controlling the most common and prevalent pests and diseases in cash crops, showed that bakaina, titepati, nimtel, and simali were promising for controlling *Helocoverpa armigera* (fruit borer), and lemon grass and kantakari for controlling *Phythoptera infestans* (late blight) (Prajapati Merz and Bhandari 2002).

The treatment technology and methods for preparing the extracts were discussed with farmers. Four on-farm trial plots were established in 2000 with four farmer groups associated with the NGO the Centre for Environment and Agricultural Policy Research, Extension and Development (CEAPRED). The trials saw good success in controlling pests and diseases, but the farmers were not keen to adopt this technology as preparing the plant extracts is labour intensive whilst chemical pesticides are cheap and readily available.

The NGO Ranipani Gram Sewa Kendra approached the PARDYP team in 2003 for support to organise an organic pest management programme specifically to control *Lissorhoptrus oryzophylus* (rice water weevil) on rice. The beetle was proving particularly problematic as it was becoming resistant to Metaphos or Phorate — the strongest chemical pesticides available in the market, and ones classed by the World Health Organisation as 'extremely hazardous'.

Experimental plots were established on a farmer's field with an equal area of control and treated plot. The farmer applied pesticides and fertiliser in the control plot according to normal practice. Extracts of simali, bakaina, and titepati were used as pesticides. Equal proportions of green biomass of all three plants was combined and applied directly at the rate of 0.25 kg/m^2, a week before rice planting to control any weevil eggs or larvae in the soil. One month after planting the treated plot was sprayed with a 10% solution of the mixed extract every week until the flowering stage, then at two weeks and four weeks later. Spraying in the control plot only began after the onset of damage with about 5% of the plot being damaged. This area was sprayed with the chemical pesticides Forate, Nuvan and Fanfan once every four days.

Full results are not available for these treatments as the farmer did not record detailed data on the impact of the treatments on pest populations in the different paddy growth phases. It was however reported that there was no loss of plants in the plot sprayed with plant extracts and it had about 5% more yield of paddy than the control plot.

Grasses and hedgerow species for fodder and green manure

Introducing new species of grass and hedgerow bushes and trees has great potential to improve the availability of fodder, provide green manure to improve soil fertility, and lessen soil erosion loss.

The first trial was established in 1996 at the Baghkhor PARDYP experimental site in the Jhikhu Khola watershed. The aim was to test the performance and adaptability of nitrogen and non-nitrogen fixing grass and hedgerow species to local conditions. About 15 species were tested. The site was established to produce seeds and other planting materials and to grow-on promising species to promote to farmers. The PARDYP team discussed the usefulness of these species for fodder and green manure when visiting farms. Amongst these demonstration species, 11 were picked out by farmers as potentially useful (Table 3.5). However, farmers were only able to try out five of them because of the limited availability of planting material.

Table 3.5: **Grass and hedgerow species selected by farmers to test on -farm**

Forages		Hedgerow species	
Legume	**Grasses**	**N- fixing**	**Non N-fixing**
Stylo	Molasses	Flemingia	Guatemala grass
	Dinanath	Tephrosia	Napier grass
	Vetiver grass	Sunhemp	Broom grass
			Tithonia

The first on-farm demonstration trials were established in 2000 on 50 farms. The farmers found Napier grass, molasses, broom grass and flemingia the most useful species and tithonia the least useful. They reported biomass of 4.6 kg/m^2 over a period of a few months for sunhemp followed by Napier with 4.2 kg/m^2, broom grass (4.0), and molasses (3.9). Tithonia, although known to be a valuable green manure, was least preferred because it is only palatable to goats amongst the livestock kept by farmers. The species that are easy to establish and readily eaten by the range of livestock are most preferred by farmers. Stylo, although being a good fodder, had a lower rating because of its poor germination and slow initial growth.

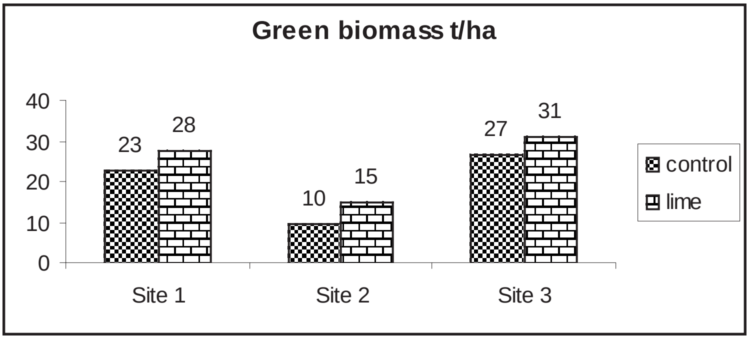

Figure 3.9: **Maize green biomass yields on limed and non-limed treatments in the Jhikhu Khola watershed**

More than 700 farmers across the Jhikhu Khola watershed have started growing fodder grasses and hedgerow species on terrace risers for supplementary animal feed during the dry season and to provide animal bedding material.

Soil liming trials

A number of Jhikhu Khola farmers suffer from deteriorating soil pH, especially in rainfed fields with red soils. The negative impact of this on yields is a major concern for farmers. The PARDYP team held discussions with farmers and proposed adding lime as a possible way of increasing soil pH. The farmers selected six possible rainfed fields for carrying out the lime trials. Three whole-terrace plots ranging from 34 to 90m^2 and with pHs from 4.2 to 5.5 were selected. Treatment plots with lime added and control plots with no lime added were set up at each site. Farmers 1 and 3 used the Dolakha variety of maize to grow whilst farmer 2 used the Jhikhu Khola local variety. The dosages of lime were calculated depending on soil pH and soil texture according to standard recommended figures (HMGN Ministry of Agriculture 2001). Recommended doses of NPK and organic matter were applied (N: 35, P: 30, K: 30 kg/ha and 10 t/ha of organic matter). The lime was applied 17 days before sowing the maize in plot 1, 33 days before in plot 2, and 28 days before in plot 3. The site 2 farmer applied lime and fertiliser only along the line where the maize was to be sown. At the two other sites lime and fertiliser were broadcast over the plots.

The lime showed a positive impact on the productivity of both maize varieties on all soils. Green biomass increased by 14 to 50% and grain yield (12% moisture content) increased by 22 to 41% over control (Figure 3.9 and 3.10).

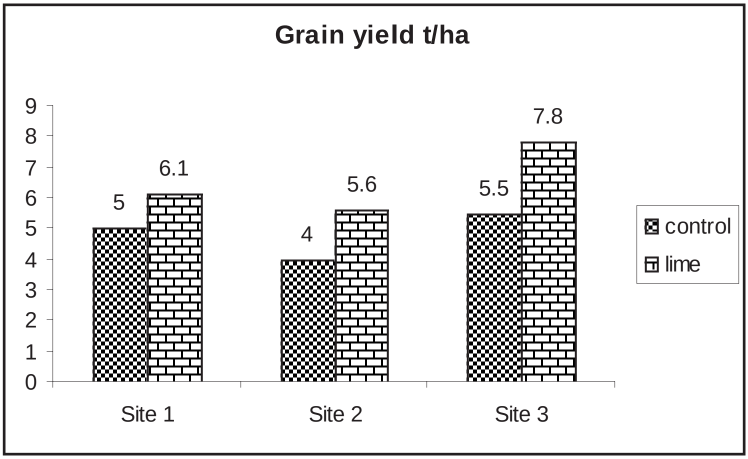

Figure 3.10: **Maize grain yield on limed and non-limed fields in the Jhikhu Khola watershed**

The preliminary results of liming were encouraging. The farmers reported increased yields and noticed that the land had become easier to plough after treatment. They wanted to continue to treat their fields with lime. In coming seasons the project plans to test the effect of adding lime on different crops and in split doses. The pH of the plots has remained the same or has slightly increased in the limed plots and it is too early to show any significant changes. It usually takes more than one year for liming to make a significant difference on soil pH.

Plastic-lined water harvesting ponds

The 2002 PARDYP drip irrigation trials in Lamdihi determined that about 5000-6000 litres of water was needed to drip irrigate an area of between 144 and 200m^2 to grow cash crops during the dry season. Precipitation data for 1999-2001 indicates that the pre-monsoon season can be drier than 2002 conditions. These issues were discussed with farmers and the decision was taken to build 8,000 to 9,000 litre capacity ponds as backup sources of water for the drip irrigation systems. A plastic-lined 9,000 litres water harvesting pond was built in Lamdihi in 2002 measuring 3m x 2m and 1.5m deep. A shaded site was selected to minimise evaporation. The cost of building it was about US$30. The stored water was used to irrigate bitter gourd. Three more of these ponds were built by local farmers to supply their micro-sprinklers and drip irrigation systems.

Collaboration

PARDYP's research trials and the dissemination of the results are being carried out in collaboration with a range of local and national organisations.

In 2003, a two-day participatory monitoring and evaluation workshop was held to discuss the approach taken and the progress made by PARDYP in the Jhikhu Khola watershed. Representatives from government line agencies, district development committees, village development committees, and farmers, and NGOs participating in the programme were invited to evaluate the contribution of PARDYP's work. This workshop gave the project team valuable feedback that will be used to improve research activities and activity planning.

Figure 3.11: **A plastic-lined water harvesting pond**

PARDYP-Nepal has worked closely with the following four organisations.

Horticulture centre — From the beginning of its Phase 2 in 1999 PARDYP has run collaborative programmes with the Paanchkhal Horticulture Centre. Research and demonstration plots have been established to test new technologies and varieties of cash crops. Trials on the System for Rice Intensification, drip irrigation, biofertilisers, organic pest management, and tomato varieties have been carried out. The centre is providing technical support and training to local farmers.

Patlekhet Model Village Development Committee — The following activities have been successfully initiated and demonstrated in Patlekhet VDC in collaboration with this committee:

- cultivating off-season vegetables using drip irrigation and micro-sprinklers;
- building plastic-lined water harvesting ponds for off-season vegetable production;
- cultivating fodder grasses and hedgerow species on terrace risers;
- intercropping bush beans in rainfed maize;
- distributing improved fruit seedlings and introducing new fruit varieties;
- demonstrating soil conservation technologies on rainfed terraces; and
- running training courses on mushroom production, vegetable nursery management, and seed production.

Ranipani Gram Sewa Kendra — This local community development NGO looked at PARDYP's work and picked out drip irrigation and organic pest management as the most promising activities for promoting community development. It has promoted these by distributing subsidised drip irrigation systems. The organisation seeks future collaboration and PARDYP support especially for improving soil fertility.

The Centre for Environment and Agricultural Policy Research, Extension and Development — CEAPRED is a national NGO working on agricultural development and related issues. It has worked in the Jhikhu Khola watershed with vegetable farmer groups to promote the growing of off-season vegetables and on the organic pest management trials.

Other collaboration

PARDYP has also carried out its work in the Jhikhu Khola watershed by:

- sharing ideas on innovative farming practices with the District Agriculture Development Office. This office is one of the main candidate organisations to spread the PARDYP-introduced technologies.
- exchanging knowledge, especially on soil fertility issues, with the National Agriculture Research Council (NARC);
- contracting the Centre for Agriculture Technology (CAT) to provide trainings and technical advice on mushroom cultivation;
- contracting the Agriculture Technology Centre (ATC) to provide technical support for soil fertility analysis. PARDYP is currently evaluating ATC's soil testing kit for farmer use;
- getting planting materials from the Australian-funded Third Livestock Development Program (TLDP). PARDYP has tested TLDP's recommended seed varieties in the Jhikhu Khola watershed for their performance and suitability to local conditions. Multiple options have been provided to farmers to test forage and grass species on terrace risers and in private forests;
- sharing ideas with the Swiss-funded Sustainable Soil Management Program (SSMP). This project has a PARDYP staff member on its technical advisory committee; and
- sharing ideas with the SRI-Nepal Network. This network of 13 organisations works on adapting SRI to use in Nepal by exchanging knowledge between its members. PARDYP is a founding member.

Discussion and conclusions

PARDYP's current work in the Jhikhu Khola watershed has two phases. In the first phase demonstration activities are established to test and then modify potential technologies for the local environment. This also allows farmers to observe their effectiveness. In the second phase, participatory trials and demonstrations are carried out with farmers to see if these technologies can be adapted by farmers. This allows the project team to test technologies under different management conditions.

Farmer to farmer visits have given farmers the chance to evaluate the benefits of new technologies with other farmers and find out how to use them. This builds up a network of interested farmers within the watershed. Collaboration and networking with other organisations is enabling the exchange and dissemination of knowledge generated at field level. This can be very useful for disseminating a particular technology to another part of the watershed.

PARDYP's overall approach is to implement its activities by fostering dialogue and interaction between farmers and local organisations. The project's findings are being shared with district line agencies and local organisations to further adapt and scale-up the new technologies and farming practises.

In summary, the approaches used to implement project activities have had both positive and negative impacts (Table 3.6).

Table 3.6: **Impacts of PARDYP Nepal's work in the Jhikhu Khola watershed**		
Approaches	**Positive aspects**	**Negative aspects**
Research trials and demonstrations	• Trial design is under researchers' control leading to less errors than in farmers' fields • Makes it easy for farmers to understand and observe technologies being tested, promoting discussions amongst them • Increases awareness and participation of farmers to select appropriate technologies • Assists researchers to modify technologies to fit local condition s before testing in farmers' field • Failed trials do not reflect too much on the project's credibility	• The participation of farmers is passive during this first phase • There is a controlled research environment and findings may not apply to farmers' fields
Participatory trials and demonstrations	• Farmers are active partners in demonstrations and adapt technologies to better suit them • Farmers are the direct beneficiaries • Documented results are based on practical not hypothetical conditions	• Trial design is part icipatory and so may not be scientific • Farmers are directly affected if trials fail and there is a danger of the project losing credibility
Farmer to farmer visits	• A good way of disseminating findings • Allows farmers to observe farm interventions directly • Facilitates networking between farmers from different parts of the watershed	• Sometimes participating farmers' interest can be just touristic (but even so may stimulate interest)
Collaboration with other organisations and projects	• Promotes knowledge shari ng and dissemination amongst partners • Helps avoid duplication • Helps farmers understand new technologies	• The interest of partner organisations can suddenly change
Demand driven interventions	• Encourages active participation of farmers • Encourages sense of ow nership among farmers	• Initiatives may not fulfil project objectives

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4

Nutrient Dynamics in Farming Systems of the Jhikhu Khola Watershed

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4

Abstract

Maintaining soil fertility is very important for subsistence farmers in the middle mountains of Nepal. They are under tremendous pressure to meet the growing demand for food. Farmers with access to markets have increased productivity by intensifying their farming. In the past ten years farmers in the case study area of the Jhikhu Khola have moved from two annual staple crop rotations (rice and wheat or maize) to triple annual crop rotations (rice, potatoes, tomatoes). This has, however, led to concerns about maintaining soil fertility. Urea, the dominant fertiliser in early agricultural intensification, has been largely replaced by diammonium phosphate. Analysis of soils in the study area in the mid-1990s found widespread deficiencies in nitrogen and phosphorus. Farmers have adjusted their inputs since then and by 2000 phosphorus inputs in intensive irrigated sites were exceeding crop requirements. In contrast nitrogen and potassium had become insufficient resulting in negative nutrient balances. The potassium deficiencies were surprising as many Nepali soils have a naturally high potassium content. In contrast, the study found that in 2000 intensive rainfed sites under double and triple rotations all had surpluses of nitrogen, phosphorous, and potassium. This has negative impacts on water quality and is resulting in eutrophication problems as well as unnecessary extra expense for farmers. The findings indicate that farmers are highly motivated and aware of soil fertility problems associated with intensification and are managing to address the problems themselves.

Background

The agricultural systems of the middle mountain watersheds of the Jhikhu Khola and the Yarsha Khola in east-central Nepal are characterised by small landholdings with typically less than one hectare of cropping land per household. They are intensively cultivated with high inputs of labour. To meet the growing demand for food by the rapidly increasing population (2.6% per year population growth) the cropping systems have become very intensive. In 1996 the population density in the Jhikhu Khola was 437 km^2 and in the Yarsha Khola 386 km^2. Annual crop rotations estimated by Hagen (1980) for rainfed areas in Nepal averaged 1.3 crops/year, Panth and Gautam (1987) reported 1.6 crops/year, and Riley (1991) reported averages of 2.0-2.5 crops/year. Surveys carried out in the Jhikhu Khola (Kennedy and Dunlop 1989, Wymann 1991) reported an average of 2.7 crops per year on irrigated lands (*khet*) and 2.5 crops per year for rainfed cropping lands (*bari*). In Yarsha Khola, cropping intensities have been reported as between 1.5 and 2.0 crops per year in rainfed lands and 2.0-2.5 crops per year in irrigated areas (Brown 1997).

Agricultural intensification has brought about significant changes in the traditional farming systems with a shift towards the cultivation of seasonal cash crops. This has led to shorter fallow periods and dependency on more inputs that are often difficult to maintain by subsistence farmers. This dependency on chemical fertilisers is increasing whilst the amount of farmyard manure-compost fertiliser has remained constant. Cash crop production in irrigated areas, where profit margins are high, receive most of the farmyard manure and compost.

The cultivation of the rainfed upland fields near homesteads has also undergone a shift away from traditional practices. These changes affect the long-term sustainability of upland farming systems as organic matter – the main ingredient for maintaining soil fertility – is being diverted to apply to the irrigated sites. These large changes that have taken place over the past 20 years indicate the great adaptability of farmers.

In summary, the increases in population pressure in the study watersheds has brought about agriculture intensification, the increased use of chemical fertilisers and pesticides to maintain productivity and soil fertility, and the more intensive use of common property resources.

Agricultural expansion onto marginal lands that may be more susceptible to erosion is not of great concern because in these two watersheds the forests have been handed over to local communities to manage and are not available for conversion. The associated forest user groups generally follow strict rules and regulations on how to manage and maintain their forests. There is little spare land available for expanding the area under cultivation. However, the demand for the natural resources of forests, grazing, and water is constantly increasing to supplement intensive agricultural production systems. The use of organic materials collected from community forests and applied to cultivated areas as nutrient inputs is leading to a decline in forest soil fertility. Spring and river water sources are being heavily exploited for domestic and irrigation uses while the use of groundwater for drinking is a recent phenomenon in the Jhikhu Khola. There are acute water shortages during pre-monsoon periods.

Soil Condition

Soil and soil fertility surveys were carried out in both watersheds to document soil fertility and to serve as a baseline against which changes could be documented between 1990 and 2000. The main factors considered as important in soil fertility maintenance are topography, land use, cropping intensity, soil types and management practices.

The following soil fertility surveys were carried out:

- a detailed survey of forest and agricultural land in the Dhulikhel headwater region of the Jhikhu Khola (Wymann 1991) over 136 forestry and shrub sites and 120 agricultural sites;
- a general soil survey in 1990 (Maharjan 1991) over the entire Jhikhu Khola watershed with 350 soil pits analysed for basic nutrients;
- a detailed survey of agricultural and grazing land in 1993/94 in the Jhikhu Khola, Bela-Bhimsenthan area with a stratified sampling design to isolate slope, aspect, elevation, soil type, and land use effects over 200 sites in irrigated and dry land agricultural fields and grazing lands;
- a detailed survey in the Jhikhu Khola on the influence of land use practices on soil fertility at 10 sites where soil type, climate and topography were held constant in forests and adjacent irrigated and dry land agriculture fields; and

- a survey of the Yarsha Khola in 1998 over 150 agricultural and 190 forest sites with the watershed divided into three elevation classes, three aspect classes, three geological types and the four land use classes of forest, grazing, irrigated agriculture and rainfed agriculture.

The results of these studies allowed a comparison of the overall soil fertility status in the two watersheds (Table 4.1). This shows that despite the lower population pressure and lower agriculture intensity in the Yarsha Khola, the overall problems were similar in the two watersheds. These soil problems were low pH, low carbon content, lack of available phosphorous, and low base cations. The shortage of available phosphorus appeared to be a key problem with more than 50% of surveyed soils having very high levels of phosphorus sorption (ability to fix phosphorus and make it unavailable for plants to absorb). In the mid-slopes of the Jhikhu Khola watershed there are large areas of red soils that in all cover 37% of the watershed's area. These soils have a very high absorption capacity and although irrigation reduces this by 20-25%, this still leaves them with high absorption phosphorous absorption. About 80% of soils in both watersheds have an undesirable pH of about 5. The extensive use of acidifying fertiliser, pine litter in compost, and acidic bedrock cause this. Exchangeable potassium appears to be in adequate supply since it is widely distributed in the parent rocks.

Table 4.1: **Comparison of soil fertility values in the Jhikhu (JK) and Yarsha Khola (YK) watersheds**

	% carbon		Soil pH		Available phosphorous (mg/kg)	
	JK	YK	JK	YK	JK	YK
Mean	1.0	1.4	4.65	4.75	16.5	4.8
Maximum	3.7	6.5	6.70	7.42	127.1	52.4
Minimum	0.1	0.1	3.97	3.59	1.4	0.1
Sample size	200	340	200	340	200	340

Source: Schreier and Shah 1999

Only a third of Jhikhu Khola samples had adequate levels of carbon compared to two thirds of Yarsha Khola samples. This is due to the greater cropping intensity in the Jhikhu Khola and the more intensive use of forests. However, because of the sampling design a large proportion of the sampled soils are from higher elevations in both watersheds. The cooler climates at higher elevations may be leading to significantly higher carbon levels with elevation. About 10% of the Yarsha Khola samples had adequate phosphorous levels compared with 45% of Jhikhu Khola samples. Overall only 20% of all samples from both watersheds had adequate pH and less than 10% were within the desirable range. There was no significant difference in the overall pH values between the two watersheds.

In the Jhikhu Khola watershed during the late 1980s and early 1990s, farmers began to apply large amounts of diammonium phosphate fertiliser (DAP) to counter phosphorous deficiency. These large applications (Westarp 2002) have resulted in high levels of available phosphorous in intensively managed irrigated and rainfed sites. However a new problem has arisen with serious potassium deficiencies in triple crop rotation systems in irrigated lowlands, especially in potato fields. The intensive cropping is also expected to lead to micronutrient deficiencies. However, early surveys have not found any zinc, manganese, or copper deficiencies.

Investigations into boron and molybdenum are being carried out. Potassium was initially not perceived to be a problem since most of the bedrock contains potassium rich minerals. However, potassium deficiencies were observed for the first time in 2000 in intensively used irrigated systems growing potatoes.

Soil acidification, inherently associated with high inputs of acid-causing fertilisers (urea and ammonium based fertilisers), and acid bedrock geology, is becoming a major problem in double and triple crop rotation systems in the Jhikhu Khola area. Chitrakar (1990), Sherchan and Baniya (1991), and Suwal et al. (1991), have noted that the most commonly used fertilisers, ammonium sulphate and urea, tend to acidify soils. This acidification has serious implications as it leads to the leaching out of base cations (calcium and magnesium) and the fixing of available phosphorus in the soil thus making it unavailable to plants. Low soil pH (<5.0) slows the rate of organic matter decomposition, and makes phosphorous unavailable and leads to aluminium toxicity and micronutrient deficiencies.

PARDYP has been working in the Jhikhu Khola watershed since 1996. The PARDYP study team investigated whether or not the incorporation of pine litter in compost was contributing to soil acidification. However, earlier PARDYP experiments showed that that acidification is a slow process and different soils respond differently. In general this is a long-term problem as seen by researchers whilst farmers tend not to see it as a serious problem because it is not affecting their yields yet.

The surveys found poor overall soil fertility irrespective of land use, soil type, parent material, and management practice. In terms of land use, irrigated lowland fields had the best fertility followed by rainfed upland terraces, grazing lands, and lastly forests. This pattern was consistent regardless of soil type on red and other soils. The very poor status of forest soils indicates that long-term sustainability for productive use and management may be being jeopardised. This is likely the result of their natural low fertility and the continuous removal of litter and biomass.

Chemical Fertilisers

The use of mineral fertilisers has increased rapidly since they were first introduced in to Nepal in 1965. Their imbalanced use is known to lead to the problems of soil acidity and micronutrient deficiencies. This trend has not been accompanied by the replacement of organic matter. Farmers and researchers know that soil fertility status cannot be maintained in the medium to long term without replacing organic matter (Pandey et al. 1995, Joshi et al. 1996, Sherchan et al. 1999). Farmers have noticed that the continuous application of mineral fertilisers without adequate organic matter inputs leads to yield reduction, and deterioration in soil structure that makes it difficult to work. The above studies from other parts of Nepal have also reported deficiencies of micronutrients, notably boron, and soil acidification problems. But the literature is limited and more research is needed.

Compost Nutrient Content

Before the introduction of chemical fertilisers, compost used to be the main means of maintaining soil fertility in Nepali agriculture. Compost is usually a mixture of farmyard manure, household waste, forest litter, and other organic materials. Pine litter used as bedding material for animals is more acidic than broadleaf litter. The Swiss Agency for Development and Cooperation's Sustainable Soil Management Project (SSMP) is running an organic matter management programme throughout Nepal. It has resulted in innovations to improve the nutrient quality of farm compost. Compost nutrient content and quality vary widely across Nepal's middle mountains. The average values for the Jhikhu Khola are higher than in the other middle mountain sites given in Table 4.2. It is important to note that the moisture content of compost prior to transport is about 40-60%, but is only 25% once it reaches the fields (SSMP 2001).

Table 4.2: **Nutrient content of compost from Jhikhu Khola and comparable sites in Nepal**

Location	% N	% P	% K	Reference
Jhikhu Khola	1.93±0.41 (n=6)	0.56±0.13 (n=6)	2.15±0.27 (n=6)	Brown, pers. comm. 2001
Lumle (western Nepal)	0.6	0.06	0.6	Suwal et al.1991
Average: Jhikhu Khola + Lumle	1.27	0.31	1.38	
Middle mountain (MM) mean	0.83 (n=460)	0.72 (n=42)	2.26 (n=42)	SSMP 2001
MM range:	0.1 – 2.47	0.22 – 1.41	1.31 – 3.96	
Kavre district mean: range:	 1.38 (n=4) 1.00 – 1.97	 1.51(n=4) 0.96 – 2.10	 2.98 (n=4) 2.67 – 3.24	Bhattarai et al. 2001

Farmers in the Jhikhu Khola complain that the amount of organic matter available per unit land has declined due to land use intensification, restrictions on gathering litter from community forests, shorter fallow periods, fodder shortages, and labour constraints. Organic matter traditionally applied to rainfed lands near homesteads is being diverted to the more intensively cultivated irrigated fields.

Crop Yields

The PARDYP Nepal study team has compared crop yields from irrigated and rainfed fields in the Jhikhu Khola with average national figures and figures from experimental plots associated with agriculture research stations in Nepal (Table 4.3). The 1994 data for Jhikhu Khola represents less intensive sites with one or two crops per year, whereas the 1995 and 2000 data represents reported yields for intensive sites that have three or more crops per year.

This data shows that reported yields from Jhikhu Khola are generally greater than the national average. Reported rice yields for Jhikhu Khola in 1994, 1995, and 2000 were greater than the mean national average. Rice yields from the intensively managed sites (represented by the 1995 and 2000 Jhikhu Khola figures) were significantly greater than less intensively managed sites measured in 1994. The data indicates that yields of the major cash crops potato and tomato grown under intensive irrigation have increased, and potato yields from irrigated fields are significantly higher than national or average rainfed yields. Monsoon maize grown on rainfed fields always yield more than pre-monsoon maize in irrigated fields. Wheat yields have stagnated due to farmers' preferences for cash crops, but are still comparable to national averages. The intensification of production has resulted in larger external inputs, the greater uptake of soil nutrients by crops, and increased nutrient flows out of the system through crop harvesting.

Table 4.3: **Crop yields in Jhikhu Khola, Nepal , and the region**						
Land type	**Crop (season)**	**Year**	**No.**	**Jhikhu Khola yield (kg/ha)** Mean ± std. dev.	**National mean yield**[a] (kg/ha)	**Agric. research station mean yields (kg/ha) [range]**
Irrigated	Rice	2000 1995 1994	26 26 26	5,786±1,252 5,223±1,797 3,222±1,046	2,600 2,391 2,124	3630[b] [1179-5050][c]
Irrigated	Potato (winter)	2000 1995	26 19	23,993±6,667 22,660±11,219	na 9,854	na
Rainfed	Potato (winter)	2000 1995	13 9	10,368±6,866 9,447±7,094	8,593	na
Irrigated	Maize (pre-monsoon)	2000 1995	18 16	3,236±1,396 2540±485	na	1560[d]
Rainfed	Maize (monsoon)	2000 1995 1994	20 18 32	3,943±1,755 3,850±2,068 4,171±1,875	1,701 1,645 1,650	2600[e] 2630[f] 3600[g]
Irrigated	Tomato (pre-monsoon)	2000 1995	5 2	18,949±10,563 6919±890	na	na
Rainfed	Tomato (pre-monsoon)	2000 1995 1994	9 6 2	12,449±6,625 14,513±7,459 2,231±3,156	na	na
Rainfed	Tomato (winter)	2000	5	5,252±2,153	na	na
Irrigated	Wheat (winter)	1995 1994	6 19	2,062±683 1,494±1,046	1550 1470	2310[d] [2000-3000][h]
Rainfed	Wheat (pre-monsoon)	2000	4	1,204±164	na	na
Rainfed	Wheat (winter)	1995 1994	7 14	1,987±1,350 1,147±624	na	[1675-5984][b]

Note 1: The agricultural resource stations are Lumle in central Nepal and Pakhribas in Eastern Nepal
Note 2: No national figures are available fo r yield of tomatoes
Source of Jhikhu Khola figures: Westarp, 2002. Source of other figures: a = FAO 2000; b = Subedi et al.1995; c = Sherchan et al.1999; d = Subedi and Gurung 1991 (average national yield 1981/1982); e = Vaidya and Gurung 1995; f = Tripathi 1997; g = Subedi and Dhital 1997; h = Subedi 1994.

Rainfed Farming Systems

Crops are grown throughout the middle mountains of the Hindu Kush-Himalayas on rainfed terraced hill slopes. The dominant such system in Nepal involves a fallow period followed by maize, or maize intercropped with a mixture of beans and millet during the monsoon and a winter crop of wheat, barley, or mustard (Figure 4.1). The intensification of cultivation with the introduction of high yielding varieties that need higher nutrient inputs has had a negative effect on local genetic legume resources. These were extensively intercropped with maize. However, the high levels of nitrogen in mineral fertilisers applied to high yielding varieties of crops and the lowering of soil pH has meant that many local varieties of legume are no longer grown, probably because soil pH has become too low for effective nodulation. Suitable promising varieties (bush beans) that are tolerant to high soil nitrogen levels have been introduced and tested with positive results. Millet is no longer cultivated in the Jhikhu Khola and wheat began to be replaced by barley from 1998/99 because of barley's better drought resistance, low nutrient requirement, and better straw palatability.

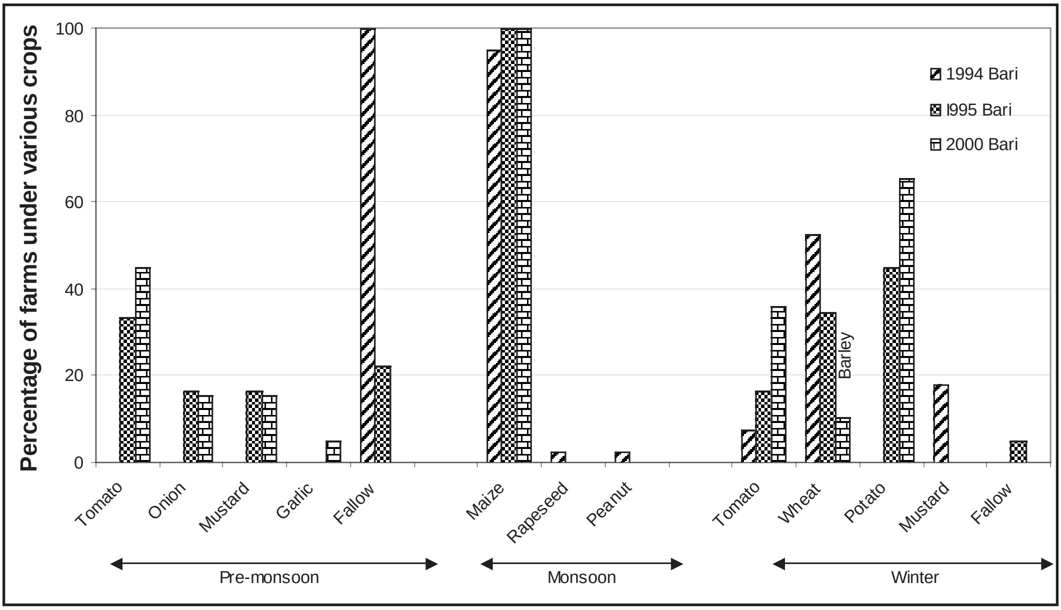

Figure 4.1: **Cropping rotations by season on rainfed fields in the Jhikhu Khola**
Source: modified from Westarp, 2002

Market oriented production has increased in intensively cultivated rainfed fields. Pre-monsoon and monsoon tomato, and monsoon potato cropping, have replaced some traditional crops. Tomato is grown instead of maize in areas with good access to market. Potato is now often intercropped with maize in late August. The area under tomato production has increased by about 50% while potato cultivation increased by about 15-20% between 1995 and 2000. The expansion of cash crop cultivation tends to be governed by the market prices of crops. Farmers prefer growing off-season cash crops as they give larger returns. Intensive rainfed systems continue to maintain a more traditional pattern of input management because of the limited availability of water.

A comparison of compost application in the Jhikhu Khola for 1995 and 2000 shows that it has remained constant at an average of 25-50 t/ha (Westarp 2002). This indicates that supplies from traditional sources (forests) have not altered (Tables 4.4 and 4.5). Overall the median annual application rate has increased by about 7t/ha due to farmers growing more cash crops in the winter and pre-monsoon periods.

The data shows that compost applications during the pre-monsoon and monsoon seasons have remained constant between 1995 and 2000, while applications to winter crops increased by 13%. Traditionally farmers have not applied compost to winter crops, but have begun to do this as they realise the importance of organic matter for maintaining soil fertility. However, increases in fertiliser use and the acidic nature of the soil parent material could cause future declines in soil pH which would accelerate the leaching out of essential minerals.

Table 4.4: **Compost application on Jhikhu Khola rainfed crops in 1995**												
1995	**Farmers sampled**	**% applying inputs**	**Compost applied (t/ha)**		**N inputs (kg/ha)**		**P inputs (kg/ha)**		**K inputs (kg/ha)**			
			M	**R**	**M**	**R**	**M**	**R**	**M**	**R**		
Monsoon maize	18	89	14.7	0–32.4	140	0-308	15	0-33	126	0–278		
Winter total	18	67	9.8	0–14.7	93	0-140	10	0-15	84	0-126		
Potato	9	100	12.3	9.8–14.7	117	93-140	12	10-15	105	85-126		
Wheat	7	14	0	0–9.8	0	0-93	0	0-10	0	0-84		
Pre-monsoon total	14	79	4.6	0–14.7	30	0-140	3	0-15	27	0-126		
Tomato	6	100	12.3	0–14.7	117	0-140	12	0-15	105	0-126		
Annual			31.9	0–49.6	303	0-471	32	0-50	273	0-425		

Source: Westarp 2002 Abbreviations: M = median, R = range

Table 4.5: **Compost application on Jhikhu Khola rainfed crops in 2000**										
2000	**Farmers sampled**	**% applying Inputs**	**Compost applied (t/ha)**		**N input (kg/ha)**		**P input (kg/ha)**		**K input (kg/ha)**	
			M	**R**	**M**	**R**	**M**	**R**	**M**	**R**
Monsoon Maize	20	90	14.7	0–49.1	140	0-466	15	0-50	126	0-421
Winter total	20	80	14.7	0–24.6	140	0-233	15	0-25	126	0-210
Potato	13	100	14.7	0–24.6	140	0-233	15	0-25	126	0-210
Tomato	5	90	5.9	0–24.6	56	0-233	6	0-25	50	0-210
Pre-monsoon total	20	75	4.9	0–16.2	47	0-154	5	0-16	42	0-139
Tomato	9	100	14.7	3.4–16.2	140	33-154	15	3-16	126	29-139
Wheat	4	25	0	0–3.4	0	0-33	0	0-3	0	0-29
Annual			39.2	9.8–54.6	372	93-520	40	10-56	336	84-470

Source: Westarp 2002 Abbreviations: M = median, R = range

Annual fertiliser application rates for nitrogen (253-414 kg/ha) and phosphorous (43-96 kg/ha) doubled between 1995 and 2000 in the Jhikhu Khola, but the application of potassium was limited. The rainfed fields have significantly higher levels of exchangeable potassium and soils are not exhibiting reduced levels of percent base saturation (calcium and magnesium). Comparative field studies (Westarp 2002) suggest that soil nitrogen, phosphorous, and potassium increased between 1995 and 2000 due to high compost and chemical fertiliser inputs, comparatively lower cropping intensities, and two to three month fallow periods – strategies adopted by farmers to conserve soil fertility and increase production. Organic matter inputs into maize, the main monsoon crop on rainfed fields, is high and organic nutrient sources provide 52% of total nitrogen and 20% of the total phosphorous that is applied.

In 1995 and 2000 the main fertilisers used were found to be urea and DAP (Table 4.6). The variation in the use of potash and complex fertiliser (N 20: P 20: K 20) was limited, but urea inputs on tomato declined while DAP inputs increased from 1995 to 2000. Urea and DAP inputs on maize increased and the high inputs on potato remained the same in the two years as further expansion was limited by lack of irrigation water. In 1995 organic sources provided the bulk of nitrogen and phosphorous for maize and potato, while wheat received its nitrogen, phosphorous, and potassium inputs mostly from chemical sources (Table 4.5). The increase in fertiliser use by farmers corresponds to the 50% increase in the number of farmers growing cash crops.

Table 4.6: **Fertiliser use in Jhikhu Khola rainfed fields for 1995 and 2000**

2000	Crop	Range	Urea (kg/ha)		DAP (kg/ha)		Complex (kg/ha)		Potash (kg/ha)	
			1995	2000	1995	2000	1995	2000	1995	2000
Monsoon	Maize	Median	295	442	-	86	-	-	-	-
		Range	0-491	0-826	0-491	0-786	0-79	0-197	-	-
Winter	Potato	Median	236	236	236	236	-	-	-	-
		Range	59-983	79-491	0-983	0-983	0-334	0-983	-	0-236
	Tomato	Median		34		152		-		-
		Range		0-688		0-491		Na		-
	Wheat	Median	-		-		-			
		Range	0-147		0-983		0-49			
Pre-monsoon	Tomato	Median	381	157	214	353	-	-	-	-
		Range	0-688	0-491	0-983	0-491	0	-	-	0-393
	Wheat	Median				-		-	-	-
		Range				-		-	0-197	-

Source: Westarp 2002 Note: no ammonium phosphate applied in either year

Soil erosion

The erosion of topsoil from rainfed fields is a major problem that leads to soil fertility and productivity decline. Much of the soil nutrients lost by soil erosion from rainfed fields accumulates and enriches the irrigated land that usually lies below.

Long term erosion plot studies carried out by PARDYP and previous initiatives in the Jhikhu Khola watershed (1992-2002) indicate that 50-80% of annual total soil losses occur in the pre-monsoon season when vegetation cover is at a minimum. Annual erosion rates at these sites range from 1 to 42 t/ha with the lowest losses from grasslands and losses of between 2-20 t/ha from cultivated rainfed land. The soil loss from degraded sites is almost twice as much as from cultivated land. In the cultivated plots the ten heaviest rainfall events were responsible for 90% of total annual soil losses. On the degraded plots 60-70% of total soil losses occurred during only two or three rainfall events. These findings have large implications for the management and use of rainfed cropping land and degraded lands in the upper reaches of watersheds. Up to 75-90% of total annual nutrient losses, via washed out sediment, can occur where cultivation, fertiliser application, and weeding occurs just before heavy rainfall (Westarp 2002). Much of the sediment is redistributed within the system and 30-60% was found to be recaptured in lower terraces.

The average annual losses from the rainfed terracing study plots in Jhikhu Khola watershed is 25 kg N/ha, 5 kg P/ha and 13 kg Ca/ha. The losses of available phosphorous are small, but the losses of organic phosphorous could be higher where high intensity rainfall happens before it is incorporated into the soil. In general losses from forests and grasslands with full coverage are minimal whilst annual losses from degraded sites are about 34 kg N/ha and 13 kg Ca/ha (Brown 1997).

Runoff rates from upland degraded and rainfed agriculture sites vary significantly in the Jhikhu Khola watershed. In degraded land plots the average annual runoff is about 5000 m^3/ha – a loss of 21 t/ha/yr of soil. This is much more than from rainfed sites, which averaged runoff of 450 m^3/ha and lost 7 t/ha of soil (Table 4.7). The difference is due to the relatively flat surfaces of rainfed terraces, tillage practices, and weeding which increase soil infiltration capacity. Degraded sites (<10% vegetation cover) have compacted soils with surface capping and poor infiltration. The findings indicate that soil erosion is not a severe problem in farmer-managed upland terraced fields but degraded areas are vulnerable to large soil and nutrient losses. These degraded areas need to be rehabilitated to reduce soil loss and minimise the impact of sediments clogging downstream irrigation systems.

Table 4.7: **Annual runoff and soil loss from rainfed agriculture and degraded sites (1992-2002) in the Jhikhu Khola watershed**

	Agriculture		Degraded		Degraded treated	
	Runoff (m3/ha)	Soil loss (t/ha)	Runoff (m3/ha)	Soil loss (t/ha)	Runoff (m3/ha)	Soil loss (t/ha)
Max. range	232-2197	3-37	6739-7141	34-38	-	-
Mean max.	891	19	6940	36	4914	40.70
Median range	138-985	1-18	4488-5185	18-23	-	-
Mean median	450	7	4837	21	3848	12.74
Min range	49-899	0-18	4155-4447	6.4-5.9	-	-
Mean min.	281	3	4301	6	2997	0.96

Source: Nakarmi 2003

Most nutrient runoff from agricultural fields happens through the loss of nitrates and phosphates. Runoff nutrient losses on degraded sites are only from organic sources; but in agricultural upland sites they are mostly from chemical fertilisers and compost. These differences were documented by PARDYP's long-term erosion research studies (Table 4.8). Nutrient losses in runoff are becoming a serious problem and will become more so with the inevitable intensification of cultivation on upland sites. It could be reduced to tolerable limits by growing suitable grass species on terrace risers. These would control surface soil erosion and increase fodder biomass production to feed to livestock to give more manure and thus more compost for applying to fields.

Irrigated Farming Systems

Irrigated terraces are located on gently sloping or level ground. They are intensively cultivated and receive large amounts of organic matter and fertiliser. Application rates vary by season and crop type. The cropping patterns are shown in Figure 4.2. The shift from winter fallow to cash crop production has brought significant changes in the management of these lands.

Table 4.8: **Nutrient losses in runoff from rainfed agriculture and degraded sites in the Jhikhu Khola watershed**

	Agriculture		Degraded	
	Nitrate mg/l	**Phosphate mg/l**	**Nitrate mg/l**	**Phosphate mg/l**
Maximum range	19.8-22.0	6.8-7.6	2.6-4.5	1.2
Mean maximum	21	7.2	3.6	1.2
Median range	6.6-6.8	3.5-5.5	0.3-0.4	0.1-0.2
Mean median	6.7	4.5	0.4	0.15
Minimum range	2.4-2.8	0.4-0.6	0	0
Mean minimum	2.6	0.5	0	0

Source: Nakarmi 2003

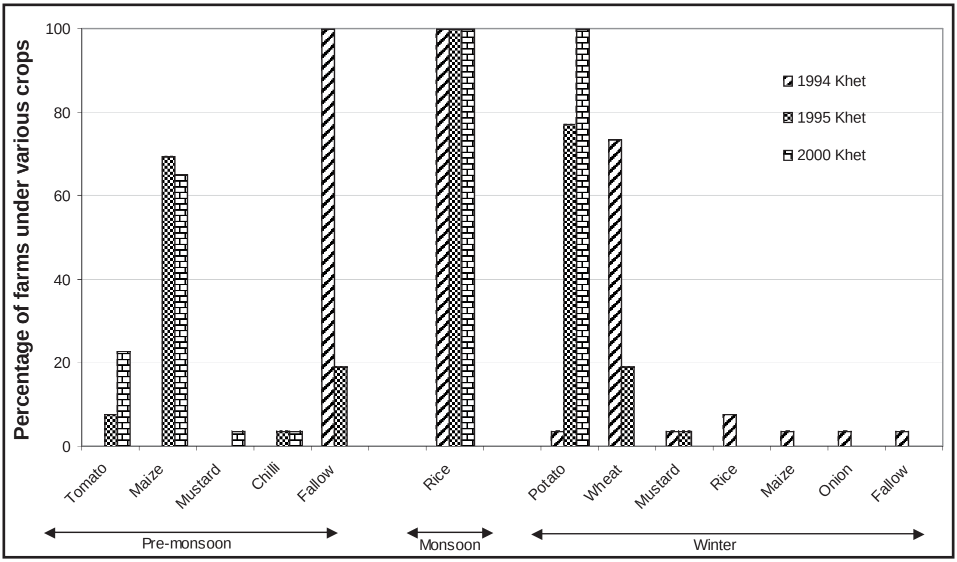

Figure 4.2: Cropping rotations by seasons on irrigated fields (khet)

Source: Modified after Westarp 2002

Comparative studies (Westarp 2002) found winter potatoes receiving the largest amount of organic matter and chemical fertiliser in both 1995 and 2000. A maximum application rate of 29 t/ha was recorded in 2000. Yearly average values reported by farmers for 1995 and 2000 were 12.2 and 14.7 t/ha. These figures are within the range documented by Gurung and Neupane in eastern Nepal (1991: 11 t/ha). Almost all of the farmers surveyed (96%) applied 11-14 t/ha of organic matter to their winter potatoes. The organic matter applied to pre-monsoon and monsoon crops was found to have declined by 11-15% between 1995 and 2000 (Tables 4.9 and 4.10). This reduction is due to the application of organic matter for the winter cultivation of potatoes by many farmers. No changes were recorded in organic matter addition to pre-monsoon crops, but applications have declined for monsoon rice between

1995 and 2000. The cultivation of the cash crops potato, tomato, and other vegetables has brought about a significant transfer of organic matter from less intensively managed rainfed and irrigated fields to intensive sites nearby roads with good access to markets.

Table 4.9: **Compost application on intensive irrigated fields, 1995**

1995	No. of farmers	% farmers applying inputs	Compost applied (t/ha)		N inputs (kg/ha)		P inputs (kg/ha)		K inputs (kg/ha)	
		%	M	R	M	R	M	R	M	R
Monsoon rice	26	8	0	0-27.0	0	0-256	0	0-27	0	0-231
Winter	26	77	9.83	0-29.5	93	0-280	10	0-30	42	0-125
Potato	19	19	11.3	0-29.5	107	0- 80	11	0-30	97	0-252
Wheat	6	17	0	0-9.8	0	0-93	0	0 -10	0	0- 84
Pre-monsoon Total	18	11	0	0-14.3	0	0-135	0	0-14	0	0-122
Annual	-	-	12.3	0-41.3	117	0-392	12	0-42	105	0-353

Source: Westarp 2002 Abbreviations: M = median, R = range

Table 4.10: **Compost application on intensive irrigated fields, 2000**

2000	No. of farmers	% applying inputs	Compost applied (t/ha)		N inputs (kg/ha)		P inputs (kg/ha)		K inputs (kg/ha)	
		%	M	R	M	R	M	R	M	R
Monsoon rice	26	8	0	0-4.9	0	0-47	0	0-5	0	0-42
Winter potato	26	96	14.7	0-29.5	140	0-280	15	0-30	126	0-252
Pre-monsoon total	26	0	0	-	0	-	0	-	0	-
Maize	18	0	0	-	0	-	0	-	0	-
Tomato	5	0	0	-	0	-	0	-	0	-
Annual	-	-	14.7	0-29.5	140	0-280	15	0-30	126	0-252

Source: Westarp 2002 Abbreviations: M = median, R = range

Chemical fertiliser use in irrigated fields varies by season and crop type. Winter cash crops receive the most fertiliser. The percentage of farmers fertilising winter and pre-monsoon cash crops has increased by nearly 25% between 1995 and 2000 (Table 4.11). Potato, the main cash crop received the greatest amount in both 1995 and 2000, but wheat, which is gradually being replaced by more profitable cash crops, received the least fertiliser. Chemical fertiliser inputs for dominant crops have increased from 351 to 436 kg N/ha, 83 to 240 Kg P/ha and 0 to 98 kg K/ha. Urea inputs have remained the same but large increases in DAP have

Table 4.11: **Fertiliser use in irrigated fields in 1995 and 2000**											
Crop		**Urea (kg/ha)**		**DAP (kg/ha)**		**Complex (kg/ha)**		**Potash (kg/ha)**		**Ammonium sulphate (kg/ha)**	
		1995	**2000**	**1995**	**2000**	**1995**	**2000**	**1995**	**2000**	**1995**	**2000**
Monsoon											
Rice	Median	157	143	nk	216	nk	–	–	–	nk	nk
	Range	0-393	0-491	0-236	0-590	0-491	–	–	–	0-98	0-118
Winter											
Potato	Median	138	197	nk	983	786	–	nk	197	nk	nk
	Range	0-295	0-688	0-983	256-1966	0-1966	–	0-138	0-491	0-491	0-197
Wheat	Median	–	–	nk	–	–	–	–	–	–	–
	Range	–	–	0-197	–	–	–	–	–	–	–
Pre-monsoon											
Maize	Median	98	157	nk	–	nk	–	–	–	–	–
	Range	0-393	0-491	0-295	–	0-236	–	–	–	–	–
Tomato	Median	nk	–	197	–	–	–	–	–	–	–
	Range	0-295	–	0-658	–	-	–	–	–	–	–
Source: Westarp 2002, nk = not known											

happened. The dominant fertilisers applied in 1995 were urea and complex fertilisers, but by 2000 DAP had completely replaced complex fertilisers to overcome P deficiency. This has however resulted in over-fertilisation. Positive trends are noticeable in the number of farmers applying potash to potato (4% in 1995 and 81% in 2000). The rise in potash use is likely linked to promotion by extension services; reduction in yields, and enhanced farmer knowledge in trying to balance nutrient requirements for potatoes.

Farmers have responded to intensification by increasing inputs to maintain yield. Complex fertiliser (N.20:P.20: K.20) and ammonium sulphate are gradually being replaced by urea and DAP on the surveyed irrigated fields. This significant rise in fertiliser use justifies concerns about soil acidification. The increased use of organic matter could buffer the acidification of soils but it is difficult for farmers to get hold of more organic matter for composting.

Nutrient Budgets

The nutrient budget for crop rotation systems in irrigated and rainfed sites was assessed by looking at the findings of previous studies. The intensification of cropping in parts of the Jhikhu Khola watershed has led to potassium deficiencies, particularly in soils in irrigated fields where levels were previously adequate. In these fields about 6 kg N/ha, 1 kg P/ha and 13 kg K/ha comes from irrigation water. The flooding of rice fields provides an additional 15 kg N/ha/yr from biological nitrogen fixation (Brown 1997). The high input of potassium is attributed to the dominance of illite and micaceous clay minerals in the soils and bedrock of the area. Winter potatoes are irrigated about seven times in each season. This provides around 1.4 kg N/ha, 0.3 kg P/ha, and 6.5 kg K/ha (Schreier et al. 1994). The annual nutrient enrichment via suspended sediment in irrigation water in rice fields is around 1 kg P/ha, 2 kg K/ha and 28 kg Ca/ha (Shah and Schreier 1995).

Irrigated crops

The main cropping rotation system for irrigated lands in 2000 was monsoon rice-winter potato-pre monsoon maize – a rotation that remains common in 2003. In 1994 the most common rotation was monsoon rice-winter wheat-pre monsoon fallow. The new three crop rotation demands higher inputs. Consequently nitrogen input has increased from about 100 kg to almost 400 kg/ha/yr. Phosporous use has increased almost fourfold rising from 60 to nearly 240 kg/ha/yr. Intensive farms have a surplus of nearly 120 kg P/ha due to high inputs of DAP for potatoes. Potassium use has increased from 60 to 450 kg/ha/yr as a result of moving over to potato production and cultivating three crops per year (2000). However, even with these increased inputs there is about a 200 kg/ha/yr deficit of potassium on intensive sites. Sanchez (1976) documented comparable uptake values of 342 kg/ha/yr for rice-potato-wheat rotations.

In triple crop rotation systems overall N and K balances have been found to be negative but P shows significant surpluses. The P surplus is due to the heavy application of DAP for potato cultivation and other crops. But potato has the largest negative K budget followed by rice and maize (Table 4.12). Under less intensive management systems overall nutrients have been balanced.

Table 4.12: **Median nutrient balance for irrigated crops**

Cropping system	Crop	N balance (kg/ha/yr)	P balance (kg/ha/yr)	K balance (kg/ha/yr)
Intensive (2000)	Rice (n=26)	-79	+88	-51
	Potato (n=26)	+13	+19	-118
	Maize (n=18)	-8	+7	-16
Less intensive (1994)	Rice (n=26)	+15	+11	-27
	Wheat (n=19)	-5	+1	+6

Source: Westarp, 2002

Rainfed crops

The more intensive cropping of rainfed lands has had a positive effect on the overall nitrogen, phosphorous and potassium budgets of soils. In 1994, 50% of all farms examined showed negative nitrogen balances, 12% had negative phosphorous balances, and 72% had negative potassium balances. By 2000 only 30% of the intensive rainfed sites had negative potassium balances (Table 4.13). These positive trends are due to increased fertiliser application. However, despite these higher inputs, yields have not increased much and the yields of rainfed potatoes remain significantly lower than those in irrigated fields. Maize yields have become higher due to the introduction of new monsoon varieties.

Table 4.13: **Median nutrient balance for rainfed cropping**

Cropping system	Crop	N budget (kg/ha/yr)	P budget (kg/ha/yr)	K budget (kg/ha/yr)
Intensive (2000)	Maize (n=20)	33	2	-12
"	Potato (n=13)	119	31	6
"	Tomato (n=14)	116	40	61
Less intensive (1994)	Maize (n=31)	-84	-3	-68
"	Wheat (n=14)	10	3	9

Source: Westarp, 2002

4

The dominant cropping rotation of maize with wheat/mustard fallow in 1994 had been replaced in 2000 by maize-potato-tomato. Fertiliser inputs have increased dramatically to 100-450 kg of N and 50-150 kg of P ha/yr. Potassium inputs come mostly from organic sources.

The increase in intensive rainfed cropping is due to the cultivation of cash crops; with potatoes and tomatoes needing high inputs of fertiliser and organic matter. For rainfed maize on the less intensive systems the nitrogen and potassium balance was found to be negative whilst in the more intensive system potassium deficits were small (Table 4.13).

Soil Fertility Dynamics

The greatly increased production of cash crops has led to an intensification of the farming systems studied and significant effects on the nutrient budget and soil nutrient pools of irrigated and rainfed crops. No changes were observed in soil pH between intensively and less-intensively farmed sites; but a slight decline was noted in irrigated fields and a slight increase in rainfed fields. This intensification has not led to more acid soils as the soils are already acidic with a pH of about 5 and it would probably need higher levels of acidic inputs to cause further declines. Also the calcium enriched irrigation water tends to buffer the effects of soil acidity in irrigated sites.

Substantial surpluses of phosphorous were noticed in intensive systems but exchangeable calcium, magnesium and the percentage base saturation were lower in comparison to less intensive sites. The field observations and study results do not support the notion that acidification is a widespread problem despite increased fertiliser use. The large amounts of compost applied by farmers also seem to be buffering soil acidity.

Carbon and nitrogen levels are significantly higher in irrigated fields than rainfed fields contrary to previous observations. This is believed to have occurred recently due to changes in the cropping patterns and the application of higher levels of inputs. The carbon and nitrogen levels in soils in rainfed and irrigated fields under three or four crop rotations per year are below desirable levels. The most significant findings of interest to both farmers and researchers is that potassium levels have dropped dramatically in intensively managed irrigated systems and phosphorous levels have increased in intensively managed irrigated and rainfed sites.

Soil erosion is not a major problem but nutrient losses in runoff from rainfed sites were found to be substantial. Farmers readily adopt new practices as land intensification increases. What seems to be happening is that as the deficiency of one nutrient is corrected another becomes deficient. The deficiencies in the macronutrients nitrogen, phosphorous and potassium have been addressed but deficiencies in calcium, magnesium, sulphur, and the micronutrients will likely become deficient if intensification increases. These nutrients will need to be evaluated in the future to maintain a balanced nutrient supply for long term sustainability.

Acknowledgements

This paper presents the research findings of PARDYP's long-term soil fertility studies in the Jhikhu and Yarsha Khola watersheds. These studies have been carried out in collaboration with the University of British Columbia. The support from PARDYP Nepal team members is highly appreciated, especially from Regional Coordinator Roger White for his valuable comments on this paper and Samma Shakya for help with putting it into a presentable format.

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5

Resource Dynamics and Promising Livelihood Options: A Study of the Bheta Gad-Garur Ganga Watershed, Indian Central Himalayas

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Abstract

The Himalayas are ecologically fragile and economically underdeveloped with severe limitations on resource productivity. Subsistence agriculture is the main source of livelihood. Rapid population growth has led to extensive land use changes mainly through the extension of agricultural land and widespread deforestation. The People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP) focuses on building local capacity to better manage the available resources to provide for people's livelihoods. This study reports on project work in the Garur Ganga watershed, northwest India to demonstrate and introduce new farm-based technologies that are mostly low cost. These include polyhouses, improved composting, apiculture, small-scale fish farming, improved seed varieties, and soil and water conservation techniques. The rehabilitation of degraded lands, seedling raising, and improved fodder have also been promoted.

Introduction

The Himalayan region of India occupies about 18% of India's area and is inhabited by 6% of its people. The Himalayan economy is mostly agricultural and farm incomes are generally very low. Key strategies to improve farm incomes include growing higher value commercial crops and processing agricultural produce and natural resources such as minor forest products.

The diverse agro-ecological conditions of this part of the Himalayas form niches for the growing of certain horticultural crops, flowers, spices, tree fruits, medicinal plants and fish. These can be grown in the hills at a comparative advantage as they cannot be produced in the plains areas to the south. Many specific products are only being produced in these hilly areas either due to favourable growing conditions or the availability of traditional skills. Some skills are traditional while others have developed recently in response to market opportunities.

Environmental constraints and ineffective development planning mean that there are few off-farm livelihood opportunities in this area. Most local people rely on the unproductive agricultural economy for their livelihoods. It is very difficult for this subsistence agriculture to provide a decent livelihood to the growing population even if agricultural productivity is greatly increased. Most households in the study watershed have small landholdings of less than half a hectare.

To significantly increase incomes in this area must involve a shift from subsistence to more enterprise oriented production. However, such a shift needs improved infrastructure to give better access to inputs, markets, and improved institutional support. The strengthening of links to local and national markets would greatly encourage the development of micro-enterprises. This study suggests ways for local people to improve their livelihoods.

The Problem

As in other parts of the Himalayas, the economy of the Bheta Gad-Garur Ganga watershed mainly depends on traditional agriculture. However, on average there is only 0.13 ha of cultivable land per person and the productivity of local agriculture is low. Consequently, the local economy is subsistence dominated with food grains accounting for most production. This leads to a large section of the adult male population having to migrate out of the area in search of better livelihood opportunities (Bisht and Tiwari 1997). About a quarter of local people live and work outside the watershed for at least a part of the year (Topal et al. 1999).

Other problems in this area that are common to the Himalayan region in general are:

- rainfed agriculture largely depends on traditional farmyard manure for improving and maintaining soil fertility in the absence of chemical fertilisers;
- scattered and small land holdings;
- large areas of waste land;
- increasing human and livestock populations with increasing demands for food, fuel and fodder;
- lack of advanced technological inputs, and
- lack of water for drinking and irrigation (Rawat et al. 1997a and 1997b; Bisht et al. 2000 and 2002).

There is an urgent need to improve the area's farming systems and provide alternative sources of income.

Study Area

The Garur Ganga watershed covers 82 km^2 and is administered under the Garur block of Bageshwar district, Uttaranchal, in northwestern India. Bageshwar is the major population centre lying 40 km away from the watershed. The watershed has 63 revenue villages with a 1991 census population of 14,524 giving a density of about 175 person/km^2. About 72% of the population are engaged in agricultural activities.

Population growth in this watershed between 1951 and 1991 was 1.52% with a very high growth rate between 1971 and 1981 of 3.2%. The area has 1025 females to every 1000 males – much higher than the national average figure of 929. The per capita availability of cultivable land is 0.13 ha, slightly higher than that of the entire Indian Central Himalayan region (0.12 ha), but lower than the national average of 0.20 ha. The watershed is centrally located in Uttaranchal and has great physical and cultural diversity.

Land Use and Population Dynamics

Pinus roxburghii (chir pine) forest cover much of the watershed. These forests provide fuelwood, fodder, and non-timber forest products and have significant economic potential. Agricultural and settlement land accounts for 42% of the total area. Table 5.1 shows land use changes in the watershed over the 34 years between 1963 and 1996 from geographical information system and remote sensing information. The area under agriculture and settlements has increased by over 7% due to the large increases in population. The major agricultural expansion has happened close to settlements. There has been a corresponding 5% decrease in forest area.

Table 5.1: **Land resource pattern and dynamics, 1963-96, in the Garur Ganga watershed**

Land-use type	1963		1996		Changes (%)
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	1963-1996
Agriculture/settlement	28.89	34.97	34.98	42.34	+7.37
Forests	50.11	60.65	45.92	55.58	-5.07
Barren land	3.00	3.63	1.09	1.32	-2.31
Other	0.62	0.75	0.63	0.76	+0.01

Source: B. S. Bisht and B.P. Kothyari, 2001

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In the Himalayas, excessive population growth tends to be detrimental to economic development, the sustainable use and management of natural resources, and improvements in the quality of life (Bisht and Tiwari 1996). The watershed registered a 44% growth in population between 1951 and 1991 although 1981-91 saw a decline of 5% in the population. This decline was mainly due to the lack of economic opportunities in the area.

Sustainable Livelihoods

The majority of the area's people rely on agriculture and the surrounding natural resources for their livelihoods. It is therefore crucial that their livelihood strategies are sustainable otherwise these natural resources could disappear. The area's main livelihood resources are described below.

Forests – Forests cover 56% of the watershed's area and play a major role in local livelihoods. Their economic utility depends on their geographic location, slope and altitude. The area's forests include reserved forests, civil forests, and panchayat forests.

Agriculture – Agricultural land covers 42% of the watershed with the largest part falling between 1200 and 1600m altitude. About 80% of the watershed's population is engaged in agriculture but this does not provide enough to feed the local population. Local farming systems produce three crops over each two year period in rainfed conditions and two crops per year on irrigated lands (Table 5.2). Over time local people have adapted their farming practices to a sustainable pattern of mixed cropping with leguminous and minor crops mixed with the main staple crops.

Table 5.2: **Traditional cropping pattern in the Garur Ganga watershed**

Season	Main crop	Other crops
Rabi season winter crops	Wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*)	Sarson (*Brassica campestris*), muter (*Pisum sativum*), and masoor (*Lens esculenta*)
Kharif monsoon season crops on irrigated land	Rice (*Oryza sativa*)	Koni (*Setaria italica*), til (*Sesamum orientale*), and urd (*Phaseolus radiates*)
Kharif monsoon season crops on unirrigated land	Finger millet – mandua (*Eleusine coracana*)	Ramdana (*Amaranthus paniculatus*), jowar (*Sorghum vulgare*), soyabean (*Glycine max*), gahat (*Dolichos uniflorus*), urd (*Phaseolus radiatas*)

Cash crops – The Himalayan region has a vast potential for cash crop cultivation. Such crops substantially contribute to local people's livelihoods. However, there is a tremendous scope for adding more value to increase economic benefits. For example, local people sell potatoes locally. Processing them into potato chips would realise much more profit. Similarly, ginger, chillies, garlic, peas, and other crops are sold unprocessed with no value added.

Alternative potential cash crops include large cardamom. This can be cultivated on sloping, moist wasteland; along water channels, field bunds and terrace risers; and under the shade of nitrogen fixing trees where other crops cannot easily grow.

A major focus of watershed development programmes is to improve local incomes to reverse out-migration. Huge opportunities exist within the watershed for farmers to increase their incomes. The introduction of off-season vegetable cultivation for the local market is one such area. PARDYP began to promote this in 1997 by building a small polyhouse on Girish Tiwari's farm at Talli Nakuri on an area of degraded grazing land.

Table 5.3 shows how Tiwari's income has increased by using polyhouses and polypits. He built two polyhouses and two polypits to raise vegetable seedlings in the early spring to get a several week's advantage in vegetable production. The area under cultivation has been 0.10 ha. In 1999 his total gain from the polyhouse was Indian rupees (IR) 3055 (US$66) increasing to IR 21,557 by 2002 (US$ 469). This was on top of the substantial extra nutritious vegetables consumed by the family. The polyhouses were used to grow seedlings for his own use and to sell on to other farmers.

A variety of horticultural fruits are also produced in the area, but only citrus fruits, pears and walnuts are sold. Improving the market infrastructure and carrying out some primary processing would greatly add value to these products. Improving the local roads is a large task that takes time. Adding value to the primary products and improving marketing can be done relatively quickly. Horticulture has great potential for the development of this area. However, the government has given little attention to horticultural development in this region.

Table 5.3: **Economic analysis of farmer Girish Tiwari's innovations**

Year	1999 (IR)	2000 (IR)	2001 (IR)	2002 (IR)
Inputs				
Farmyard manure (600 kg)	650	650	800	1,000
Seeds	500	750	1,000	1,200
Polyhouses and polypits	650	-	-	-
Labour	Self – no cost	Self – no cost	Self – no cost	Self – no cost
Pesticides	50	50	100	150
Transport to market	350	1,150	1,400	1,600
Total inputs	**2,200**	**2,600**	**3,300**	**3,950**
Outputs				
Vegetable and flowers	5,455	12,393	16,385	18,357
Seedlings	5,650	6,150	6,500	7,150
Total outputs	**11,105**	**18,543**	**22,885**	**25,507**
Total net gain	**8,905**	**15,943**	**19,585**	**21,557**

Water harvesting – Local people suffer from serious water shortages. Paradoxically a huge amount of water is available through rainfall and subsurface flow; but poor management means that only small amounts are available. This mismanagement leads to constant shortages of drinking water in dry seasons and the very limited area of irrigated cropland. The improved availability of water is a prerequisite for the development of this watershed. PARDYP has introduced a simple and cheap water harvesting technology to store rainfall for dry season use. Polythene lined ponds are built to collect and store rainwater, unused spring water, and wastewater for domestic and minor irrigation purposes. PARDYP has successfully mobilised many village communities to adopt this technology.

Fish farming – PARDYP is promoting small scale domestic fish farming to improve farm incomes. Participatory research carried out by PARDYP India in 2001 raised the three species of grass carp, common carp, and silver carp in farm ponds. The promising results led to 40 farmers taking up fish farming in 2003. It is estimated that over three years households with a stock of 1,000 fish have earned a net profit of about IR 30,000 per year (Table 5.4).

Table 5.4: **Economic analysis of small scale fish production in the Garur Ganga watershed**

Farmer	Village	No. Tanks and type	Costs (IR)			Income (RIR)	Profit
			Up-keep	Feed	Medicine & nutrients		
Prakash Singh Khatri	Pingalkot	5 (MPL)	1000	2000	250	18000	14750
Ishwar Singh	Jeona	3 (MPL)	800	500	10	5600	4200
Balwant Singh	Majherchaura	4 (cement)	500	1000	200	5200	4000
Bahadur Singh	Gewar	2 (MPL + cement)	400	500	-	4000	3100
Rajendra Sen	Dumlot	4 (MPL)	400	800	-	4000	2800
DS Bisht	Kausani	1 (MPL)	200	1000	200	4000	2600
Sun Bahadur	Dumlot	3 (MPL)	200	400	-	3200	2600
Ramesh Ram	Jadapani	1 (MPL)	400	500	50	3200	2250
Manohar Singh	Lawbanj	1 (cement)	-	100	-	2000	1900
DS Parihar	Arah	1 (MPL)	200	800	200	2800	1600
Harish Ram	Jadapani	1 (MPL)	200	250	-	2000	1550
Rajendra Singh	Deonai	1 (MPL)	250	300	-	2000	1450
Madhan Singh	Pingalkot	1 (MPL)	400	500	100	2400	1400
Narayan Giri	Pokhari	1 (MPL)	200	200	-	1600	1200

Note: Only farmers making more than IR 1,000 profit included. Cost of tank construction not included in income calculation. MPL = mud polythene lined

Degraded lands – This watershed has many areas of pasture that are moderately to highly degraded. PARDYP has initiated work to improve the condition of these lands and reduce women's workload and improve local economic conditions. Community forestry offers great scope for rehabilitating degraded lands. PARDYP selected a highly degraded 4.5 ha site owned by several Lawbanj families. The locally preferred tree species *Grewia optiva, Quercus* *glauca, Quercus incana, Celtis tetranda, Alnus nepalensis,* and *Toona serrata* were planted by local people. They closed the site to grazing. During the first year there was a huge increase in ground vegetation and the villagers collected about 28,000 kg of green grass worth about IR 36,000 (US$ 780). In-line with PARDYP suggestions local people established nutritious grass species such as species of *Thysanoleana, Setaria,* and *Pennisetum* on to empty patches of forest land.

Other Sources of Livelihood

The watershed has immense potential for developing livestock raising, apiculture, poultry and medicinal plants. Economic inputs and new skills are needed to take advantage of these resources.

Livestock farming is a very important source of income and nutrition. Cows and buffaloes produce milk, ghee, and khoya (solid milk), bullocks provide draught power, and goats are kept for their meat.

PARDYP has made considerable efforts to raise awareness among beekeepers about the importance of conserving indigenous honey bees and especially the local species (*Apis indica*). More than 20 farmers have become fully engaged in bee keeping.

A number of farmers in the watershed are taking up poultry farming. It is proving a lucrative enterprise. PARDYP provided advice on the most appropriate technology and management issues. This has significantly uplifted the economic status of many households including that of Ram Prasad Dudila. Ram Prasad is one of the most efficient and experienced poultry farmers in the watershed. In 1999 he built a poultry house costing IR 50,000. The amount he has earned has risen every year and in 2002 he made a profit of IR 49,000 (US$ 1,065). He makes this amount from one lot of chickens but is usually able to raise two lots a year. He sells the birds at the local market at Garur and to local hotels (Table 5.5).

Table 5.5: **Economic analysis of Ram Prasad Dudila's poultry enterprise**

	1999 (R)	2000 (IR)	2001 (IR)	2002 (RF)
Chicks	2,000	3,500	5,000	5,000
Transportation	1,700	2,500	4,500	5,000
Medicines	1,600	1,800	2,000	1,500
Poultry feed	3,000	4,000	5,500	6,000
Electricity	1,800	2,000	3,000	3,000
Water pots	1,000	200	1,500	
Feeders	1,000	-	-	-
Maintenance	700	800	1,000	500
Total cost of inputs	**12,800**	**14,800**	**22,500**	**21,000**
Income after 3 to 4 months	48,000	60,000	70,000	70,000
Net gain	**35,200**	**45,200**	**47,500**	**49,000**

Note: this analysis is on a per lot basis. Normally two lots are produced in a year.

The Indian Himalayan region is home to 1748 species of medicinal plants. Most of these are being harvested from the wild, often in an unsustainable way. This has adversely affected the existence of a number of valuable plants. Local people in the watershed have much knowledge about medicinal plants. Their lack of access to modern medicine means that many people turn to locally available herbal remedies. However, this knowledge is fast disappearing and needs to be preserved. The cultivation of medicinal plants has great potential for improving livelihoods in the watershed

Conclusions

The main conclusions of the action research are:

- the initiatives being tried out in the Garur Ganga watershed have great potential to promote the sustainable and equitable development of marginalised families and communities in the Hindu Kush-Himalayas;
- the study area's farmers are not passive inflexible victims of unsustainable development. They are highly active, adaptive and dynamic actors;
- great progress has been made towards initiating and extending better livelihood strategies for local people in the study watershed; and
- the introduction of fish farming has been one of the most beneficial initiatives.

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Acknowledgements

This study is based on the work of the People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP). The authors are grateful to IDRC, SDC and ICIMOD for financial assistance. They are also thankful to the director of the G.B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, India for facilities and support. The authors also thank the PARDYP India team for their help and suggestions.

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6

Traditional Land Use and Environmental Degradation in the Chittagong Hill Tracts of Bangladesh

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Abstract

Many of the tribal communities that live in the Chittagong Hill Tracts (CHT) practice shifting cultivation (jhum). However, traditional jhum cultivation has proved to be destructive and unsustainable as cropped land is no longer given enough time to recover its fertility between cropping cycles. Increasing pressure on the land to meet the needs of the growing populations has led to the shortening of fallow periods to only three to five years. The problem was exacerbated by the building of the Kaptai Dam that displaced 100,000 tribal valley cultivators and pushed them in to practising jhum cultivation on the forested slopes. Traditional jhum cultivation can no longer meet local people's subsistence requirements and the removal of large areas of forest has had an adverse effect on the environment causing much soil erosion. The system has caused enormous deforestation, soil degradation, fertility reduction, and siltation in lakes and waterways. This paper recommends that jhum cultivation be adapted to make it environmentally friendly. The Chittagong Hill Tracts have a wealth of natural resources. A detailed inventory needs carrying out of the area's resources to guide a coordinated programme involving the government, semi-government organisations, politicians, researchers, planners, NGOs and, most importantly, native hill dwellers in meeting their needs whilst conserving the area's natural resources.

Introduction

Bangladesh is a predominantly agricultural country. Most of the area is made up of alluvial floodplains and deltaic sediments. Only about 12% is hilly uplands. The hilly areas are mostly in the Chittagong division in the far southeast, and Sylhet division in the northeast. The alluvial floodplain soils of Bangladesh are highly fertile but vulnerable to flood, drought, river erosion and siltation. These lands are mostly level, subject to seasonal flooding in the rainy season, and suited for rice, jute and wheat production. There is little scope to expand cultivation in these areas as cropping intensities already exceed 200% coverage. The areas with the greatest potential to expand food production are the hilly areas of the country.

Due to its regular flooding, only a limited number of crops can be grown in the alluvial plain lands. The hills are mostly free from seasonal flooding and are suitable for growing a wide range of field crops, spices, horticultural crops, forest plantations, rubber, coffee, and tea. Land use in the hilly areas is different to the plain alluvial areas, although the valleys and level to nearly level piedmont areas are cultivated in a similar way. Most hilly areas are closely dissected and sharply ridged with steep slopes that have shallow to moderately deep soils. The hill soils of Bangladesh are slightly to very strongly acid, rich in iron, manganese and potassium, and deficient in nitrogen, phosphorus, boron and zinc.

The natural vegetation of these hills is dense jungle that provided a safe habitat for numerous species of flora and fauna. Nowadays, human intrusion in the shape of shifting cultivation (locally called *jhum*), the reckless felling of trees, and the cultivation of annual and perennial crops on steep and very steep slopes is causing severe soil erosion, runoff, and landslides. This is leading to the siltation of stream beds, low lying areas, natural drainage lines, and lakes. In the past jhum cultivators left land fallow for 15 to 20 years before returning. This helped to restore soil fertility and productivity. Presently, because of rapid deforestation and increased population pressure, the fallow period is down to only three to five years resulting in accelerated soil erosion, nutrient depletion, land degradation, and a severe threat to biodiversity (Borggaard et al. 2002). Moreover, the monocropping of tuber crops like aroid, turmeric, ginger, and potato on hill slopes with deep ploughing and no soil or water conservation measures has increased degradation.

Physiography and Land Use

Bangladesh's four main physiographic units are the alluvial plains covering 75% of the area, mangrove forest covering 5%, terraced cultivation covering 8% and the hills covering 12% (SRDI 1997).

The major sloping upland areas of the country are the hills of greater Mymensingh, Sylhet, Chittagong district and the Chittagong Hill Tracts (CHT). These lie in the southeast and northeast of the country. They are part of the Hindu Kush-Himalayan region and are one of the youngest mountain chains of the mid-Pliocene to early Pleistocene ages. The geology is characterised by three main series of rock with the two older series (Surma and Tipam) exposed in the higher elevations of the anticlines, and the relatively younger Dupi Tila series eroded at higher elevations and now underlying the low hills of the synclines (Hassan 1999). Most of these hills are closely dissected and sharp edged with mainly steep slopes ranging up to an altitude of 1000m.

The Chittagong Hill Tracts cover about 76% of Bangladesh's hilly area. Officially 26% of this area is under reserved forest and the rest is under unclassed state forest. Large areas are fallow, made up of abandoned jhum fields that have been replaced by secondary undergrowth of shrubs, vines, sun grasses, thickets and weeds. The rest is covered by horticulture, forest plantations, bamboo, cane, rubber, and tea plantations.

Small dams in the hilly creeks and streams capture large amounts of rain and seepage water for domestic use. These reservoirs are used for raising fish, watering livestock, irrigation and as tourist attractions.

Valley lands are used for cultivating rice. Farmers use fertilisers and high yielding varieties. The fields are irrigated by building earthen dams across streams, canals, and rivers to divert water into the fields. Irrigation is also done by low-lift pumps, tube wells and other local equipment. So far, deep tube-wells have not worked well in this area possibly due to the embedded sandstones and shale beds at shallow depths and the absence of desirable water layers.

Agricultural Potential of CHT

Bangladesh's Soil Resource Development Institute (SRDI) has mapped the soils and land resources of the Chittagong Hill Tracts (SRDI 1986). Most agricultural development programmes in the tracts have been based on this work's recommendations. SRDI carried out a soil survey of the CHT's 25 administrative areas (thana/upazila) from 1994 to 2002 to assess the existing natural resources. The results were published in Bengali (SRDI 1994-2002). The slope class data in Table 6.1 is based on these reports.

There is only limited land suitable for agriculture in the CHT as 79% of its area is steeply sloping with severe to very severe limitations on agriculture (Table 6.1). Many of these areas have shallow soils and suffer from soil erosion as a result of deforestation and jhum cultivation.

Table 6.1: **Distribution and extent of slope classes in Chittagong Hill Tracts**

Slope class	Slope %	Area (ha)	% Covered	Crop suitability	Crop limitations
Nearly level	< 5	83,104	6.2	Very good	Minor limitations
Gently sloping	5-15	26,518	2.0	Good	Few limitations
Moderately sloping	15-30	102,136	7.7	Fair	Moderate limitations
Steep	30-50	297,536	22.4	Less suitable	Severe limitations
Very steep	50-70	399,482	30.0	Restricted for agricultural use but good for watershed protection purposes	Very severe limitations
Excessively steep	> 70	349,786	26.3	Unsuitable for agriculture – only useful for watershed protection purposes	Very severe limitations
Settlements & water	30-70	71,939	5.4	Mostly urban areas, cluster villages, Kaptai lake, and rivers	
Total		**1,330,501**	**100**		

Source: SRDI 1994-2002

Land Rights

Reserved forests cover 3,483 km^2 (26%) of the Chittagong Hill Tracts. The rest is unclassed state forest areas used mostly for jhum cultivation. The problem of land rights is acute in this region. The CHT regulations have regulated land rights in this area since 1900. The objectives of the regulations were to "protect the rights and interests of tribal people, their customs and practices, their local and racial peculiarities and prejudices and thus preserve their cultural identities" (Shelley 1992). The CHT was divided into three taxation circles, each headed by tribal chiefs (raja). The regulation's rules were amended a numbers of times to 1935. These led to the repeal of the permit system and the declaration of CHT as a 'backward tract', thus enabling the then ruling power – the Governor General of India – to govern CHT as an excluded area. The restriction on the entry of non-tribals was lifted in 1964, causing much dissatisfaction among tribal people (Mohabbat 2002).

The building of the Kaptai Hydroelectric Dam in the middle of the hill tracts in the 1960s accelerated the destruction of the area's forests. It displaced 100,000 tribal people by submerging much of the best agricultural lands. These people were forced to take up shifting cultivation. The 1973-1996 armed conflict displaced thousands more. The peace treaty signed in December 1997 between the government and the tribal insurgents ended the conflict. A regional council was formed and a land commission set up in June 1999 to solve the land problems of displaced people.

Land ownership in most of the CHT is not clearly defined as a cadastral survey has only been carried out in the valley areas. The sloping upland areas have not been demarcated. The district administration and tribal chiefs are both involved in administering these lands. This dual responsibility has resulted in conflicts between land users and landowners. The farmers do not own the land and so attach little importance to conserving its future productivity. In each jhum season they exploit the soil to its maximum. These farmers do this in the knowledge that they may never use the plot again. This outlook is destroying the long-time sustainability of the hill soils. The nomadic *jhumias* have traditionally not practised settled agriculture and have given no attention to restoring the lost fertility and productivity of fallowed lands, mainly due to their lack of land rights (Borggaard et al. 2002). The possession of land rights is almost a pre-condition for practising sustainable production as it creates social, political and economic awareness among farmers. The CHT needs a cadastral survey to work out permanent ownership status for land users or to implement some sort of long-term lease system.

Shifting Cultivation

Shifting cultivation is the traditional cultivation practice of tribal communities in Bangladesh's hilly regions. This mixed cropping system is practiced in CHT and in the hills of the greater Chittagong district. In this rainfed upland cultivation system, an area is entirely cleared of its vegetation by cutting and then burning the cut material in the dry season. Seeds are sown or broadcast after the first April showers. The usual practice is for seeds of hill paddy, maize, millet, vegetables, chilly, melon, pumpkin, hill cotton, spices, and other species to be mixed and sown into small holes (Figure 6.1).

Figure 6.1: **Traditional jhum field on a steep slope in CHT**

As the rains set in the seeds and weeds germinate after which weeding is carried out (Borggaard et al. 2002). The crops are harvested as they ripen from July through to December. Afterwards, the jhum cultivator moves onto another site. Up to about 50 years ago the jhum cropping cycle was 15-20 years, which left enough time for soils to restore their fertility. But, increased population pressure and the scarcity of suitable land has led to the period between cropping dropping to 3-5 years. During the peak jhum season of May to July, the hilly areas receive heavy high intensity rainfall. The cleared jhum plots are very susceptible to soil erosion during this time (Gafur et al. 2002).

After cropping, abandoned jhum fields are left fallow. The jhum cultivators do nothing to restore the fertility of these areas as they have no title to these areas. The abandoned fields produce weeds, sun grass, shrubs and trees which have little economic value. After the 3-5 year fallow period these areas are again cleared and the cycle is repeated. The areas may be cleared within different boundaries and by different farmers.

The resultant washing away of the fertile topsoil of many hill slopes has turned vast areas of CHT into barren, nutrient deficient, unproductive lands. A study found that 41 tonnes/ha^2 of soil was lost through the jhum cultivation of a moderately steep to steeply sloping jhum field in one season (Gafur, et al. 2002). This suggests that the long term effect of jhum cultivation is more damaging than previously presumed. Commenting on jhum cultivation practised in the adjoining area of Mizoram, Northeast India, Lienzela (1997) called for the banning of shifting cultivation "to save Mizoram and her environment". The situation in CHT is even more urgent due to the three times greater population pressure and the much shorter fallow periods. Even though only about 2.5% of the CHT's hilly areas are currently used for shifting cultivation each year, almost the whole mountainous area except for the Kaptai Lake and reserved forest areas have been jhum cultivated in the recent past (Borggaard et al. 2002).

Back in 1965 the Canadian Forestal Survey Group (SRDI 1986) raised the alarm about rapidly decreasing fertility and yield decreases in jhum plots caused by the reduction in the fallow periods. They also reported increased landslides, soil erosion, nutrient depletion and the irreversible degradation of land, soil and environment. Since then these problems have increased as the population density has increased from 29 km^2 in 1961 (BBS 1993) to 96 km^2 in 2000 (Gain 2000). Jhum cultivation is practised mainly by the area's 13 tribes.

Population increases, mainly from in-migration from the plain areas, is causing new problems. These settlers are introducing plain land cultivation techniques on the hill slopes. They practise deep ploughing (spading), and grow tuber crops like potato, aroids, ginger, and turmeric along the slopes rather than along the contours (Figure 6.2) a pattern of cropping that is very susceptible to soil erosion.

With an estimated output of only US$362 against an input of US$380 ha/yr jhum cultivation in CHT is not cost-effective (Gafur et al. 2002a). At present production levels the system cannot even feed a family of four. It is very labour demanding with 88% of total 'expenditure' going on labour.

Most jhum cultivators do not have regular unemployment. When not working on their jhum plots they often sit in their *tang ghars* (temporary huts in the jhum field) making household items from forest products. Elderly family members make baskets, mats, furniture and ornamental goods out of bamboo, cane, cotton and other materials. There is a good demand for these handicrafts and they provide a crucial extra source of income for jhumia families.

Figure 6.2: **Tuber crops like Arum are grown across slope contours**

The jhum system results in severe losses of soil and essential plant nutrients by erosion each year. Assuming 2.5% of the CHT's land is under jhum each year, it has been estimated that nearly one million tonnes of soil, containing several tonnes of nutrients, is lost from the jhum cultivated areas of CHT each year. Compensating for this loss of nitrogen, calcium, potassium, phosphorous, sulphur, boron and zinc would involve applying about 14,000 tonnes of commercial fertilisers per year. The cost of applying this, as of March 2001, was about US$1.8 million per year (Gafur et al. 2002a).

Plantations

Rubber

Over the last two decades rubber (*Hevea brasiliensis*) has emerged as an important economic activity in the CHT. Many countries have used rubber cultivation to replace shifting cultivation. Rubber plantations give better economic returns, a more equitable distribution of income, and better forest cover to reduce soil erosion (Jayasena and Wickramanayake 1996). The Bangladesh Forest Industries Development Corporation (BFIDC) suggests that rubber cultivation is economically sound giving an internal rate of return of 15%. The 1965 Canadian forest survey (SRDI 1986) estimated that about 0.24 million hectares of the CHT's medium sloping unproductive uplands were suitable for rubber, coffee and other agroforestry crops. Many other hilly areas of the country are also suitable, but only about 25,000 ha of land, amounting to 10% of the area of suitable land, is being used for growing rubber. However, the viability of rubber plantations is being threatened in recent years as synthetic rubber is becoming popular.

This problem needs addressing by government and private initiatives to encourage cultivators to move away from monocultures of rubber to mixed plantations of rubber with timber, fruit orchards, and other crops. Another suggestion is to ban the import of synthetic rubber to stabilise the price of locally produced rubber. In addition, on-farm research on rubber should be initiated to identify higher yielding varieties and clones that are more appropriate for the Bangladeshi environment.

Tea

Tea (*Camellia sinensis*) is one of Bangladesh's main exports. Tea plantations cover more than 2% of the country's area and account for 2.8% of world tea production. Since 1950 the number of tea gardens in Bangladesh has increased from 103 to 160 in 2000. There is a growing demand for tea within Bangladesh such that it has been estimated that in 10-15 years domestic production will match domestic demand. The average productivity of Bangladesh's tea gardens is only 1,176 kg ha^2, compared to average figures for India of 1,800 kg, and for Kenya of 2500 kg ha^2. In about 12,000 ha of old tea gardens the productivity is only 460 kg ha^2. The average land use is only 44% of the granted area and the remaining 56% of government allocated land has not been brought into tea production.

6

A major intervention is needed to encourage smallholder tea production in suitable parts of the country, not only to meet increasing demand, but also to provide employment opportunities to CHT people. A feasibility study carried out by the Bangladesh Tea Board (BTB 2000) suggested that an additional area of 46,856 ha of land in three CHT districts could be converted into small holding tea plantations. This would create jobs for about 100,000 families, reduce soil erosion, and improve the local environment. Smallholder tea plantations are beginning to be established in many parts of CHT.

Small Watersheds — a Hidden Treasure

CHT's small watersheds offer great potential for introducing sustainable development measures to protect these environments and improve local livelihoods.

In small watersheds integrated, participatory, and sustainable development programmes can be implemented for community empowerment to meet livelihood and food security needs. For a long time the CHT's watersheds have experienced excessive erosion, organic matter depletion, nutrient removal by runoff and burning, deep ploughing on steep slopes, indiscriminate logging, and destruction of flora and fauna. This has led to many watersheds becoming barren and unproductive.

The average annual rainfall in CHT is 2682 mm. There are distinct wet and dry seasons with the rainy season running from May to October. There is a sharp increase in rainfall from May to June with July rainfall accounting for 24% of annual rainfall. The annual reference evapotranspiration is about 1350 mm leaving a potential rainfall excess of 1350 mm/yr (Gafur et al. 2002). This huge amount of excess rainfall drains out of the hills along with eroded soil material through the CHT's numerous watercourses. The heavy rainy season downpours are followed by serious dry season water scarcity. The surplus rainwater could be preserved by building more small dams to satisfy year-round water needs for irrigation, fisheries and other uses.

The CHT have small, medium, and large watersheds. These can serve as water reservoirs by building small earthen dams to store water. The Bangladesh Agriculture Development Corporation, local government councils, the Chittagong Hill Tract Development Board, the fisheries department, NGOs and private entrepreneurs have built such dams. These initiatives should be extended across all Bangladesh's hilly areas. In some areas micro-hydro systems are being installed to produce electricity. In plains areas huge earthworks are needed to make a pond. This is not the case in the sloping uplands as building a dam or embankment on the side of a watercourse preserves a large amount of water. This can have a large positive impact on local people's socioeconomic conditions and on the local environment. In 1961 the building of a dam across the Karnaphuli River created the 596 km^2 Kaptai reservoir. Building dams across the rivers Sangu and Matamuhari would also create large reservoirs. However, this displaces many families, which could reignite insurgency activities.

The government is working to bring small watersheds under diversified production systems using the integrated efforts of all stakeholders for the efficient economic use and sustainable development of these areas.

Conclusion and Recommendations

Introducing sustainable production systems in CHT is a difficult job. The urgent implementation of the following recommendations would help ensure the sustainable productivity and the biodiversity of the Chittagong Hill Tracts and the socioeconomic well-being of the area's people. The author looks forward to seeing the prudent management of the CHT's natural resources to support future generations.

- Promote the gradual abandonment of jhum cultivation and the rehabilitation of affected jhum cultivators.
- Leave reserve forests intact and carry out a massive afforestation and social forestry programme on unclassed state forest lands to promote the production of tea, rubber, fruit, spices and other forest species.
- Stop the cultivation of steep hill slopes for growing annual and seasonal crops. These areas should only be used with caution for long-term plantations with contouring, strip cropping, and sloping agricultural land technologies (SALT).
- Introduce secure land rights or land titles and measures to rehabilitate displaced people and migrants.
- Develop sustainable and environmentally friendly cultivation techniques as substitutes for jhum cultivation including promoting tea growing and rubber plantations mixed with timber, fruit trees, spices, and other crops.
- Undertake programmes in the CHT's small watersheds to promote the building of small earthen dams to preserve water. Multipurpose use of this water, including small hydro schemes, will improve the socioeconomic conditions of hill dwellers. This approach should be spread to all sloping upland areas in Bangladesh and should involve the carrying out of associated research.

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Part Two

Water and Erosion

7

Water Resource Dynamics: A Comparison of Five Watersheds in the Hindu Kush-Himalayas

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Abstract

PARDYP is a regional research for development watershed and natural resources management project. Much of its work focuses on water and sediment-related issues in the heavily populated areas of five watersheds of the HKH middle mountains. This paper presents the project's findings on the water resource dynamics in these watersheds. PARDYP set up a network of measuring stations to provide long-term hydrological and meteorological data to better understand the situation of water availability in the region. This network is making an important contribution to compiling and sharing information across the region to promote the better management of water resources and address water scarcity problems. This paper presents the main findings from measuring the rainfall, runoff, soil loss, high flow, and low flow patterns in the PARDYP watersheds. Unsurprisingly it was found that much of the rainfall occurs during the monsoon period. Measurements from erosion plots show that degraded and grass lands yield more runoff than agricultural land. On degraded and grassland plots rainfall events of 3 mm generated runoff whereas on rainfed agriculture plots events of 5 mm were needed to generate runoff. In many cases high flow events at plot level were found to lead to high discharges at sub-watershed and watershed level. In all five watersheds more than 80% of soil loss occurred in the April to September period for all land use types reaching a maximum of 10 t/ha in a single event from degraded land. All five watersheds had low flow situations over more than half the year.

Introduction

The Hindu-Kush Himalayas (HKH) are a huge source of water. Resource degradation and unmanaged land use are key problems in the middle mountains of the HKH. Land use changes are influencing the area's water resources. Demand is rising due to increasing population, agricultural intensification, and changing lifestyles. Most agriculture in the area relies on seasonal rainfall. This varies with monsoon high flows and associated high rates of soil erosion, and water scarcities during the dry seasons. Dry season shortages of irrigation and drinking water are the major water related issues in the region (PARDYP 2002). A good network of stations is essential to provide long-term hydrological and meteorological data to better understand the water availability situation. This did not exist prior to PARDYP and available datasets had not been analysed scientifically. Additionally, there was little regional cooperation to exchange knowledge and experiences to help better manage water resources and solve water scarcity problems.

Study Area

The People and Resource Dynamics of Mountain Watersheds in the Hindu Kush-Himalayas (PARDYP) project is a regional research for development project that focuses on watershed and natural resources management issues including water and sediment-related issues in the heavily populated areas of the middle mountains of the Hindu-Kush Himalayas. The project has generated considerable hydro-meteorological and soil erosion data that can be analysed and compared to better understand the water resource dynamics of the region.

The project is being implemented in the five watersheds of Xizhuang in China, Bheta Gad in India, Hilkot in Pakistan, and Yarsha Khola and Jhikhu Khola in Nepal (see PARDYP Teams 2005 in this volume for watershed descriptions).

Methodology

A network of meteorological, hydrological stations and erosion plots was established in the Jhikhu Khola watershed, central Nepal in 1992. This network has been continuously upgraded since then. Other networks were established in the Xizhuang, Bheta Gad, Hilkot, and Yarsha Khola watersheds in mid-1997. The networks were set up as nested series of networks from plot to watershed level in all five watersheds as described by Hofer (1998).

Information is generated at plot, sub-watershed, watershed, and regional levels. Rainfall data is derived from 8-inch diameter tipping buckets of 0.2 mm capacity per tip, and each event of 0.2 mm has been recorded on a HOBO data logger except in Xizhuang watershed. Symphonic rain gauges are used in Xizhuang. Data is crosschecked with observations from ordinary daily storage rain gauges. At hydrometric stations, water levels are measured by pressure transducers (digital) and floaters (analogue). The people responsible for taking these readings crosscheck them each day against readings from staff gauges. Discharge measurements are taken from streams and rivers at different water levels using current meters, the salt dilution method, and tracers. Based on these measurements, rating curves are developed that give the relationship between water level and discharge. The HYMOS software is used to develop rating curves of water level against discharge and to compute the discharge at various water levels. Erosion plots of between 50 and 100m^2 in size were established on areas of degraded, agriculture, and grassland. The station readers collect the sediment washed from the erosion plots into the drums after each significant rainfall event.

Hilkot watershed, Pakistan has a complete dataset for 2000-2002, Bheta Gad for 1999-2002, Jhikhu Khola for 1993-2002, Yarsha Khola for 1998-mid 2001 and Xizhuang for 1999-2002. These datasets have been compiled by PARDYP and are available as yearbooks in hard and soft copy formats from the PARDYP partner organisations (for example see GBPIHED 2003). The number of hydrological stations, meteorological stations, and erosion plots in PARDYP's watersheds are given in Table 7.1 and the seasonal climatic conditions in Figure 7.1.

Results and Discussion

Rainfall patterns

All five watersheds have excessive rainfall during the monsoon seasons causing high flows and surface erosion. They have generally low amounts of rainfall over the rest of the year. The Yarsha Khola and Xizhuang watersheds receive the most rainfall whilst Pakistan's Hilkot watershed receives the least.

Table 7.1: **Measurement sites in the five PARDYP watersheds (as of 2002)**

Watershed	Hydrological stations	Meteorological stations	Erosion plots
Xizhuang	5	10	6
Bheta Gad	6	5	4
Jhikhu Khola	5	10	7
Yarsha Khola	6	11	4
Hilkot	5	6	4

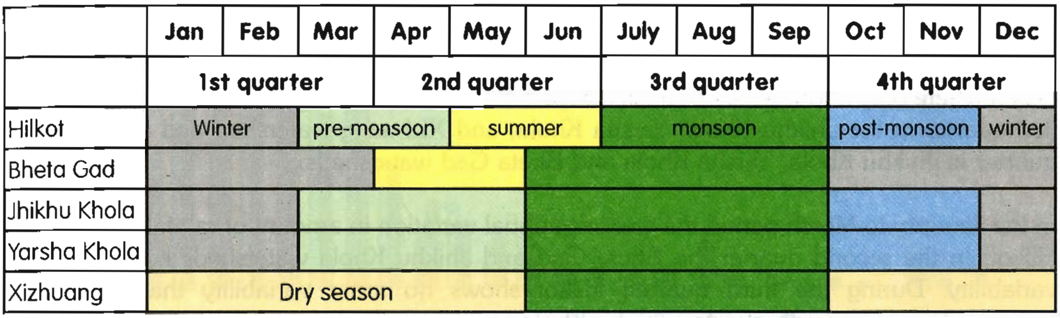

Figure 7.1: **Timing of seasons in PARDYP's watersheds**

Most rainfall occurs between May to October in all the watersheds with only small amounts the rest of the year (Figure 7.2). Yarsha Khola has the highest rainfall in any one month (July). Overall, the most rainfall occurs in July and August except for Xizhuang where it is highest in September. The most winter rainfall occurs in the Hilkot and Bheta Gad watersheds. In Hilkot much of the winter precipitation falls as snow.

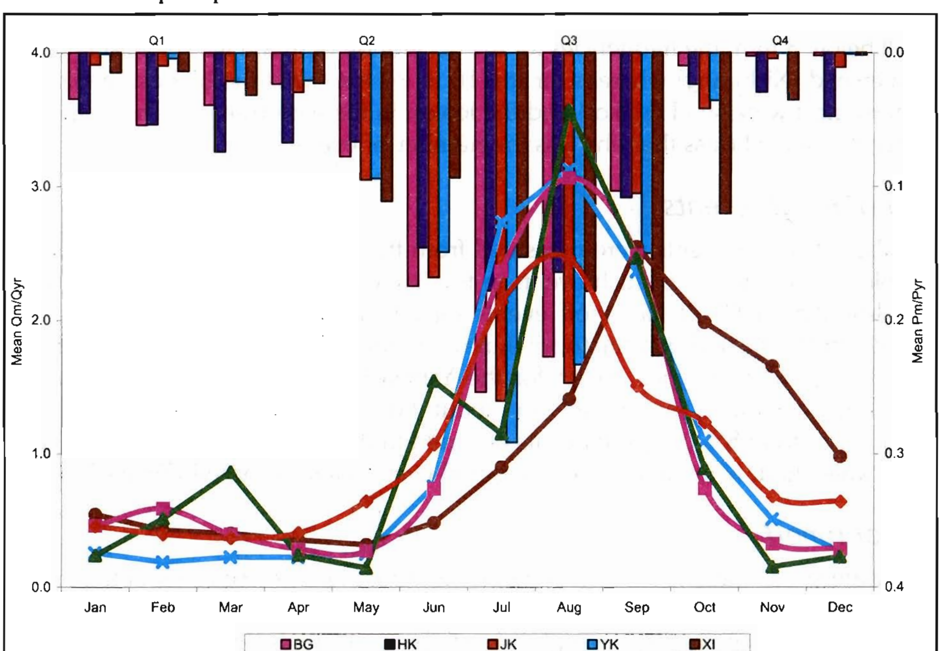

Figure 7.2: **Mean monthly rainfall and discharge at the main hydrological and meteorological stations, five PARDYP watersheds, 1997-2002**

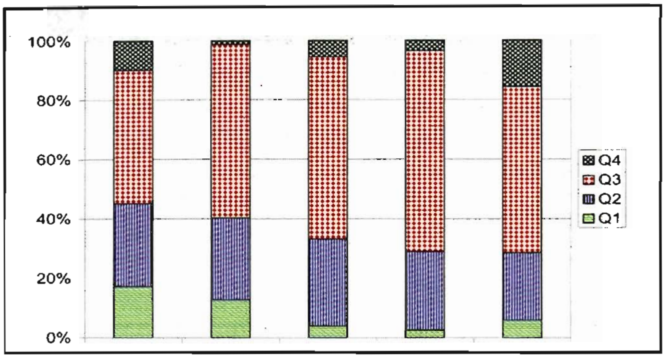

Figure 7.3: **Quarterly distribution of rainfall at the main PARDYP meteorological stations**

More than 60% of rainfall occurs in the third quarter of the year in all watersheds except for Hilkot where only about 40% occurs in this period (Figure 7.3). Very little rainfall occurs in the first quarter in the Jhikhu Khola, Yarsha Khola, and Xizhuang watershed and in the fourth quarter in Jhikhu Khola, Yarsha Khola and Bheta Gad watersheds.

In the January to March period the greatest annual variation in amount of rainfall occurred in Hilkot. In the second quarter the Bheta Gad and Jhikhu Khola watersheds have the most variability. During the third quarter, Hilkot shows no more variability than the other watersheds. In the fourth quarter, Jhikhu Khola and Bheta Gad have the most variability.

Rainfall runoff

The project recorded the number of rainfall events where significant amounts of rainfall fell in order to be able to trace the soil loss and discharge patterns. To analyse the recorded rainfall runoff events, the amount of rainfall in each runoff event was measured and then these measurements were put into 8 mm class intervals. This showed that the most events gave 8-16 mm of rainfall runoff accounting for about 30% of all events (Figure 7.4). For class intervals of rainfall below 8 mm, the frequencies for the generation of runoff was highest in the eastern-most watershed (Xizhuang) whereas for the 16 to 24 mm class the highest readings were in the western-most watershed (Hilkot) and the lowest in the eastern-most. The data shows that the higher the rainfall class then the less the number of events.

Number of runoff events

The number of runoff events were measured from the degraded, agricultural, and grassland erosion plots. The number of such events in the first quarters (January to March) amounted for only less than 10% of all runoff events for all the kinds of land use plots in all five watersheds. In the second quarter (April-June), the number of events amounted to between 20 and 30% on all plot types except for the Yarsha Khola degraded land plots. The third quarter (July-September) accounted for about 60% of runoff events except for Hilkot watershed. Less than 8% of runoff events occurred in the fourth quarter (Oct-Dec) except for Xizhuang watershed, when about 14% of runoff events were recorded (Figure 7.5).

Pattern of runoff

The five watersheds have monsoon climates with most rainfall occurring between June and September. High intensity pre-monsoon and monsoon rainfall causes most of the annual rainfall runoff across all the land use plots in all the watersheds. In Yarsha Khola and Jhikhu Khola watershed more than 92% runoff, in Bheta Gad and Xizhuang more than 85%, and in Hilkot more than 75% of total runoff occurred in the April to September period (Figure 7.6).

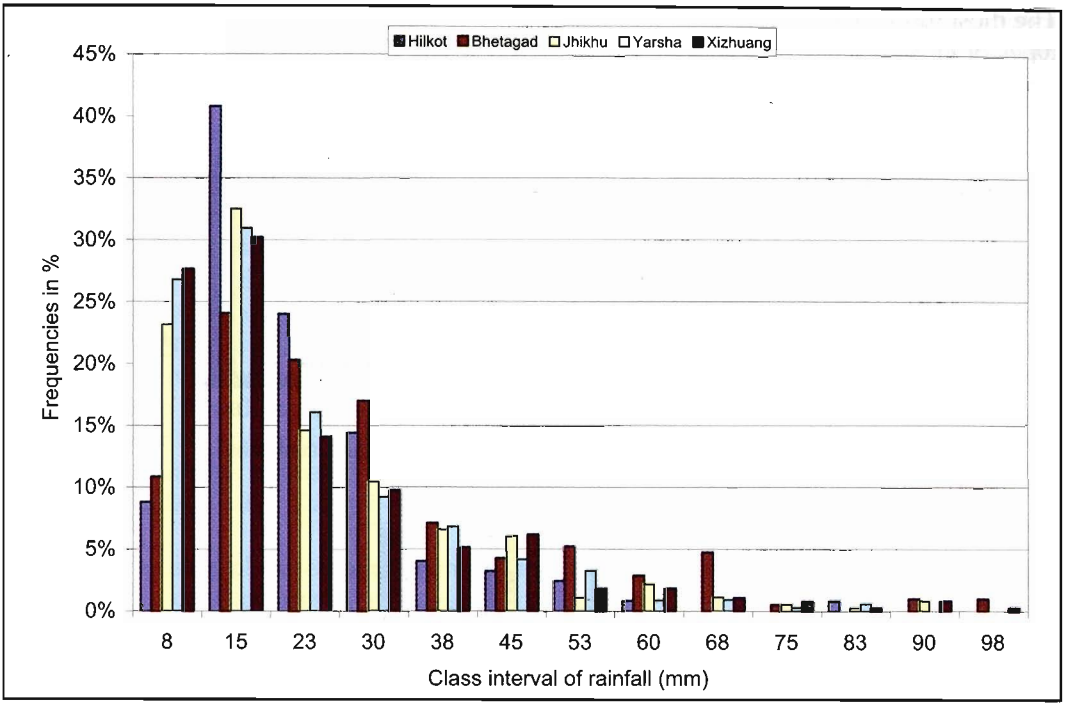

Figure 7.4: **Rainfall frequency which generates runoff on erosion plots**

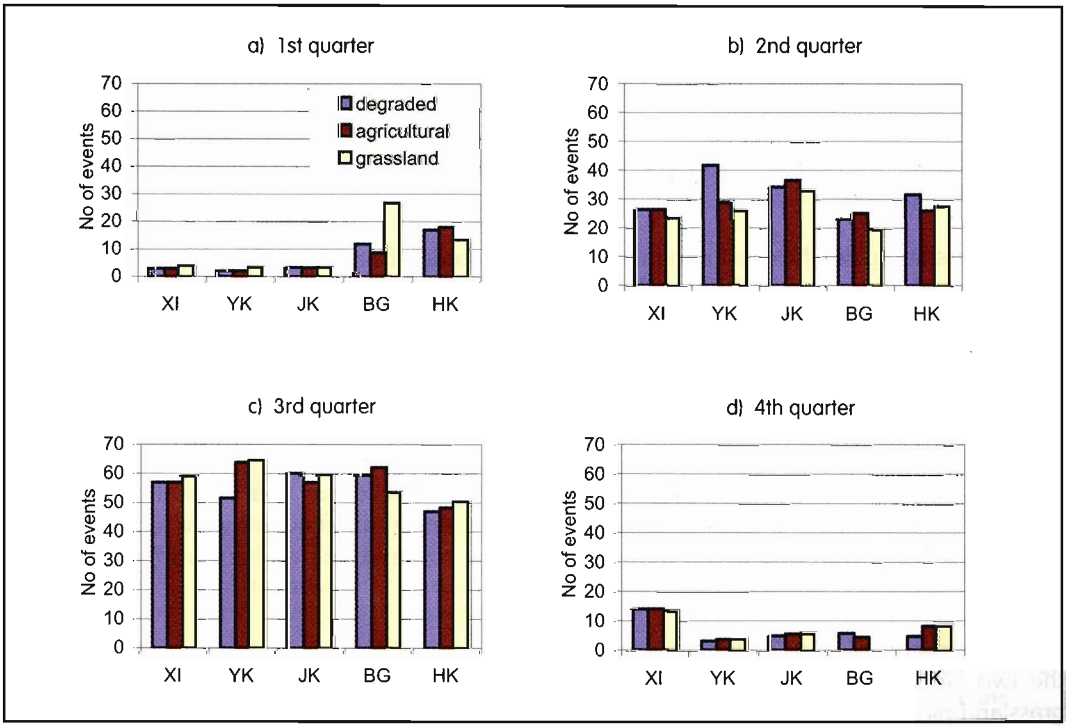

Figure 7.5: **Number of runoff events per quarter**

The most runoff was measured in the Yarsha Khola and Jhikhu Khola watershed for all three types of erosion plots. The amount was very low in the Bheta Gad and Hilkot watersheds probably due to their lower amounts of rainfall.

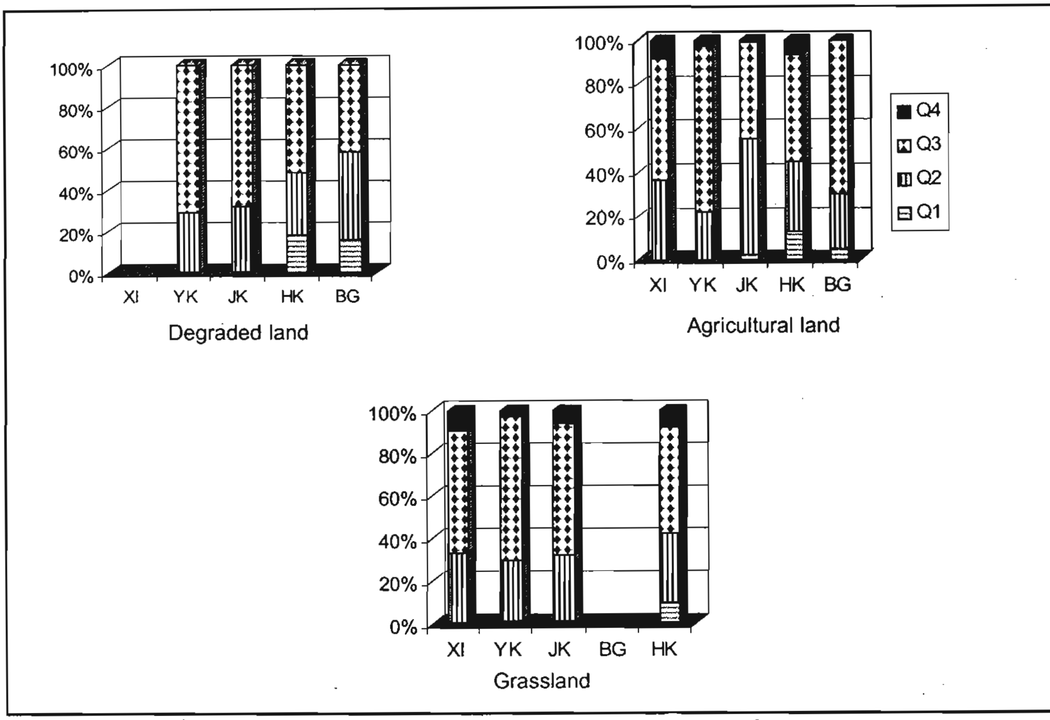

Figure 7.6: **Distribution of runoff on degraded land, agricultural land, and grassland plots**

The amounts of runoff varied between the different types of erosion plots. The highest annual rates were recorded on the degraded land plots in Jhikhu Khola watershed where it reached up to 6740 m^3/ha/yr. The runoff from the Hilkot and Bheta Gad degraded plots was only about 500 m^3/ha/yr.

In the grassland plots the most annual runoff was recorded from the Jhikhu Khola and Yarsha Khola watersheds with over 7000 m^3/ha. The lowest amounts occurred at Hilkot with 226-436 m^3/ha/yr. Annual runoff from the agriculture land plots was the highest in the Yarsha Khola watersheds (4587 m^3/ha/yr). The runoff in the Jhikhu Khola and Bheta Gad watersheds was low, with only 50 and 61 m^3/ha/yr of annual runoff recorded.

Biggest runoff events

Big rainfall runoff events were associated with a major portion of total annual runoff in all three land use type plots in all watersheds. The largest single runoff events were recorded from the Jhikhu Khola with 588 m^3/ha from the grassland plot and 561 m^3/ha from the degraded plot.

About six events of over 300 m^3/ha were recorded on the degraded and grassland plots from the two Nepal watersheds. The largest event in the Yarsha Khola was 320 m^3/ha on the grassland plot. The largest event recorded from Hilkot was only 80 m^3/ha on its grassland plot and the largest from Bheta Gad was from its degraded land plot at around 300 m^3/ha with very little runoff from the agricultural plot. The largest runoff events on the Xizhuang watershed were much less than those recorded from the Yarsha Khola, Jhikhu Khola and Bheta Gad watersheds.

Runoff from different land uses

Rainfed agriculture, grazing and degraded lands are likely to have larger levels of rainfall runoff than irrigated land which generally has inward-sloping terraces that accumulate water (Agarwal and Narain 1991). Likewise, well-managed forests reduce peak flows at the micro- and lower meso-scale (Bruijnzeel and Bremmer 1989). In general, records from the five watersheds show a good correlation between rainfall and runoff on degraded land but a poor one on agriculture land (Figure 7.7). The rates of runoff on the degraded and grassland plots are generally higher than from agricultural land plots with the highest events leading to the runoff of more than 10 mm of rainfall. The amount of rainfall that produces runoff was lower on the degraded and grassland plots than on the rainfed agricultural plots. The threshold amount of rainfall is estimated at 3 mm on the degraded and grassland plots and 5 mm on rainfed agriculture plots (Dangol et al. 2002).

On all the erosion plots seasonality only affected runoff on some of the rainfed agriculture plots where second quarter rainfall events yielded higher runoff rates than in the rest of the year. This is probably due to rainfall occurring when the plots were unvegetated and cultivated. Fields are typically prepared after the first pre-monsoon rains occur between the end of April and early May.

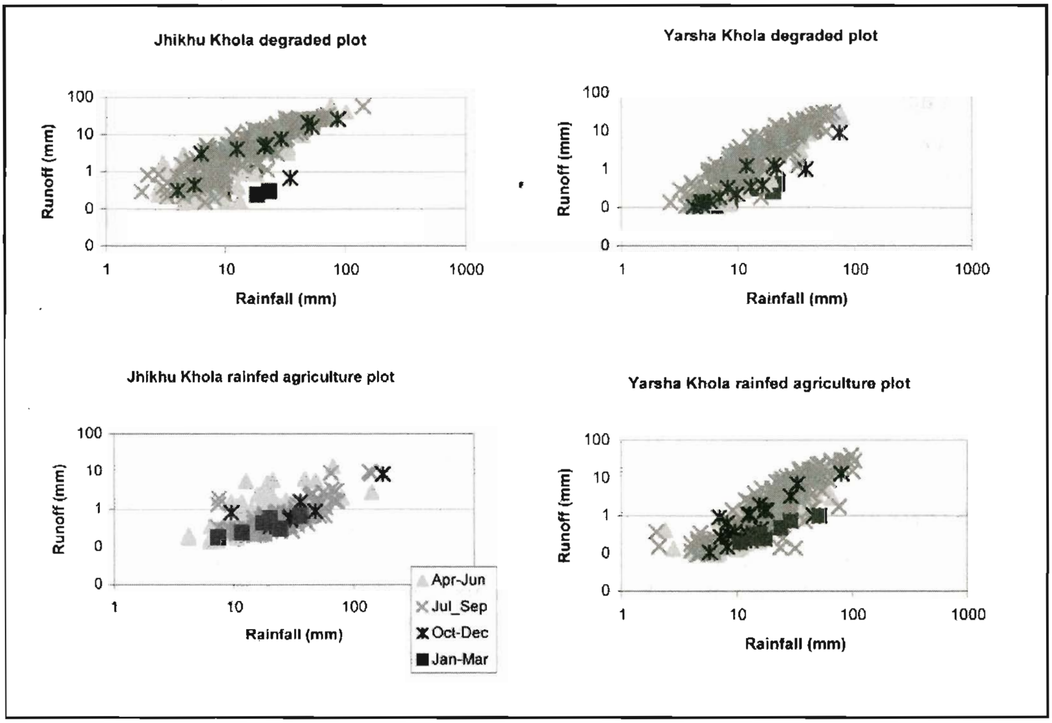

Figure 7.7: **Daily rainfall verses daily runoff on degraded plots and rainfed agriculture plots**

Correlation of plot and watershed scale runoff

The five largest plot runoff events were selected to investigate the relation between plot-scale and watershed-level runoff. Graphs of total runoff against discharge at each watershed's outlet are given at Figure 7.8. This analysis shows that in Hilkot four of the five largest runoff events on the erosion plots occurred at the same time as large events recorded at the main station at the main outlet point. On the Jhikhu Khola and Yarsha Khola watersheds between two and four of the five largest events (depending on land use type) matched the largest events at the main hydro station. But in Bheta Gad and Xizhuang watersheds events on erosion plots and main hydro station events did not match.

Summary of runoff measurements

- Rainfall amounts of between 8 and 16 mm generate the most runoff events.
- The number of runoff events from erosion plots was greatest in the eastern-most watershed's plots (Xizhuang) in the first quarter and least in the fourth quarter.
- More than 75% of annual total runoff in all land uses occurred in the second and third quarters in all watersheds.
- Most runoff was generated in the Yarsha Khola and Jhikhu Khola watersheds in all land uses while it was very low in Bheta Gad and Hilkot watersheds.
- Degraded and grassland plots yielded more runoff than agricultural land plots.
- Runoff events were the largest in the Jhikhu Khola watershed, especially from degraded and grassland plots.
- Degraded and grassland plots did not show seasonal effects, while the agriculture land plots (especially in the Jhikhu watershed) showed clear seasonal effects.
- On the degraded and grassland plots about 3 mm of rainfall generated runoff whilst on the rainfed agriculture plots the threshold was 5mm.
- The data showed much less runoff of rainfall from the agricultural plots than from the degraded and grassland plots.
- In most cases plot level runoff events occurred at the same time as high level flows at sub-watershed and watershed level.

Soil loss

Over 80% of soil loss from all the erosion plots occurred in the second and third quarters of the year (Figure 7.9). In the Jhikhu Khola and Yarsha Khola watersheds 95 to 99% of soil loss occurred in these two quarters and in Bheta Gad 83 to 96% occurred. In the first and fourth quarters only a little soil loss occurred due to the low level and intensity of rainfall.

Soil loss response

In most years across all five watersheds the highest rates of soil loss occurred in the Jhikhu Khola plots with between 23 and 38 t/ha from its grassland plot compared to only 0.1 to 0.4 t/ha from the Yarsha Khola grassland plot and 0.3 to 5 t/ha from the Hilkot grassland plot. Soil loss in the Hilkot watershed was low due to well-established vegetative cover and well-compacted soil. Soil loss in the Bheta Gad watershed was very low because of its rocky soil. Total annual soil loss from the agricultural land plots was comparatively higher in Hilkot and Xizhuang ranging from 3-5.5 t/ha in the former and 4.1-5.2 t/ha in the latter. Soil loss from the agriculture land plot was negligible at Bheta Gad.

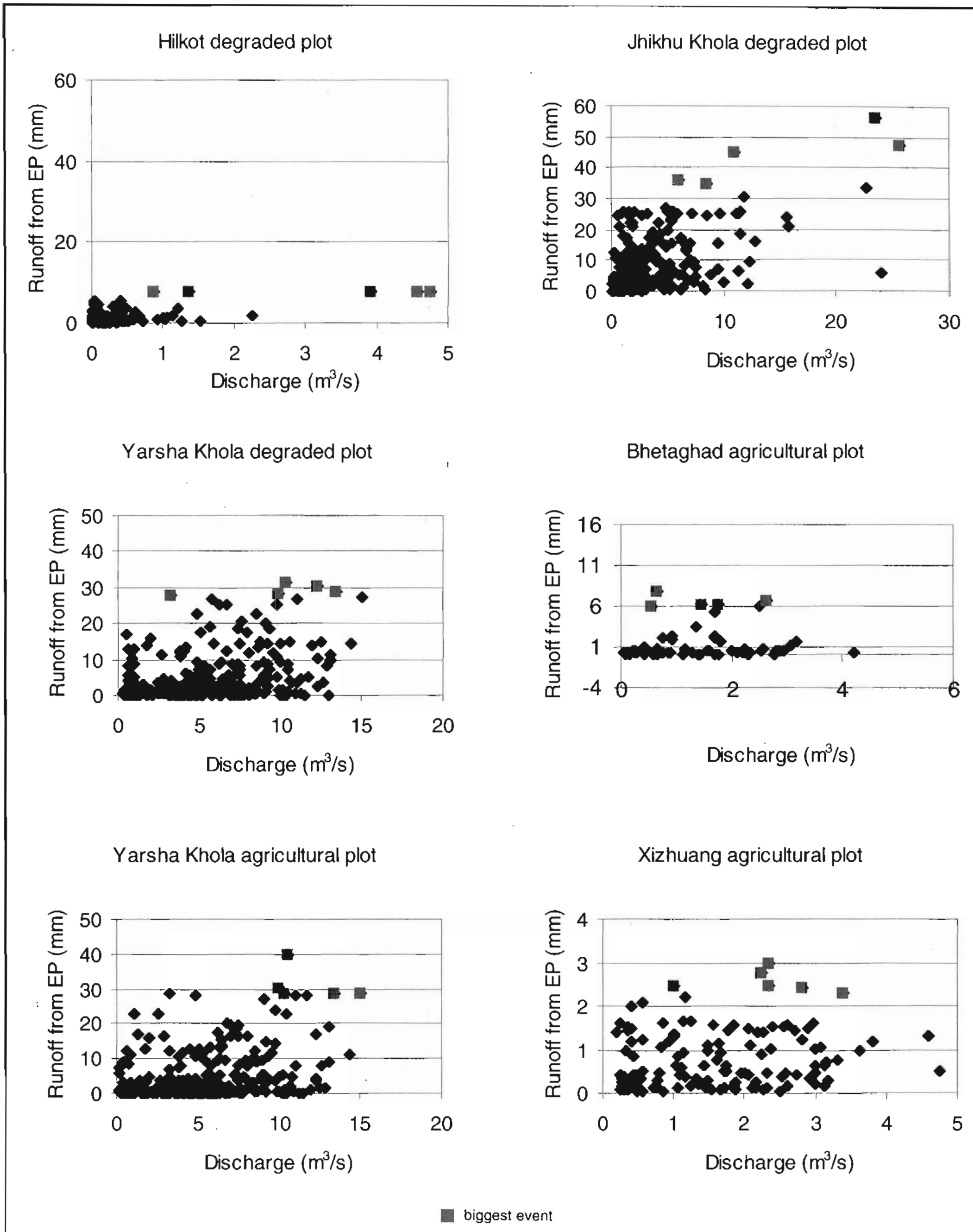

Figure 7.8: **Five biggest runoff events and runoff from erosion plot versus discharge at watershed outlets**

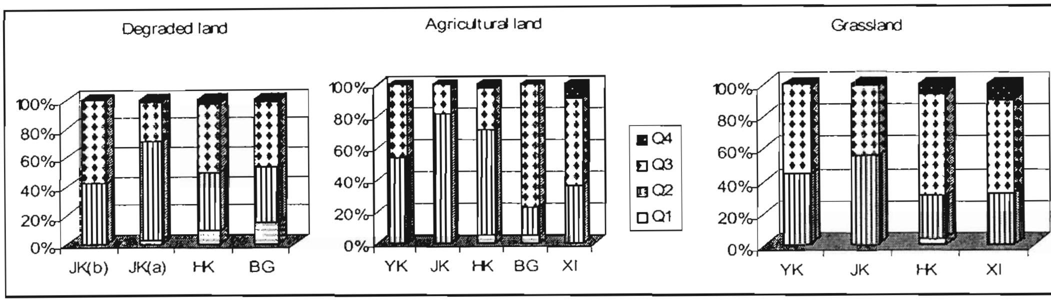

Figure 7.9: **Quarterly distribution of soil loss from three types of erosion plots**

Biggest soil loss events

Several events were recorded that led to large amounts of soil erosion in a short time. These occurred in pre-monsoon and monsoon seasons when the land surface was desiccated and bare or only partially covered with vegetation and therefore vulnerable to erosion. The most such events occurred in the Jhikhu Khola plots with losses from degraded land of 10 t/ha and 7.5 t/ha from the grassland plot in a single rainfall events. At Hilkot only one big soil-loss event was recorded with a loss of 3 t/ha when soil was bare and soft just after sowing. Such intense rainfall caused losses of less than 1 t/ha when there was more vegetative cover.

Summary of soil loss

- Eighty percent of soil loss occurred in the second and third quarters of the year on all plot types.
- Total soil loss was highest from the Jhikhu Khola's degraded and grass plots.
- Total annual soil loss from the agricultural land plots was highest at Hilkot and Xizhuang.
- The largest soil loss events were in the Jhikhu Khola degraded and grassland plots.

Discharge Patterns

Most water discharge occurs during the monsoon months causing flooding and soil erosion. The rest of the year there are limited or low flows leading to a lack of irrigation and drinking water. The discharge peaks in August in all watersheds except Xizhuang where it peaks in September (Figure 7.2). The only source of streamflow in four of the watersheds is rainfall. Hilkot's streamflow is contributed to by large amounts of winter snow. The Yarsha Khola watershed has the higher and Bheta Gad and Hilkot watersheds the lowest levels of discharge. Figure 7.10 shows the low flow conditions over more than half the year in all the watersheds. As measured at the watersheds' outlets, more than 55% of discharge occurs in the third quarter and about 10% in each of the remaining three quarters except for Xizhuang, which has about 40% of its discharge in the fourth quarter because of high winter rainfall (Figure 7.10).

Flow pattern

The annual flow duration curves (three year averages) for the five watersheds are presented in Figure 7.11. The flow is the most variable in Hilkot and Jhikhu Khola. The other three watersheds have a more stable flow. However, the flow magnitudes are very low in Hilkot with a few big events accounting for the variability. All five watersheds have low flows during more than half of the year in the fourth and first quarters of the year.

Frequency distributions

The frequency distributions of the flow, as measured at the main stations of the five watersheds, are presented in Figure 7.12. For all five watersheds flow values were divided into twenty equal class intervals were plotted with their frequencies at the same scale to allow for comparison. In the Hilkot, Bheta Gad, and

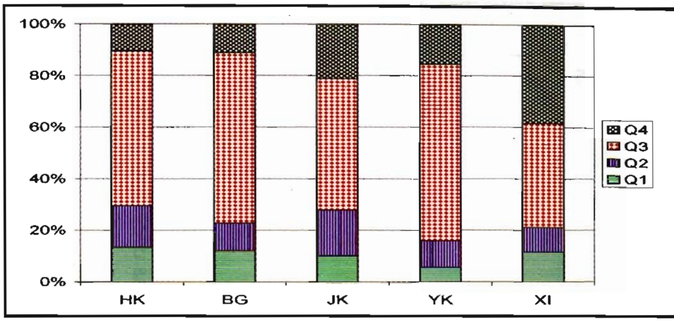

Figure 7.10: **Quarterly distribution of discharge at watershed outlets**

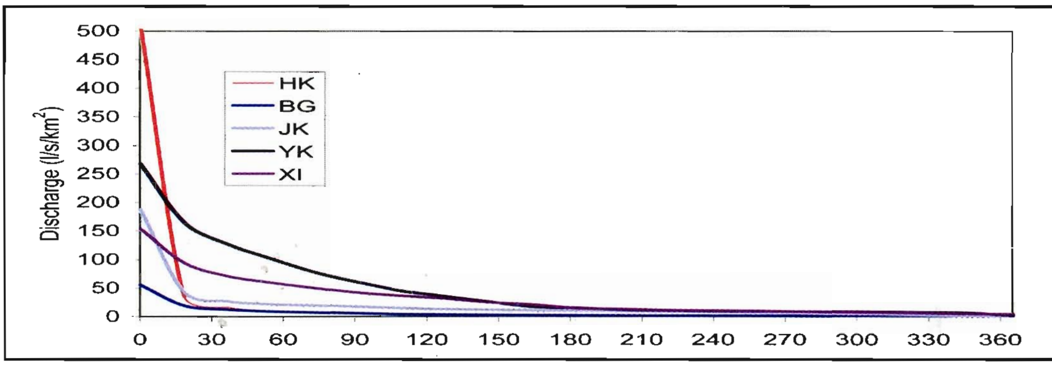

Figure 7.11: **Flow duration curve in the PARDYP watersheds (3 year averages)**

Jhikhu Khola watersheds about 90% of the time had low flow discharges with class upper limits of 25 l/s/km^2, while in the Yarsha Khola and Xizhuang watersheds this happened for about 60% of the time. These results show that low flows dominate for longer in Bheta Gad, Hilkot and Jhikhu Khola than in the Yarsha Khola and Xizhuang watersheds.

Low flow frequencies

The ten lowest flow values for each of the three years were identified for all five watersheds. Then these 30 lowest low flow values were divided into twenty equal class intervals and their frequency was analysed. Figure 7.13 shows that the frequency of lowest low flow (here classed up to 0.5 litres/s/km^2) was the highest in Hilkot (100%) and the Jhikhu Khola watersheds (60%). Yarsha Khola and Xizhuang watershed had more other classes of low flow, comparatively more widely distributed over time. The results suggest that Hilkot, Jhikhu Khola, and Bheta Gad are more susceptible to prolonged low flows whilst the situation in Yarsha Khola and Xizhuang is more variable.

Base flow patterns

Base flow index analysis was carried out according to the method in Institute of Hydrology (1992). The results are presented in Figure 7.14. The base flow index is calculated as the volume of water beneath the base flow line divided by the volume beneath the recorded hydrograph line. Note that the base flow index and base flow line should not be confused as they are different things. Xizhuang watershed had the highest base flow index of 0.842 and

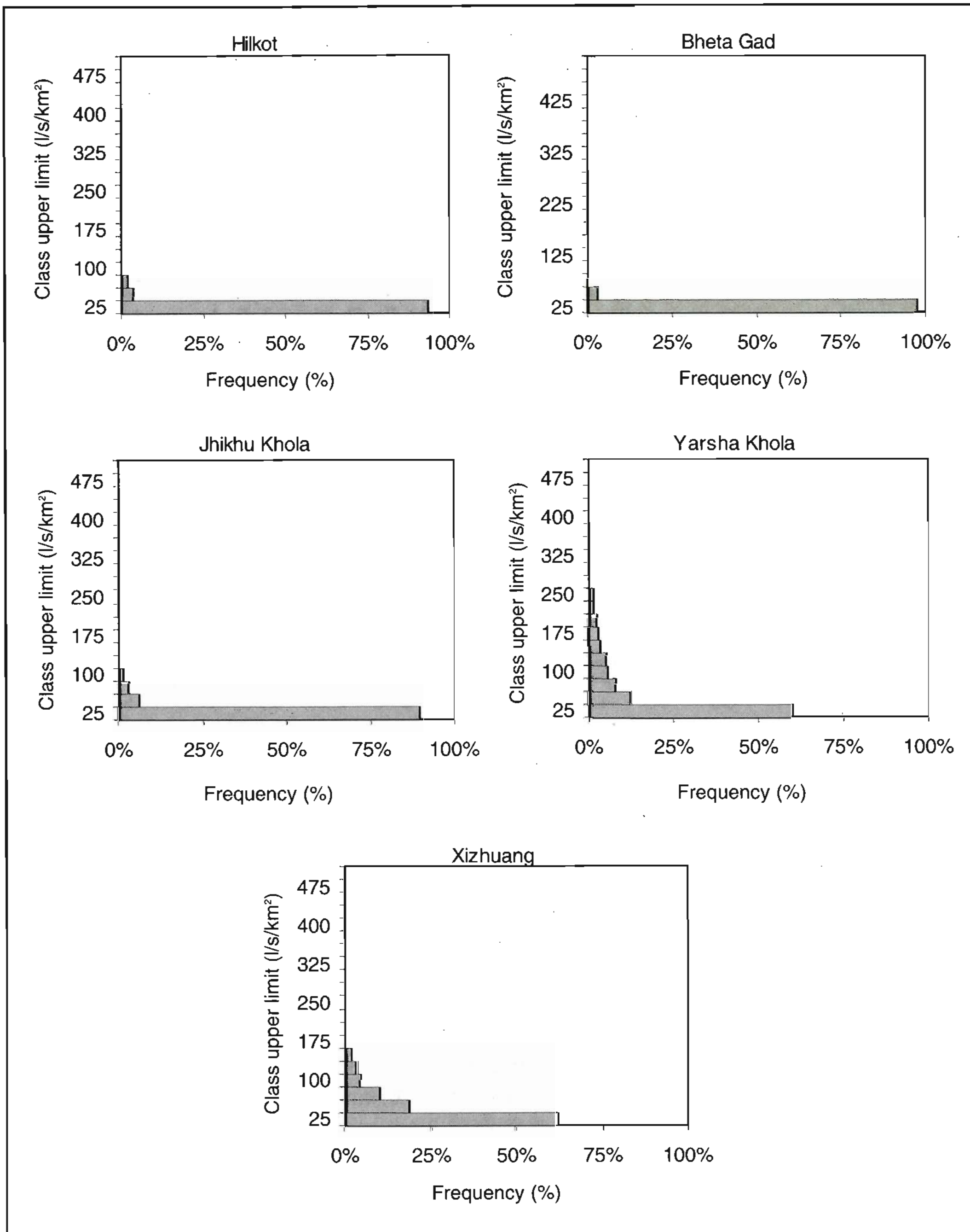

Figure 7.12: **Frequency distributions at the main stations (at outlets)**

Hilkot the lowest at 0.109. It is difficult to see the base flow line of Hilkot watershed in Figure 7.14 because of its very low discharge. Yarsha Khola had the second higher index but the magnitude of base flow was higher in Yarsha Khola than in Xizhuang. The higher the base flow index then the higher is a watershed's storage capacity. The base flow magnitudes were

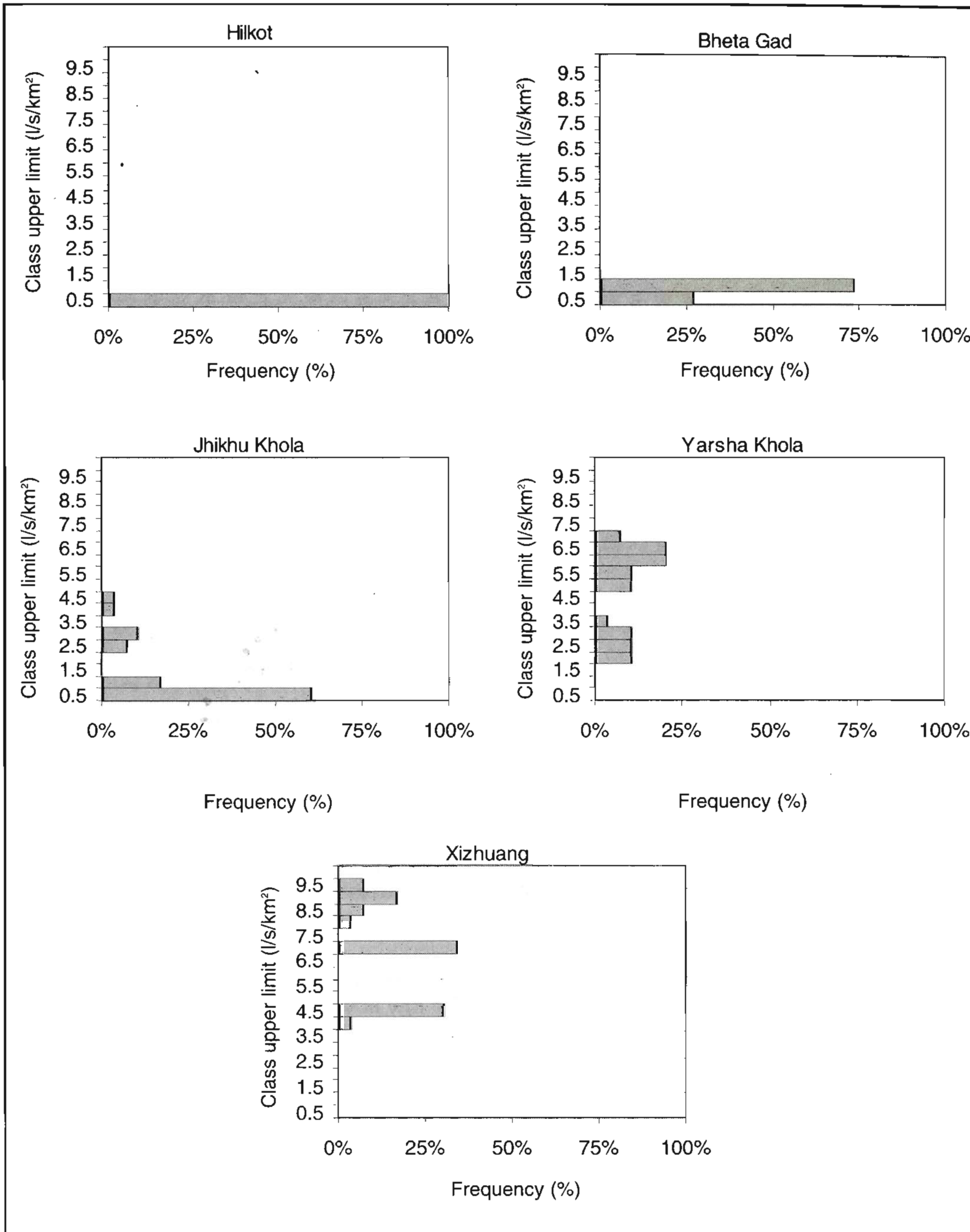

Figure 7.13: **Low flow frequency distributions**

higher in Yarsha Khola and Xizhuang watershed, though the discharge magnitudes were higher in the Jhikhu Khola watershed. Jhikhu Khola watershed had more fluctuations and peaks in the recorded hydrograph. Therefore it seems that Xizhuang and Yarsha Khola watershed have more stable base flows than the other watersheds.

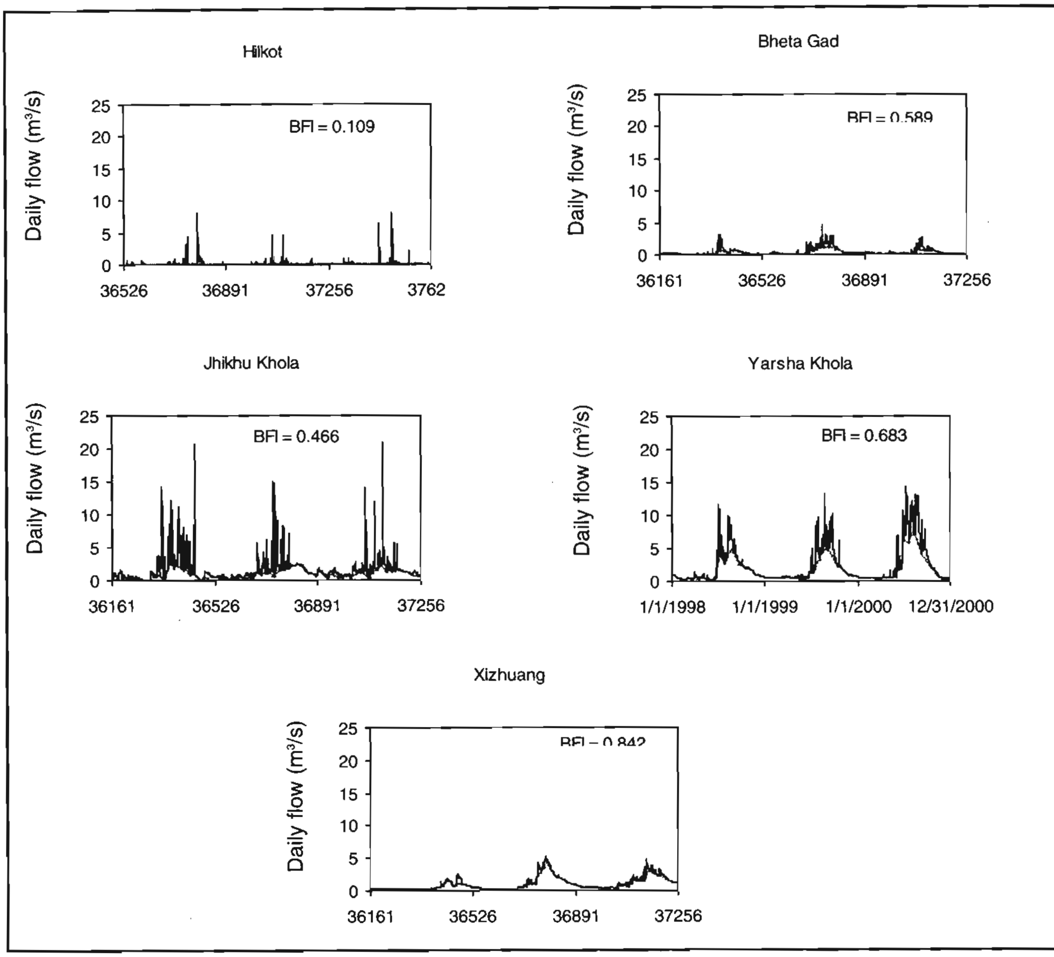

Figure 7.14: **Base flow indexes (BFI) of five PARDYP watersheds**

Low flow patterns

The low flow index (LFI) was calculated using the technique given in Institute of Hydrology (1980). The results are presented in Figure 7.15. The low flow index was higher in the Yarsha Khola then the Xizhuang watershed. Hilkot watershed had the lowest low flow index. It has already been mentioned above that the base flow magnitudes are higher in Yarsha Khola than in the Xizhuang watershed. However the base flow index (BFI) was higher in Xizhuang. This analysis suggests that the low flow index can be used to compare base flows in the watersheds.

Summary of flow at watershed outlets

- Discharge magnitude is highest in August, except in Xizhuang where it is highest in September.
- The discharge magnitude is lowest around April and May in all watersheds.
- About 55% of outlet discharge occurred in the third quarter of the year.
- All five watersheds have low flows for more than half of the year.
- Hilkot, Bheta Gad, and Jhikhu Khola watershed have prolonged low flow regimes.
- Base flow index is highest in Xizhuang watershed and lowest in Hilkot watershed.
- Low flow index is highest in Yarsha Khola watershed and lowest in Hilkot.

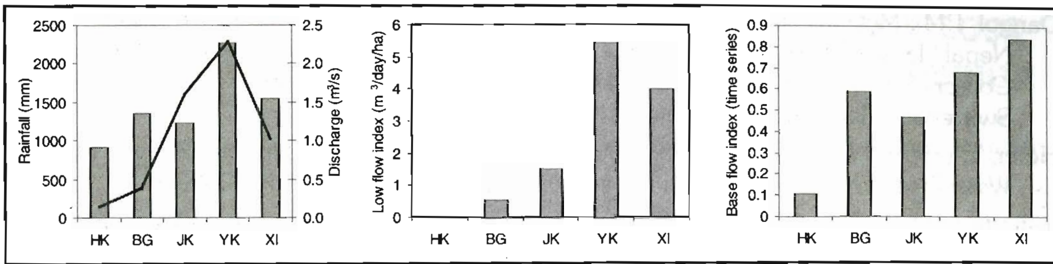

Figure 7.15: **Low flow indexes for five PARDYP watersheds**

Conclusions

All five watersheds are influenced by skewed rainfall, with much during the monsoon and little in the rest of the year. The most frequent runoff events occur when between 8 and 16 mm of rain falls. More than 75% of total annual runoff from all the land use plots occurred in the second and third quarters of the year in all watersheds with degraded and grassland plots yielding higher runoff rates than the agriculture land plots. On degraded and grassland plots rainfall events of 3 mm generated runoff whereas on rainfed agriculture plots events of 5 mm were needed to generate runoff. The degraded and grassland plots did not show seasonal effects, whilst the agriculture land plots did for runoff generation. In many cases high flow events at plot level are reflected in high discharges at sub-watershed and watershed level. All the plots lost most soil in the second and third quarters of the year. In all watersheds, more than 80% of soil loss occurred in these two quarters on all land use types. The degraded plots lost far more soil than the other plots. Over more than 50% of the year all five watersheds had low flows.

The excess surface runoff in the wet seasons can be mitigated and managed by recharging groundwater, by building eyebrow terraces, contour trenches, and water harvesting tanks, and by other soil and water conservation measures. The conserved water can then be used for dry period irrigation. Surface water can be harvested from degraded lands due to their high runoff and low infiltration rates. Soil conservation measures such as contour hedgerow, terrace improvement, gully stabilisation, rehabilitation of degraded lands reduce soil loss and runoff.

Acknowledgements

The authors would like to acknowledge the financial support for PARDYP of SDC, IDRC, and ICIMOD. The authors also acknowledge the consulting and analytical support of Rolf Weingartner and Juerg Merz. Similarly, Roger White, P.B. Shah, Gopal Nakarmi, Bhuban Shrestha, Sanjeev Bhuchar, B.P. Kothyari, H. Shah and Xu Jianchu helped us by giving their invaluable ideas and views for the analysis. Many other PARDYP staff members have helped in different ways. This work would not have been possible without the local observers and field staff in the study watersheds who collected the data. The regional cooperation of the country teams for sharing data and knowledge is also acknowledged.

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8

Assessment of Runoff and Soil Loss in the Hindu Kush-Himalayan Region

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Abstract

The sediment loads of Himalayan rivers are amongst the highest in the world, causing problems such as the siltation of reservoirs, river channel blockage, and poor quality water supplies. The major sources of sediment are glacial debris, landslides, and over-grazed and intensively cultivated hill slopes. The research presented here was carried out to investigate soil erosion from different land uses. Hydrological, meteorological and soil erosion data was collected for four years from different land uses in the PARDYP watersheds in Pakistan, India, Nepal, and China. Runoff and sediment losses were monitored on erosion plots representing degraded, pasture (grassland), forest, and agriculture land use. The results show that runoff and soil loss were highest in May to September when rainfall duration and intensity were higher in all watersheds. A few big rainfall events contributed most of the annual runoff and soil loss. Annual rainfall ranges from 800 mm to 2400 mm with between 44 and 66% occurring in the monsoon period of June to September. Annual soil loss was highest from the erosion plots in the two Nepali watersheds across all four land use types. Levels of soil erosion were very low at the Hilkot, Pakistan, and Bheta Gad, India plots. At all the sites, for all land use types at least 80%, and in the case of Yarsha Khola and Jhikhu Khola 95 to 99% of soil loss occurred between April and September.

Introduction

The Hindu Kush-Himalayas is the source of Asia's six mighty rivers – the Indus, Ganges, Brahamaputra, Mekong, Yangtze and Yellow rivers. These arise in the Himalayas and flow down to the plains where they support the plains agriculture that feeds hundreds of millions of people (Banskota 2001). The environment of many Himalayan watersheds is degrading with poorly managed human activities leading to accelerated erosion. The most significant and obvious problem is the extensive deforestation of mountain slopes. This is happening as forests are converted into agricultural fields, and due to the unsustainable harvesting of firewood and timber, destruction caused by grazing animals, and forest clearance for the development of infrastructure.

The sustainable management of mountain watersheds is of global importance. The heavy monsoon rains and fragile geology pose major threats to the stability of the upland areas of the Hindu Kush-Himalayas. The expansion of agriculture, forest exploitation and populations are causing much degradation. Within upland watersheds and below, landslides and floods inflict much loss of life and damage to property and infrastructure (Suhail 1999).

The increasing population of the Hindu Kush-Himalayan region is creating a great demand for more farming land. The conversion of forests into agricultural land is accelerating whilst high population densities put more pressure on water resources. The main water problems are concerned with quantity, with too much water during the rainy season and too little in the dry period. In many places groundwater sources are being depleted and springs are drying up. Studies in Nepal show that communities on hill ridges face acute water shortages (Merz et al. 2000).

During the monsoon vast amounts of water leave the upland watersheds as surface runoff, causing slope erosion and sedimentation and flooding problems downstream. It has yet to be established to what extent these processes affect downstream areas (Bruijnzeel and Bremmer 1989).

This paper discusses the findings of runoff and soil loss research carried out by the People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP) in its five watersheds in China, India, Nepal and Pakistan. It focuses on the key factors that impact runoff and soil loss in these watersheds. The aim of these studies is to assess soil erosion, runoff and its seasonal distribution with the aim of providing recommendations on improving the use of runoff water and better controlling erosion.

Runoff and Soil Erosion Measurements

A network of hydrological stations, meteorological stations, and erosion plots were set up during 1998/1999 in the five PARDYP watersheds (Table 8.1). Ninety-four measurement sites were set up with daily measurements taken by local readers. These readers receive annual training sessions to keep them informed and motivated about their work.

Table 8.1: **Measurement sites in the five PARDYP watersheds**

Watershed	Hydrological stations	Meteorological stations	Erosion plots
Xizhuang - China	5	10	6
Bheta Gad - India	6	5	4
Jhikhu Khola - Nepal	5	10	7
Yarsha Khola - Nepal	6	11	4
Hilkot - Pakistan	5	6	4

In all the watersheds rainfall is measured using automatic tipping buckets, siphon rain gauges, and manual rain gauges. The readers record daily rainfall from the manual rain gauges. Siphon rain gauge charts for recording rainfall are replaced weekly. For the tipping buckets, the field hydrologist downloads the data once a month using the BoxCar programme. Tipping buckets and standard rain gauges are installed close to each erosion plot.

Information on the study erosion plots in the five watersheds is given in Table 8.2. These plots were selected for study because these were under similar land uses in all watersheds.

Surface runoff and soil loss was recorded from the 5 x 20m erosion plots (100m^2) for the different land uses in all five watersheds. The erosion plots were closed on the top and at either side with galvananised metal sheets pushed 15 cm into the ground with 30 cm sticking out.

Table 8.2: **Characteristics of the study erosion plots**

Site no.	Watershed	Site name	Land use	Elevation (masl)	Slope (degrees]	Textural class/soil type
4	Jhikhu Khola	Baghkhor	Grassland	940	11.5	Loam
6		Bela	Rainfed terrace	1240	20.4	Loam
14a		Kubindegaun	Degraded	880	15.0	Loam
14b		Kubindegaun	Degraded land planted with broom grass hedgerows	880	16.2	Sandy clay loam
16		Bhetawalthok	Rainfed terrace	1200	6.7	Sandy clay loam
5	Yarsa Khola	Thulachaur	Grass/shrub	2300	19.1	Sandy loam
6		Jyamire	Rainfed terrace	1950	17	Sandy loam
9a		Namdu	Rainfed terrace	1410	17.5	Loam
1	Bheta Gad	Majherchaura	Pine forest	1460	18.5	
3		Kaulag	Rainfed agriculture	1390	2	
4		Khaderia	Degraded	1350	28	
XE3a	Xizhuang	Wajintang	Pine forest	1860	12	Red soil
XE3b		Wajintang	Grassland	1860	14	Red soil
XE4c		Xizhuang	Farmland	1650	14	Red soil
1	Hilkot	Syed abad	Degraded	1677	22.7	Silt
2		Maira	Pasture	1707	19.6	Silt loam
3		Bojri	Forest	1707	19	Loam
4		Maira	Rainfed agriculture	1723	9.9	Silty clay

The lower end of each plot was left open for the gutter to divert runoff water and sediment into the collection system. The gutter was metallic and 5m long across the plot width. Rainwater ran off the plot and accumulated in the metallic gutter and flows into a drum. All plots were the same size but the slopes differed.

Four drums were placed in series below the outlet point on each plot (Figure 8.1). Where runoff is high, a splitter device was installed at the third drum's outlet. This meant that after the third drum was full then the water in the fourth drum represented only a tenth of the total actually passing into it. The volume of the runoff from the erosion plots was measured based on the amount of water collected. After each rainfall event, the volume of water in each drum was noted and sediment samples taken from each drum. For sampling, water in the drum was first agitated to mix the fine and course sediment. A composite sample of one litre was then taken from each drum. Each sample was tagged with a reference number and then the samples were filtered in the laboratory and oven dried to calculate the amount of sediment.

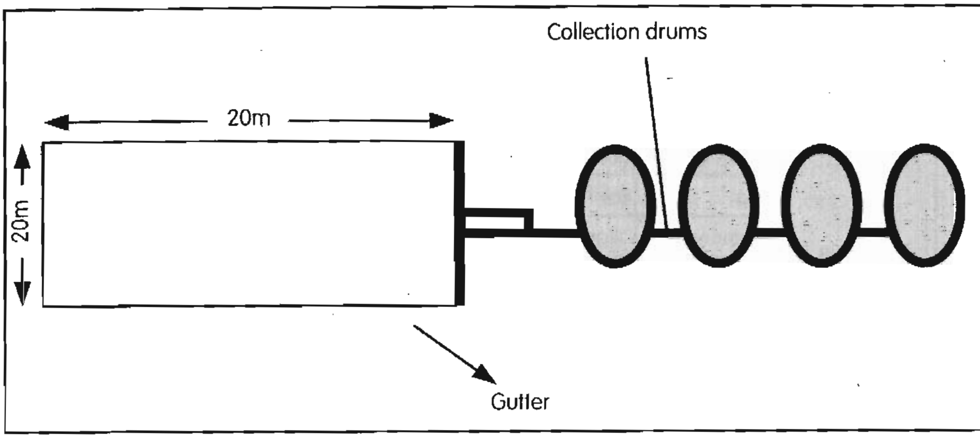

Figure 8.1: **Layout of erosion plots**

Samples were processed in the field laboratory by first drying a filter paper in an electric oven at 60-650C and weighing it before it could recapture any moisture. Then, a 100 ml sample from the drums was filtered through the filter paper following which the filter paper with sediment was dried and weighed while still warm. The weight of the sample was calculated using the following formula with grams as the unit of measurement:

Net weight of sediment = (weight of filter paper + sediment) — dry weight of filter paper (g)

All calculations were performed using an MS Excel macro developed by PARDYP (Nakarmi 1999). This creates a data entry sheet and calculates and summarises the data. Runoff and soil loss values were calculated in per hectare units. Common procedures were developed to allow results from the five watersheds to be compared. Hofer 1998b provides common guidelines for data collection, data handling, analysis, and processing. The readers and researchers responsible for collecting and analyzing data have been trained on these standard procedures. Also, researchers have visited other watershed study sites to compare approaches and to share data collection and analysis experiences and techniques. Data is cross checked within watersheds and across watersheds to maintain quality.

Table 8.3: **Available data sets for runoff studies in the five PARDYP watersheds**

	YK	JK	BG	HK	XI
Degraded					
Pasture					
Agriculture					
Forest					
Data period for the watersheds					
	YK	**JK**	**BG**	**HK**	**XI**
1999					
2000					
2001					
2002					

YK - Yarsha Khola, Nepal; JK - Jhikhu Khola, Nepal; HK - Hilkot, Pakistan, BG - Bheta Gad-Garur Ganga, India; XI - Xizhuang, China

The type of land use and the period for which data is available from the five watersheds is shown in Table 8.3.

Results

Rainfall

Monthly rainfall – The monthly rainfall varies in the five watersheds, but in all of them the most rainfall occurs during the monsoon (Figure 8.2). In the study period the Yarsa Khola watershed registered the highest month's rainfall with 716 mm in July 2000. The Jhikhu Khola's highest rainfall during the measured four years was 496 mm in July 2002. The most monthly rainfall for the other watersheds was 522 mm in Bheta Gad in August 2000, 458 mm in Xizhuang in September 2000, and 281 mm in Hilkot in March 1999.

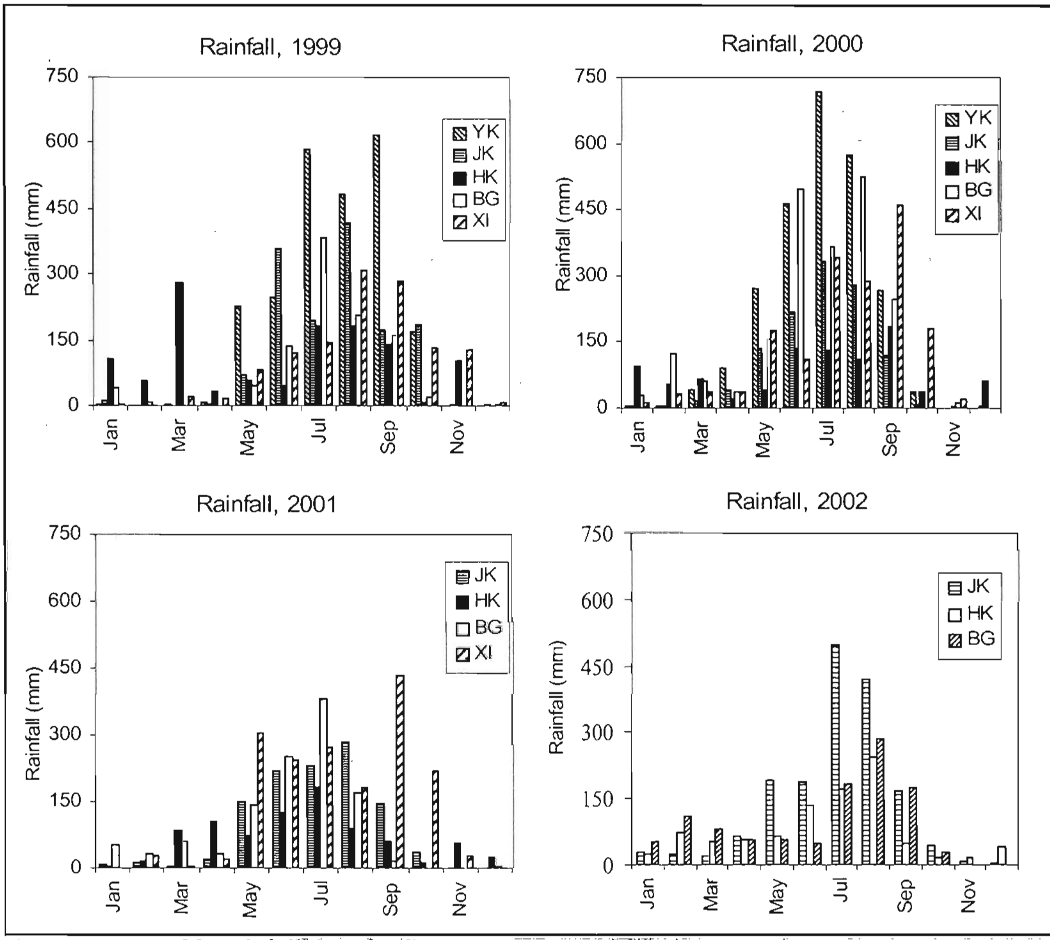

Figure 8.2: **Monthly rainfall data for five PARDYP watersheds, 1999-2002**

Annual rainfall – Annual rainfall in the five watersheds ranged from 800 mm to 2400 mm between 1999 and 2002. In this period the Yarsa Khola had the highest annual rainfall with 2469 mm in 1999 whilst Hilkot had the lowest with 837 mm in 2001 (Table 8.4).

Quarterly rainfall distribution – Between 44% and 66% of all rainfall occurred between July and September at all five sites corresponding with the monsoon season. The April to June period received between 22 and 30% of rainfall. The October to March period was largely dry except for Hilkot (Figure 8.3a). Yarsa Khola and Jhikhu Khola receive almost all their rainfall

Table 8.4: **Annual rainfall totals in the five PARDYP watersheds**

	1999	2000	2001	2002	Average
Yarsa Khola	2343	2469	na	na	2406
Jhikhu Khola	1419	1167	1110	1656	1338
Hilkot	1197	948	837	946	982
Bheta Gad	1011	2048	1147	1089	1322
Xizhuang	1254	1689	1706	na	1550
na - not available					

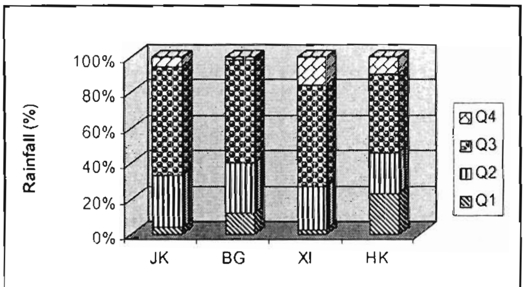

Figure 8.3a: **Quarterly distribution of rainfall**

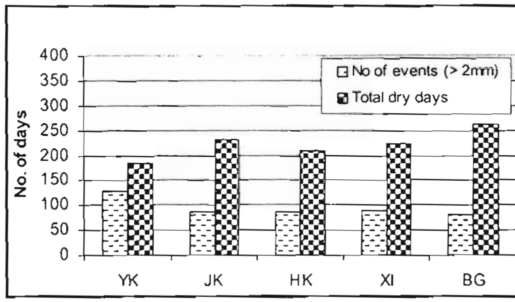

Figure 8.3b: **Rainy and dry days in watersheds**

between April and September with negligible winter rain. In contrast Hilkot receives rainfall throughout the year and, in contrast to the other areas, gets significant winter rainfall.

Rainfall intensity – Rainfall intensity, vegetation cover, aspect and slope have a direct impact on runoff and soil erosion. The maximum hourly rainfall intensity measured in Pakistan was 42 mm, which amounts to only half of the highest Nepal amount of 80 mm. Rainfall intensity is higher in the watersheds during the monsoon season. The monsoon usually starts in early June in India, in mid-June in Nepal, and in July in Pakistan. In India and Nepal high intensity rainfall events are more common in June and early July. In the Hilkot, Pakistan watershed, where rainfall occurs throughout the year, there are few high intensity rainfall events. In Nepal, most runoff and soil erosion occurs during monsoon high intensity rainfall events.

Runoff

Annual runoff

The highest measured runoff was recorded in the Yarsha Khola and Jhikhu Khola watersheds for all land use types (Figure 8.4). The rates of runoff were very low in Bheta Gad and Hilkot due to low amount and intensity of rainfall. The runoff from the different land uses differed widely due to differences in vegetative cover, soil texture, slope, and other factors.

On the degraded land plots the most runoff recorded from the Jhikhu Khola treated (planted with broom grass hedgerows) and untreated degraded plots was 6740 m^3/ha. The lowest recorded amount was from the Hilkot degraded plots where it ranged between 505 and 756 m^3/ha annually. In Bheta Gad the annual values ranged from 510 to 2262 m^3/ha over the four years.

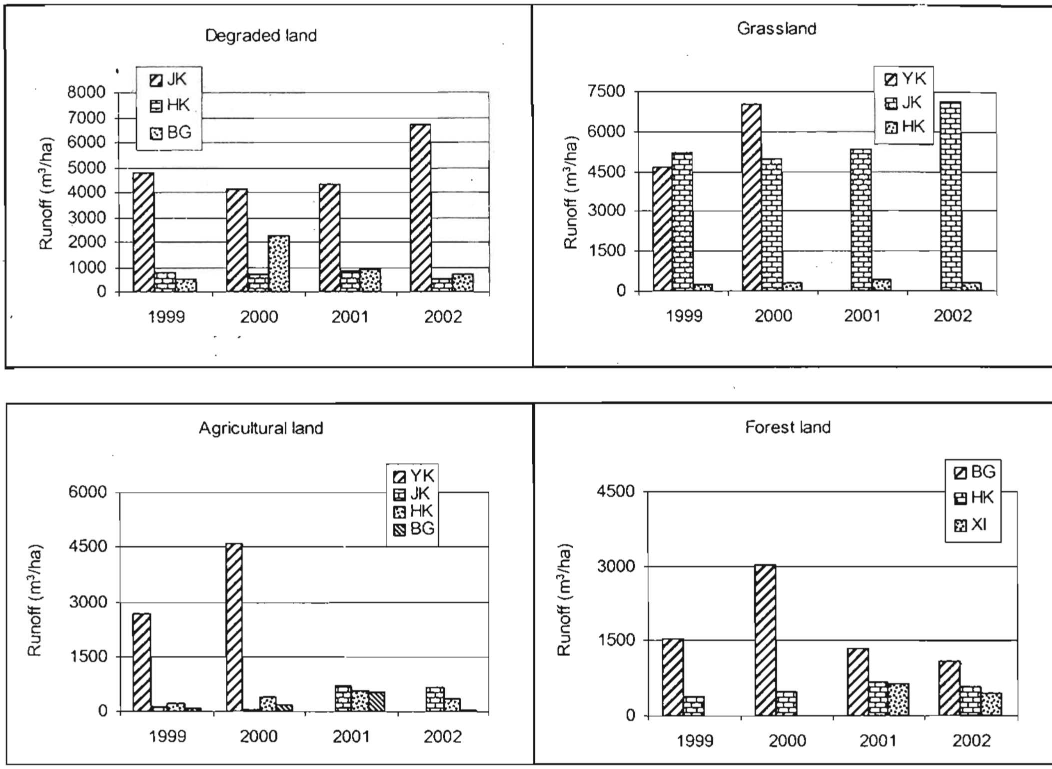

Figure 8.4: **Annual runoff from four types of erosion plots in PARDYP watersheds**

On the grassland plots the highest annual runoff was recorded in the Jhikhu Khola plots with up to 7142 m³/ha and Yarsa Khola with up to 7040 m³/ha. The lowest annual runoff on this type of plot happened in Hilkot with between 226 and 436 m³/ha over the four years. Runoff was also very low on the Xizhuang grassland plots.

Annual runoff from agriculture land was very high in Yarsha Khola at 4587 m³/ha. Runoff at Yarsha Khola was the highest due to the lesser vegetation cover and the high intensity rainfall. In the Jhikhu Khola watershed only 50 and 61 m³/ha annual runoff were recorded due to the plot being on well maintained agricultural terraces.

On the forest erosion plot the highest runoff was recorded at Bheta Gad with between 1102 and 3026 m³/ha. The amount of runoff was low in Hilkot and Xizhuang's forest plots.

Distribution of runoff

The monthly results show higher levels of runoff occurring from May to September when rainfall duration and intensity is highest in all the watersheds. The monthly runoff was the highest:

- from the degraded land plots in the Jhikhu Khola with 2068 m³/ha in July 2002;
- from the grassland plots in the Yarsa Khola in July 2000 with 2235 m³/ha;
- from the agriculture plot in Yarsa Khola with 1822 m³/ha recorded in July 2000 (runoff from the Bheta Gad agriculture plots was very low at 62 m³/ha); and
- from the forest plots in Bheta Gad with 938 m³/ha.

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High intensity monsoon rainfall caused most annual runoff on all land use types in all watersheds. Figure 8.5 shows that in Yarsha Khola more than 92% of runoff, and in Jhikhu Khola 92% to 96% of runoff in all land uses occurred between April and September. There was almost no runoff in these two watersheds from January to March. In Hilkot, 75% and 90% of runoff occurred between April and September and only 6-7% in the October to December period. In Bheta Gad between 83% and 94% of runoff occurred between April and September. There was low runoff in the January to March period except in the Bheta Gad and Hilkot degraded plots where 15% of runoff happened in this period. At Xizhuang 87% to 90% of runoff was recorded in the April to September period. No runoff was recorded in the January to March period at Xizhuang across all land uses.

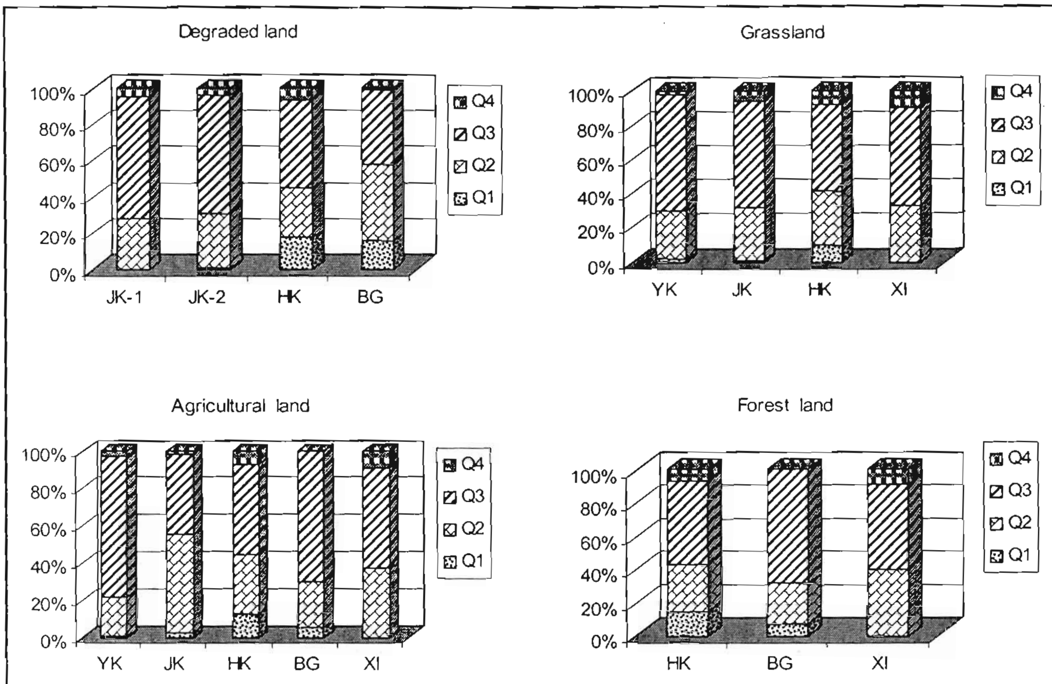

Figure 8.5: **Quarterly distribution of runoff from PARDYP watersheds**

Biggest runoff events

A runoff event is the point during rainfall where the intensity of rainfall exceeds the soils infiltration capacity. Such events contributed the major portion of total annual runoff from different land uses in all watersheds. Runoff events in Jhikhu Khola were larger than other watersheds especially in the degraded and grassland plots. The biggest runoff events in the watersheds were:

- in the Jhikhu Khola area, with 588 m^3/ha of yearly runoff on the grassland plots, and the second-most in the Jhikhu Khola degraded plot with 561 m^3/ha. This is thought to be because of the negligible infiltration of the rainfall into the surface. In this area about seven events of over 300 m^3/ha occurred on the degraded and grassland plots between 1999 and 2002;
- in the Yarsha Khola area – 320 m^3/ha on the grassland plot;
- in Bheta Gad – at 300 m^3/ha on the degraded and forest land (runoff on the agricultural plot was very low due to good terrace management including grasses planted on risers);

- in Hilkot – only 80 m³/ha on the grassland plot; and
- in Xizhuang – generally low with only between 28 and 33 m³/ha.

Soil loss

Annual soil loss

Rainfall and surface runoff are responsible for the detachment of particles on the land surface. Sediment from upland catchments is delivered to a stream and then transported downstream. The results of the soil loss studies for the four land use types were as follows (Figure 8.6).

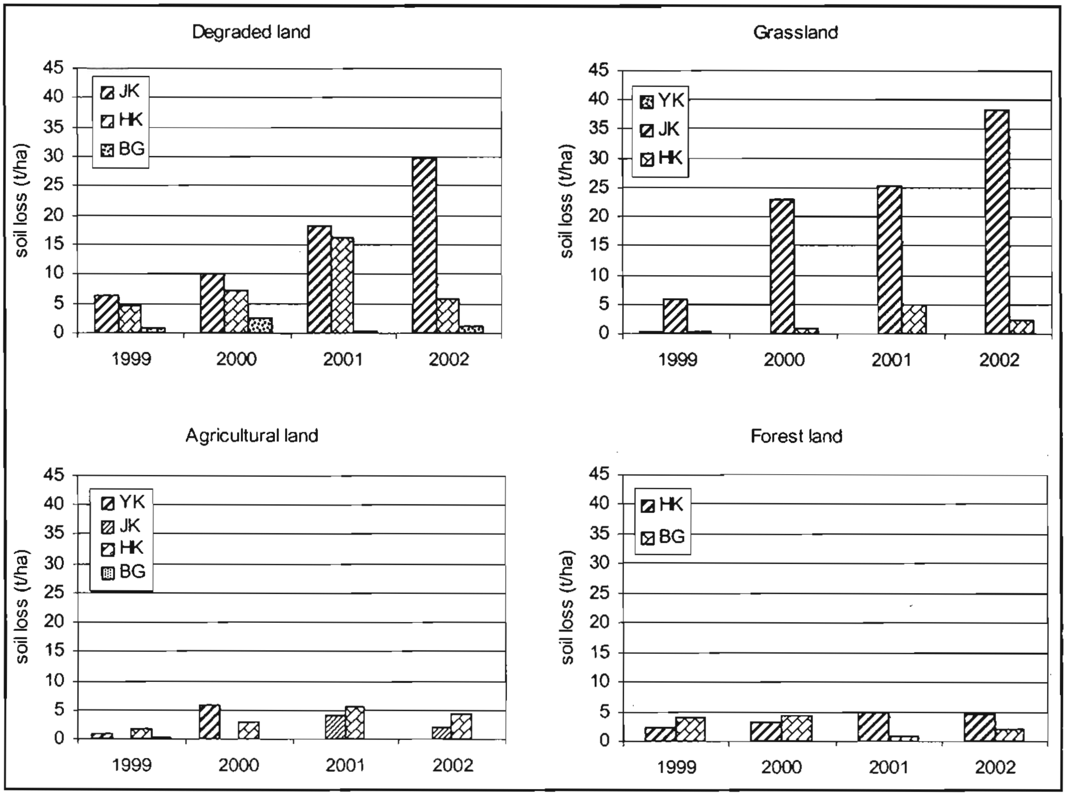

Figure 8.6: **Annual soil loss from land use plots in the PARDYP watersheds**

- In the degraded land plots annual soil loss was highest in the Jhikhu Khola watershed on the treated degraded land in 1999 at 40 t/ha when the broom grass was newly planted. In the same year soil loss on the untreated plot was only 6.4 t/ha. In all four years soil loss was highest from the Jhikhu Khola degraded plots. On the Bheta Gad plots soil loss was very low probably because of its rocky soil.
- The Jhikhu Khola grassland plots had much higher annual soil loss than the Yarsa Khola and Hilkot plots. The most soil loss was 38 t/ha at Jhikhu Khola in 2002 due to the sparse vegetative cover on its plots. In the Yarsha Khola and Hilkot there was hardly any soil loss due to the well-established vegetative cover and compacted soil on the plots.
- The total annual soil loss on the agricultural plots was low. Most was recorded from the Yarsha Khola in 2000 at 5.7 t/ha of soil lost. The negligible losses from Bheta Gad were

probably due to the well-maintained terraces and the dense grasses grown on the terrace edges. This suggests that current farmer practices prevent soil erosion.
- On the forest plots annual soil loss was similar in all watersheds with a range of 0.93 to 4.35 t/ha in Bheta Gad, 2.17 to 4.6 t/ha in Hilkot and 1.32 to 3.89 t/ha in Xizhuang.

Monthly soil loss

For the degraded plots most soil erosion was recorded from the Jhikhu Khola's treated degraded plot in August 1999 at 18 t/ha when the plot was newly established. Due to the planting of broom grass hedgerows soil erosion reduced to less than 1 t/ha/year in 2002. The maximum soil loss on the Jhikhu Khola's untreated degraded plot was 12 t/ha in June 2002. Hilkot recorded a high of 5.5 t/ha in June 2001 on its degraded plot. The main reasons for the high soil losses on these degraded plots was the sparse vegetation and the soil type (sandy loam). Soil loss was very high in the Jhikhu Khola at a maximum of 10 t/ha but very low on the grassland sites in Hilkot, Xizhuang, and Yarsha Khola.

In the agricultural plots soil loss was comparatively low because most rainfall occurs in the monsoon period when the plots were well-covered with vegetation. The highest monthly loss was recorded in May and June at Hilkot and Jhikhu Khola because at that time the plot soil was bare and the high intensity rain eroded much of the soil away. After July, when the plant cover had established, soil loss became very low for the rest of the year – much lower than from the degraded and grassland sites. In the forest plots soil loss was comparatively high in Hilkot and Bheta Gad watersheds as compared to other watersheds. Maximum monthly soil loss was recorded at Bheta Gad in September 1999 at 3 t/ha. See Figure 8.7 for graphical representation on monthly soil loss data for all watersheds and land use types.

Distribution of soil loss

Monsoon rainfall in the five watersheds is often of high intensity causing sudden runoff and much soil loss. All the plots show the highest rates of soil loss in the April to September monsoon period. Soil loss in the April to September period across all land types accounted for 95% to 99% of Yarsha Khola and Jhikhu Khola soil loss, 80% to 90% of Hilkot soil loss, 83% to 96% of Bheta Gad soil loss, and 90% of Xizhuang soil loss (Figure 8.8). Soil loss in the January to March period was negligible on all land uses.

Biggest soil loss events

The highest levels of soil loss at one time occurred pre-monsoon when the land surface was desiccated and in the early monsoon when fields were bare and vulnerable to erosion. High intensity rainfall in June-July will cause much soil erosion as the newly planted crops have not developed. Heavy rain that occurs when surface cover is only partially developed are very likely to cause significant soil losses. The highest single soil loss event on the degraded plots was about 10 t/ha and 7.5 t/ha on pasture land in the Jhikhu Khola watershed. In Hilkot only one big soil loss event was recorded with 3 t/ha lost at a time of year when the soil was bare and soft after sowing. On Hilkot's degraded plot one soil loss event of 2.2 t/ha was recorded while all other events on all land uses in Hilkot were below 1 t/ha due to good vegetative cover. There was only one significant heavy soil loss event in the Bheta Gad watershed with 2 t/ha lost from the forest plot.

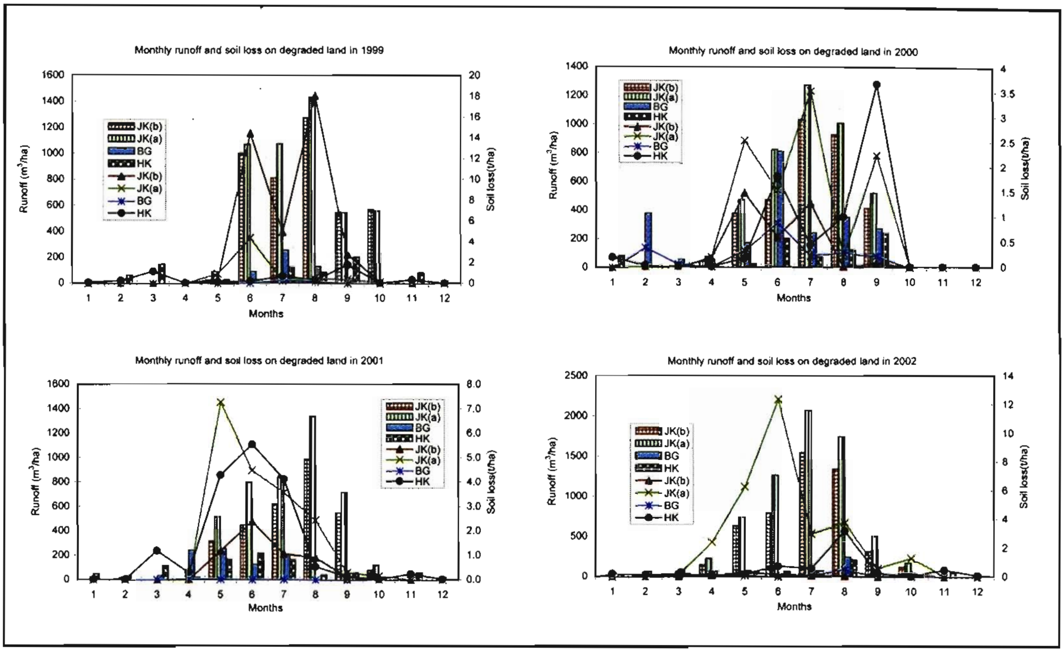

Figure 8.7a: **Monthly runoff and soil loss on degraded land PARDYP plots, 1999-2002**

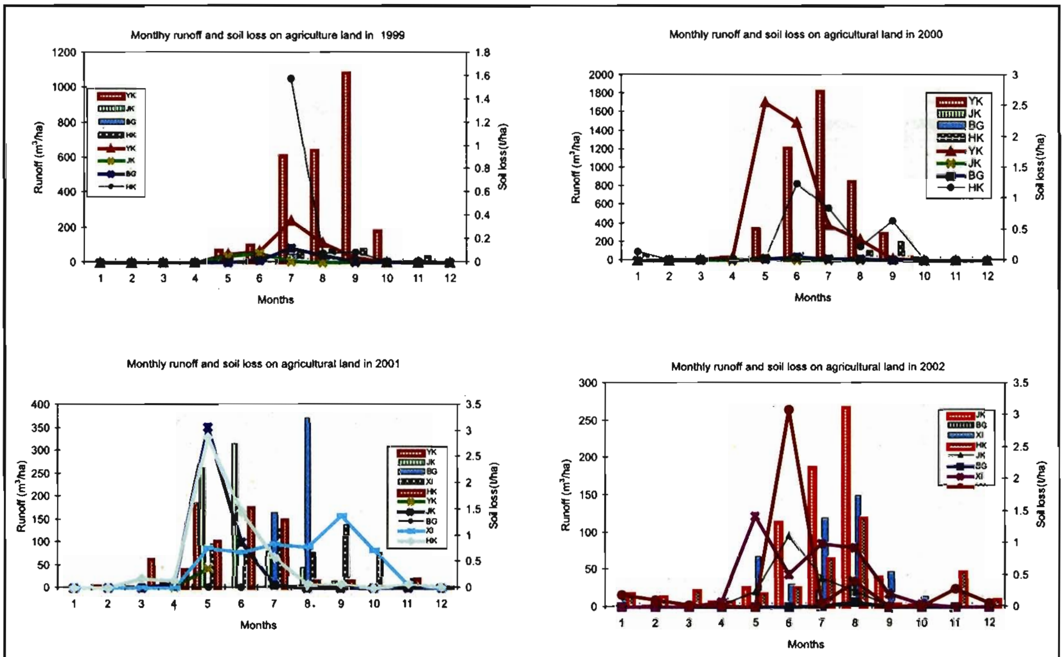

Figure 8.7b: **Monthly runoff and soil loss on agricultural land PARDYP plots, 1999-2002**

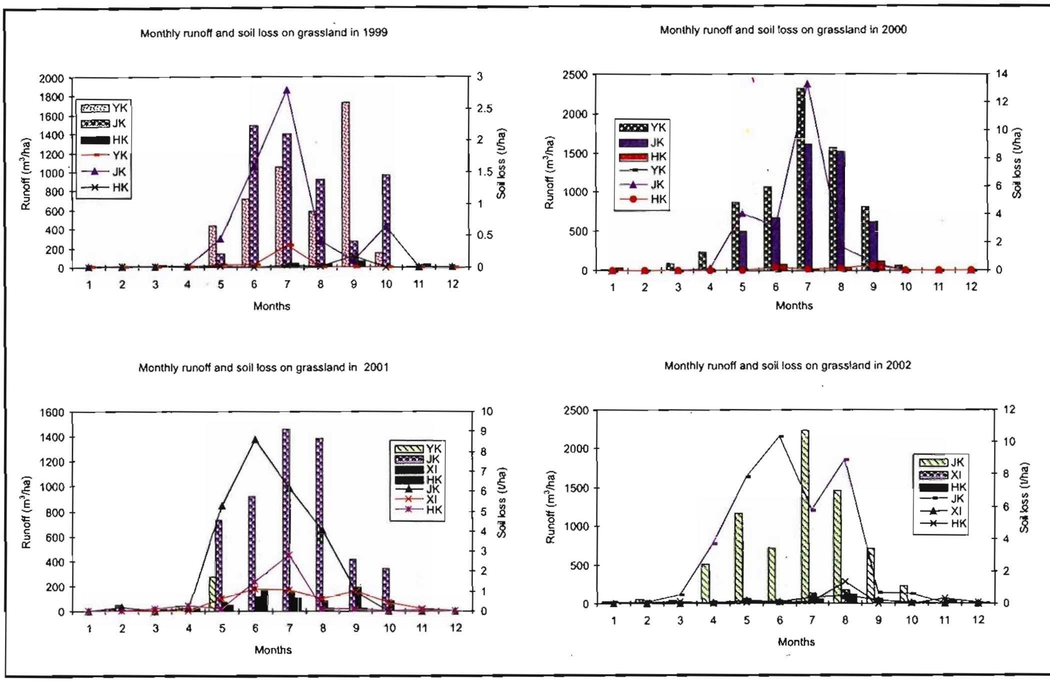

Figure 8.7c: **Monthly runoff and soil loss from grassland PARDYP plots, 1999-2002**

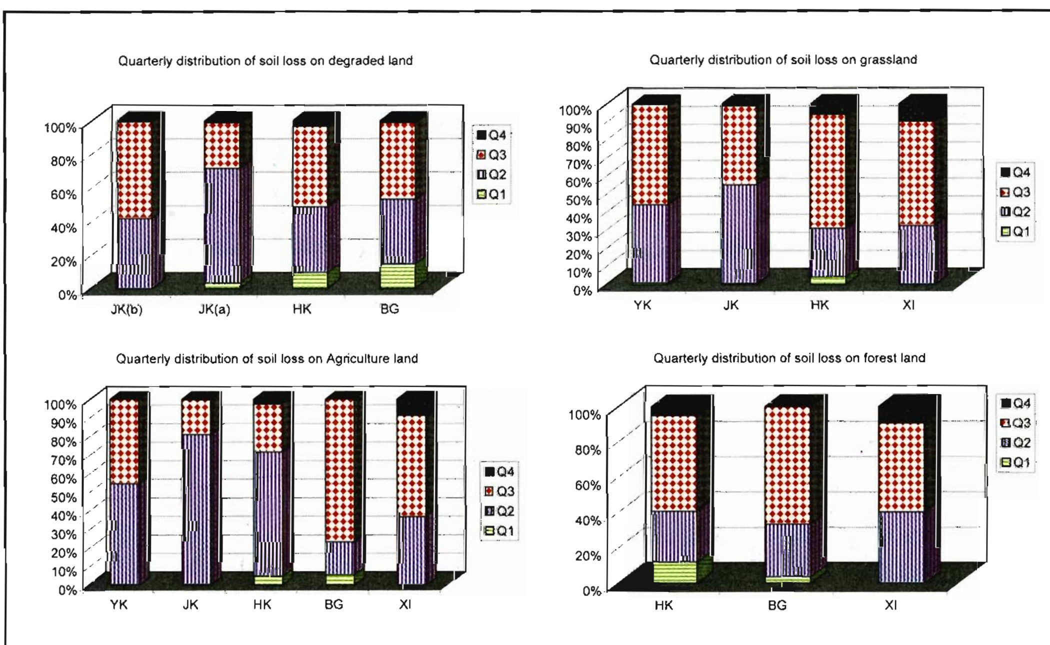

Figure 8.8: **Quarterly distribution of soil loss from different land uses**

Rainfall-runoff relationship

Runoff was measured on degraded, forest, grass and agriculture land in most of the watersheds on equal area plots of $100m^2$. A meteorological station was placed at each plot. Table 8.5 shows the recorded relationship at all sites between rainfall and runoff, runoff and soil loss, and between rainfall and soil loss. The general trend unsurprisingly shows that runoff increases with increased rainfall and decreases with decreased rainfall. There is a clear and strong relationship between rainfall and runoff on most plots. This rainfall-runoff relationship was very strong in both agriculture and grassland for the Yarsha Khola where R2 value were about 92% and 95% respectively. On the Jhikhu Khola plots this relationship was very weak on the degraded (12%) and agriculture (19%) plots, but very strong for grassland (83%).

On the Bheta Gad plots a strong relationship was found between amount of rainfall and amount of runoff in the forest plots (73%) while in degraded land it was only 28%. In Xizhuang the rainfall-runoff relationship was very strong across all land uses and was strongest on the agricultural plot at 94%. In Hilkot the rainfall-runoff relationship was similar in all four plots ranging from 55% in the forest plot down to 38% for the grassland.

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Runoff-soil loss relationship

Runoff water plays an important role in soil erosion. The results of the statistical analysis (Table

Table 8.5: **Relationship between rainfall, runoff, and soil loss in terms of R^2 values for different land uses in PARDYP watersheds**

Watersheds	1. Rainfall-runoff relationship			
	Degraded	Pasture	Agriculture	Forest
Yarsha Khola	na	0.95	0.92	na
Jhikhu Khola	0.12	0.83	0.19	na
Bheta Gad	0.28	na	0.56	0.73
Xizhuang	na	0.88	0.94	0.90
Hilkot	0.48	0.38	0.44	0.54
	2. Runoff-soil loss relationship			
Yarsha Khola	na	0.32	0.30	na
Jhikhu Khola	0.27	0.21	0.45	na
Bheta Gad	0.46	na	0.55	0.44
Xizhuang	na	0.78	0.79	0.67
Hilkot	0.69	0.55	0.23	0.86
	3. Rainfall-soil loss relationship			
Yarsha Khola	na	0.29	0.30	na
Jhikhu Khola	0.02	0.06	0.04	na
Bheta Gad	0.41	na	0.19	0.30
Xizhuang	na	0.80	0.96	0.67
Hilkot	0.33	0.24	0.19	0.38

Note: R^2 values show the relationship between two parameters — the effect of one factor on the other. However, many other factors also have effects which is why relationships vary at different times.

8.5) show that in the Yarsha Khola plots the relationship was only 30% for the agricultural plot and 32% for the grassland plot. In the Jhikhu Khola the relationship was 45% for the agriculture plot but 2% for the degraded plot. In Bheta Gad the relationship was quite good between runoff and soil loss on all plots (45 to 55%). Xizhuang had very good relationships ranging from 79% on the agricultural plot to 67% on the forest plot. In Hilkot the relationship was very good on all plots except for agriculture where it was only 15%. This is explained by the fact that in this area, although there is not so much rain in the pre-monsoon season, runoff and soil loss is quite high due to the bare and loose soil being exposed to the rain that does occur. The strongest runoff-soil loss relationship at Hilkot was on the forest plot (86%).

Rainfall-soil loss relationship

Intense rainfall plays a major role in detaching soil and moving it downhill. The relationship between the amount of rainfall and the amount of soil loss on a monthly basis in the erosion plots were also calculated (Table 8.5). The rainfall-soil loss relationship was not very strong across all land uses. This is probably mainly because of rainfall intensity, soil texture, plant cover, rainfall duration and previous rainfall history causing soil erosion. If the soil is already saturated from previous rainfall the infiltration will be reduced and more runoff will occur resulting in more soil erosion.

Forests tend to check soil erosion because of their ground vegetation and litter and the stabilising effect of their root networks. On steep slopes the net stabilising effect of trees is usually positive. Also, it is believed that vegetation cover can prevent shallow landslides from occurring (Bruijnzeel 1990) although large landslides on steep terrain are not influenced by vegetation cover.

Analysis of the study results show a good rainfall-soil loss relationship in Yarsa Khola on the agricultural and grassland plots with a 30% relationship recorded. The Jhikhu Khola plots showed a weak relationship across all land use types. At Bheta Gad the strongest rainfall-soil loss relationship was on the degraded plot (41%). The Xizhuang results showed a very good relationship on all three plots with a 96% relationship on the agriculture plot. In Hilkot the best relationship was on the forest plot (38%) due to it being protected from rainfall by the forest canopy while on the agriculture plot it was only 19% due to the intensity, time and duration of rainfall at the times when there was little crop cover.

Findings and Conclusions

- Annual rainfall in the study areas ranged from 800 mm to 2400 mm in the 1999 to 2002 period. Between 44% and 66% of rainfall occurred in the July to September period mostly in the monsoon season. The April to June period received between 22% and 30% of rainfall.
- The amount of rainfall lost through runoff was 37% from the Jhikhu Khola plots, 24% from the Bheta Gad plots, and 7% from the Hilkot plots. About 75% to 95% of runoff was recorded in the April to September period.
- Most runoff and soil loss was recorded in the monsoon. In all five watersheds 80 to 99% of soil loss occurred between April and September.
- The results from the erosion plots showed that runoff increases with increased rainfall and decreases with decreased rainfall.
- Runoff and soil losses were highest in the agricultural land when the land was being prepared for sowing as the soil is loose and most susceptible to erosion at these times. Soil erosion is less when the land is covered with crops.

- The erosion rates from forest and grasslands were low due to the presence of ground cover. Good crop canopies reduce the rainfall intensity and increase soil infiltration consequently reducing runoff and soil losses. Also, soil loss is less in forest areas as an area densely covered with vegetation yields less runoff than bare ground.

Recommendations

- In studies of runoff and soil erosion, treated and control (untreated) plots should be established for every land use to compare results and see the impact of treatments.
- New advanced types of data collection techniques and analysis tools enable the comparison of results from different areas and countries.
- Data analysis models need to be developed for regional data analysis.
- Vegetation cover should be improved in the PARDYP watersheds to improve the infiltration of soil and control runoff and soil loss.
- Water harvesting technologies should be applied to collect water lost as runoff during the monsoon to use in the dry periods to get maximum advantage from water resources in the PARDYP watersheds.

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Acknowledgements

The authors acknowledge the financial support of the Swiss Agency for Development and Cooperation (SDC), the International Development Research Centre (IDRC) and the International Centre for Integrated Mountain Development (ICIMOD) and technical support of the University of Berne and the University of British Colombia (UBC). Thanks are extended to Regional Coordinator, Roger White, assistant regional coordinators, P.B. Shah and Sanjeev Bhuchar for their support in organising regional workshops and other regional activities. We are highly thankful to country coordinators Hakim Shah, B.P. Kothyari, Bhuban Shrestha, and Xu Jianchu for their consistent support in data collection and other field activities.

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9

Challenges in Water Management in Intensively Used Catchments in the Himalayan Region

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Abstract

The middle mountain catchments of the Hindu Kush-Himalayan region suffer from water scarcity, flooding, landslides, and soil erosion. This PARDYP study found that water scarcity is the issue of most concern. This scarcity is caused mainly by the seasonality of water resource availability. Precipitation is highly seasonal with 75 to 80% of rainfall occurring during the monsoon season and 10 to 15% during the pre-monsoon season. The remaining time is virtually dry. Evapotranspiration rates peak during the pre-monsoon season, making March to April the driest time of the year as runoff is also at its minimum during this time. Water supply for domestic use is also at a minimum and many households face great hardships. This period also is the time of lowest water quality when most contamination occurs. Local water use for agriculture is generally well adapted to the seasonality of supply. Still, farmers experience water shortages at this time as they are not able to grow any additional crops. Farmers at the tail end of irrigation systems receive inadequate supplies even during the wet seasons. The time of highest risk for farmers is the time between the first pre-monsoon rains and the onset of the monsoon as this is when maize is planted and the rice nurseries are prepared in anticipation of the rains arriving. The other time when agriculture is vulnerable is the winter season when wheat and potatoes are grown. Dry conditions can lead to damage to rainfed crops and one less crop on irrigated lands. In addition, the growing number of farmers producing cash crops is putting additional stress on water resources. This paper contributes to the further understanding of water availability and supports a future focus by researchers on the improved management of irrigation systems, the catchment-based management of water resources, improved water quality management, and appropriate technologies to reduce water demand and increase water availability during the dry season.

Introduction

The Hindu Kush-Himalayan (HKH) region is the largest storehouse of freshwater in the lower latitudes (Chalise 2000). It also contains the largest mass of ice and snow outside the Polar Regions. This mountainous area supplies freshwater to its 150 million inhabitants and to 500 million people in the adjacent plains and downstream basins. Such mighty rivers as the Indus, the Ganges, the Yarlung-Tsangpo, the Brahmaputra, the Nu-Salween, the Yangtze, the Yellow River and the Mekong originate in these mountains. Some of these rivers, such as the Huang He (the Indus) are the lifeline for lower areas. The Indus feeds the largest irrigation system in the world (Liniger et al. 1998).

The main water related issues facing the people of the HKH region are floods, soil erosion and water availability.

Floods – Each year about ten thousand people are seriously affected by medium to large flood events. These are most destructive in the adjacent plains with great human and economic losses. In Bangladesh, flooding happens every year with an average of 20% of its area affected (Hofer 1998). Bangladeshi farmers have adapted their agricultural calendar to get the most benefit from this flooding. Every 33 to 50 years catastrophic floods hit the country (Miah 1988). Floods also occur in the inner Himalayan valleys in India (Agarwal and Narain 1991, Subba 2001), and in Nepal (Chalise and Khanal 2002).

Soil erosion – Soil erosion in the foothills of the HKH is a hot topic in land degradation research (Scherr and Yadav 1996). The main issue concerns the loss of topsoil through surface erosion with subsequent declines in soil fertility. This is a serious concern for agriculture and food security and is believed to be a major ecological crisis facing the HKH region (Chalise et al. 1993). However, nutrient leaching is a more important mechanism for the loss of soil nutrients (Gardner et al. 2000). Mass wasting accounts for much of the sediment load in rivers, but is only marginally responsible for soil fertility decline. Galay et al. (2001) have shown the often very damaging impact of high sediment loads on downstream infrastructure. These lead to sedimentation in reservoirs and the build-up (aggradation) of riverbeds. The 1993 storm in the Kulekhani area in central Nepal is one example, where the water storage capacity of an important large reservoir was greatly reduced by an immense sediment input from mass wasting and stream bank erosion.

Water availability has been identified by Merz et al. (2003) as a major concern of people in midhills Nepal. Water for irrigation and domestic use are in short supply. Water pollution is becoming an increasing concern in some catchments. A number of authors (compiled in Merz et al. 2004) report water scarcity from across the HKH. Chalise et al. (1993) reports the drying up of local groundwater resources due largely to changes in local land use. Due to these changes women and children are forced to walk longer distances to collect water. These authors further report on cases from Nepal's Midhills where men are finding it difficult to find brides because of the drudgery involved for hill women to collect water.

The middle mountains are one of the most fragile and vulnerable areas in the HKH region. This zone is characterised by high rainfall, high rates of specific runoff (Alford 1992) and high population densities (over 75 people/km^2). These densities lead to high pressure on, and intensive use of, natural resources with resource degradation in many places.

The study reported in this paper asked the following questions:

- are farmers in upland catchments responsible for floods downstream?
- is soil loss a problem in the selected study catchments?
- is water scarce in middle mountain catchments?

Water availability is an issue of great concern in many parts of the world. This problem is the most frequently mentioned issue in the catchments of the People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP) in Nepal (Merz et al. 2003), and in China, India, and Pakistan (Merz et al. 2004). This paper discusses this issue in detail. The two other important issues of downstream floods and soil loss are discussed in more depth in Merz (2004) and are addressed in the papers by Jehangir et al. and Dangol et al. in this volume (2005).

Study Site and Methodology

This study is mainly based on data collected in the Jhikhu Khola (JKC) and Yarsha Khola (YKC) catchments in Nepal. An introduction to these two catchments is given in the introductory paper in this volume (The PARDYP Teams 2005). Both are headwater catchments of the middle mountains with elevations of between 790 and 2200 masl in the Jhikhu Khola and 990 to 3040 masl in the Yarsha Khola. They are purely rainfed with the exception of a couple of days of snowfall per year in areas above 2800m. They have high population densities with, in 1996, 437 people/km^2 in the Jhikhu Khola and 386 people/km^2 in the Yarsha Khola. More recent figures show the density in the Jhikhu Khola as having risen to up to 550 people/km^2.

The Jhikhu Khola catchment is one of the most intensively cultivated rural areas in Nepal's middle mountains. It is therefore not representative of other catchments in the region, but does represent the condition that many other areas in the region are tending towards. Its irrigated areas cover 1838 ha or 16.5% of the total catchment. Rainfed agricultural land covers 4266 ha or 38.3% of the total area. On irrigated land two to three, and in some cases four, crops are grown with rice during the monsoon season and potato and tomato during dry seasons. Other vegetables increasingly cultivated include cauliflower, cabbage, bitter gourd, cucumber, capsicum, and chilli.

The Yarsha Khola catchment has a total irrigated area of 744 ha (14% of its area) with rice during the monsoon season and wheat or potatoes during the dry season. On the 1996 ha of rainfed agricultural land (37% of the catchment area), maize is grown during the dry season followed by millet in the post-monsoon season as a relay crop, and wheat or potatoes during the dry season.

In both catchments the PARDYP project has run dense hydro-meteorological monitoring and research networks (Merz 2004). The study reported in this paper used data covering 1993 to 2000 for the Jhikhu Khola and 1998 to 2000 for the Yarsha Khola. The data was substantiated with data collected from household surveys, water quality surveys, and other measurements.

The study follows the approach described in Merz (2004). The conditions and dynamics of the biophysical and socioeconomic processes that govern local hydrological regimes in the HKH are changing in many places due to the pressures of land use change, population growth, and climate change. It is very important to understand the current conditions and the related processes to be able to plan to accommodate these changes.

Water Availability Study

Farmers say that the availability of irrigation and domestic supplies has decreased over the last 5 to 25 years (Merz et al. 2002). Farmers and scientists also perceive that flows out of the two catchments have decreased over the last 10 to 15 years (Merz et al. 2002). However, this could not be proven from the streamflow data due to inadequate data accuracy at the low flow level. The question therefore remains of whether or not it is true that water resources are really scarce or whether it is more an issue of shortcomings in water management and distribution. This study explored the actual water availability and the issues related to this on the basis of a water balance approach that looks at the water inputs (precipitation), the water outputs (evapotranspiration, outflow, human consumption), and water storage in the groundwater and the soil. This paper first discusses the main parameters of precipitation, evapotranspiration, runoff, storage and human consumption before this information is synthesised in a water-accounting exercise below.

Precipitation Dynamics

The two catchments are headwater catchments and precipitation is therefore the only input into their water cycle. Most precipitation occurs as rainfall with occasional snowfall in upper areas of the Yarsha Khola. The Jhikhu Khola catchment receives about 1295 mm areal rainfall per year and the Yarsha Khola 2206 mm per year. The minimum annual rainfall in the Jhikhu Khola catchment was measured in 1993 with 1082 mm, while the maximum of 1628 mm was measured in 1999.

Most of the rainfall in the Jhikhu Khola catchment falls in the monsoon season accounting for about 79% of the total. The pre-monsoon season receives 13% of annual rainfall while the remaining 8% occurs in the dry season which runs from October to May. The values in the Yarsha Khola catchment are similar with 81% of rainfall in the monsoon season, 15% in the pre-monsoon season, and 4% in the dry season. The seasonal variability of rainfall is highest during the October to May low rainfall season (Figure 9.1) indicated with coefficients of variation between 0.9 and 1.3 in the post-monsoon season, 0.5 to 1.6 in winter, and 0.3 to 0.8 in the pre-monsoon season depending on station location.

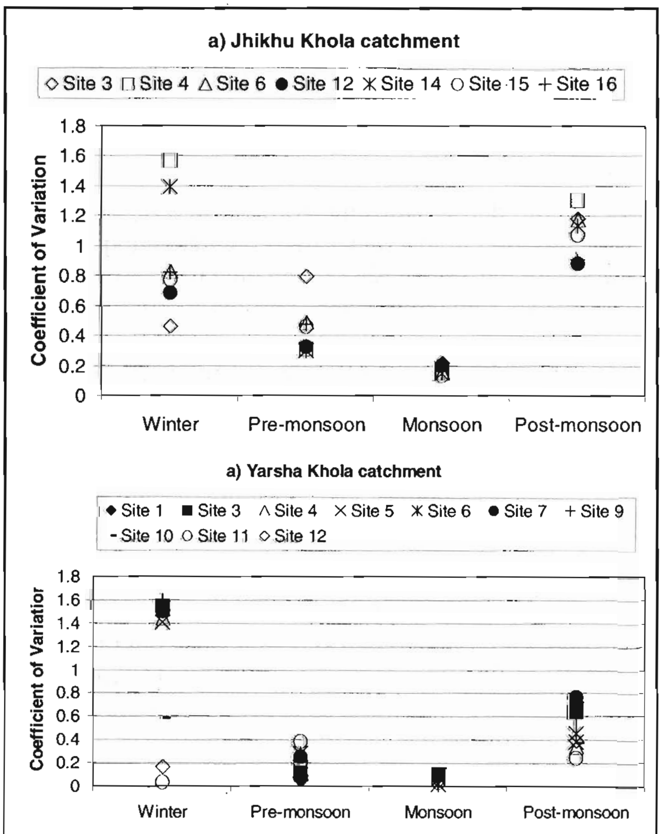

Figure 9.1: **Seasonal rainfall variability in the Jhikhu Khola (1993-2000) and Yarsha Khola (1998-2000) catchments**

In the Yarsha Khola, rainfall variability shows a similar trend as the Jhikhu Khola; but these values should be treated with caution due to the short time series of the data.

Rainfall only occurs occasionally during the dry season. The number of dry spells of 15 subsequent days without measurable rainfall (Mosley and Pearson 1997) in the Jhikhu Khola catchment ranged from nine to thirteen in number in the 1993 to 2002 period. These dry spells most frequently lasted between 25 and 50 days. The longest dry spell recorded was 144 days. The period from 1998 to 2000 was particularly dry with most dry spells lasting between 50 and 100 days. The Yarsha Khola catchment has fewer dry spells per year (about 8 to 11 in number), but they were longer. From 1998 to 2000 most dry spells lasted between 50 and 100 days.

Spatially the precipitation pattern is erratic during the dry season and no distinct pattern can be seen. Elevation provides a good relationship for annual and monsoon data and in months where exceptionally high rainfall events occur. In the Yarsha Khola catchment the elevation-precipitation relationship is consistent throughout the year, but inadequate during the dry season. As a rule of thumb there is generally higher rainfall in the upper areas of the two catchments.

In summary, there is plenty of annual rainfall for human needs in both catchments, but its distribution is skewed towards the monsoon season. At the same time the little rain falling during the remainder of the year is highly variable, which means that farmers cannot rely on it. Rainfall occurrence is also spatially variable and no distinct relationship with elevation was observed.

Evapotranspiration

In the absence of physical evaporation measurements and other sophisticated data for estimating evapotranspiration, the temperature based FAO Penman-Monteith evapotranspiration calculation approach (FAO 1998) was applied. The reference evapotranspiration values ET_0 in the Jhikhu Khola catchment range from 1.7 mm/day at different sites both in January and December up to about 5 mm/day in May (Figure 9.2). In the Yarsha Khola catchment the minimum daily ET_0 was calculated at between 1.0 and 1.5 mm/day. The maximum is reached in April and May with values ranging from 3 to 5 mm/day.

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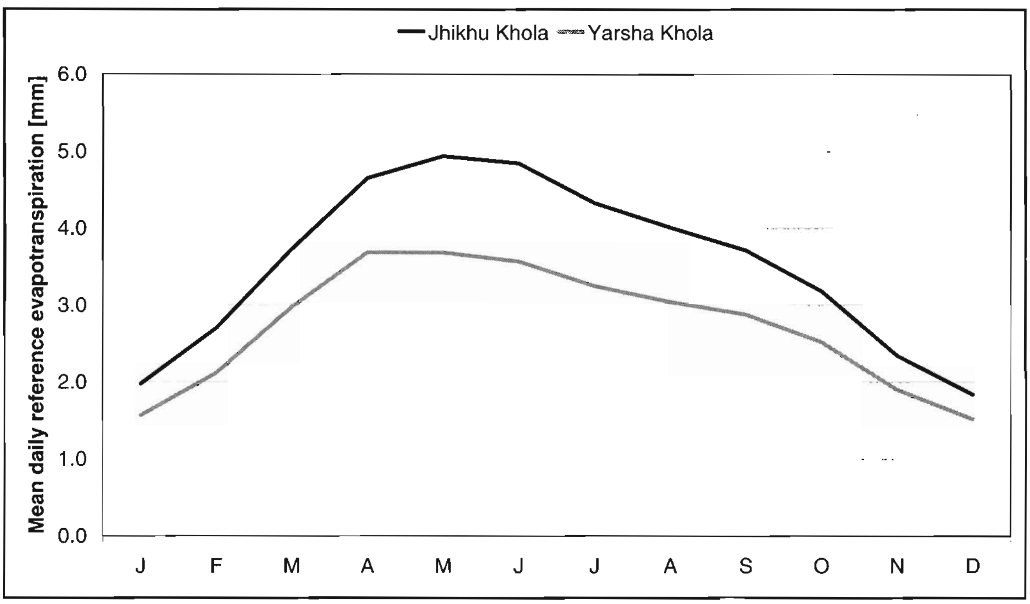

Figure 9.2: **Mean daily reference evapotranspiration at main stations of Jhikhu Khola and Yarsha Khola catchments**

These results were compared with the results of studies in Nepal by Lambert and Chitrakar (1989), MacDonald & Partners (1990), and Tahal Consulting Engineers (2002). The calculated values correspond well throughout the range with the values reported by Lambert and Chitrakar; but are slightly lower in comparison to MacDonald & Partners' values. MacDonald & Partners used the method proposed by FAO (1977), which, according to FAO

(1998) frequently overestimates ET_0. There was a considerable difference with the values reported by Tahal Consulting Engineers (2002). Mainly the values of sites higher than 1500 masl differed largely. It has to be noted that Tahal Consulting Engineers' values are all from western and central western Nepal. There is a considerable difference in sunshine duration between the western and eastern parts of the country (Jhikhu Khola and Yarsha Khola lie in the central-eastern part of Nepal). In particular April, May, and June have significantly different amounts of mean daily sunshine (Chalise et al. 1996). These are the months with the highest reference evapotranspiration rates and the differences in amount of sunshine could therefore explain the differences between the two calculations. In general, the values calculated for the study areas seem to be plausible.

On the basis of ET_0, the actual evapotranspiration AET was estimated by using the crop coefficient approach (FAO 1998). The results are presented in Table 9.1. Values of 850 to 886 mm per annum were estimated for the entire Jhikhu Khola. In the Yarsha Khola, AET values were estimated at between 730 and 790 mm per annum in the period 1998 to 2000.

Table 9.1: **Annual evapotranspiration data for the Jhikhu Khola and Yarsha Khola catchments [mm/yr]**

	1993	1994	1995	1996	1997	1998	1999	2000
Jhikhu Khola	850	886	854	873	859	884	878	869
Yarsha Khola	-	-	-	-	-	778	790	732

Flow Regime

The mean discharge of water at the main station at the outlet of the Jhikhu Khola catchment was 1.45 m^3/s in the period 1993 to 2000, ranging from 1.12 m^3/s in 1994 to 1.79 m^3/s in 1996. In this period the daily maximum discharge was about 30 m^3/s and the minimum was below 0.01 m^3/s. However, these extreme values have to be considered with caution due to inconsistencies related to the relationship between the water level of a river and its flow rate (the stage-discharge relationship).

The annual mean specific yields ranged from 10 to 16 $l/s*km^2$ of water. For a catchment area the size of the Jhikhu Khola (111 km^2), these values are very low and suggest a considerable human impact on streamflow conditions. In comparison, the nearby Rosi Khola catchment that lies to the south of the Jhikhu Khola and covers an area of 87 km^2 had a specific yield of 30 $l/s*km^2$ (Alford 1992) in the early 1990s. The main reason for the higher specific yield of this catchment is its higher rainfall that is related to its higher elevations. The catchment extends up to 2,943 masl and receives much more rainfall than the Jhikhu Khola where the highest elevation is only 2,200 masl.

There is a marked seasonality in the runoff regime of the Jhikhu Khola (Figure 9.3a). The highest mean and median flows were observed during August, followed by the months of July and June. The highest runoff is therefore a month later than the highest rainfall. The absolute minimum flows occur in March closely followed by April, February, and May, indicating the driest time of year in terms of discharge in the river system completely fed by groundwater. With the increasing pre-monsoon showers in May the flow starts to pick up and rapidly increases to the maximum flows in the monsoon season. After reaching maximum flows in the monsoon, flows decline to dry season flows in November, with September and October usually showing intermittent flow amounts.

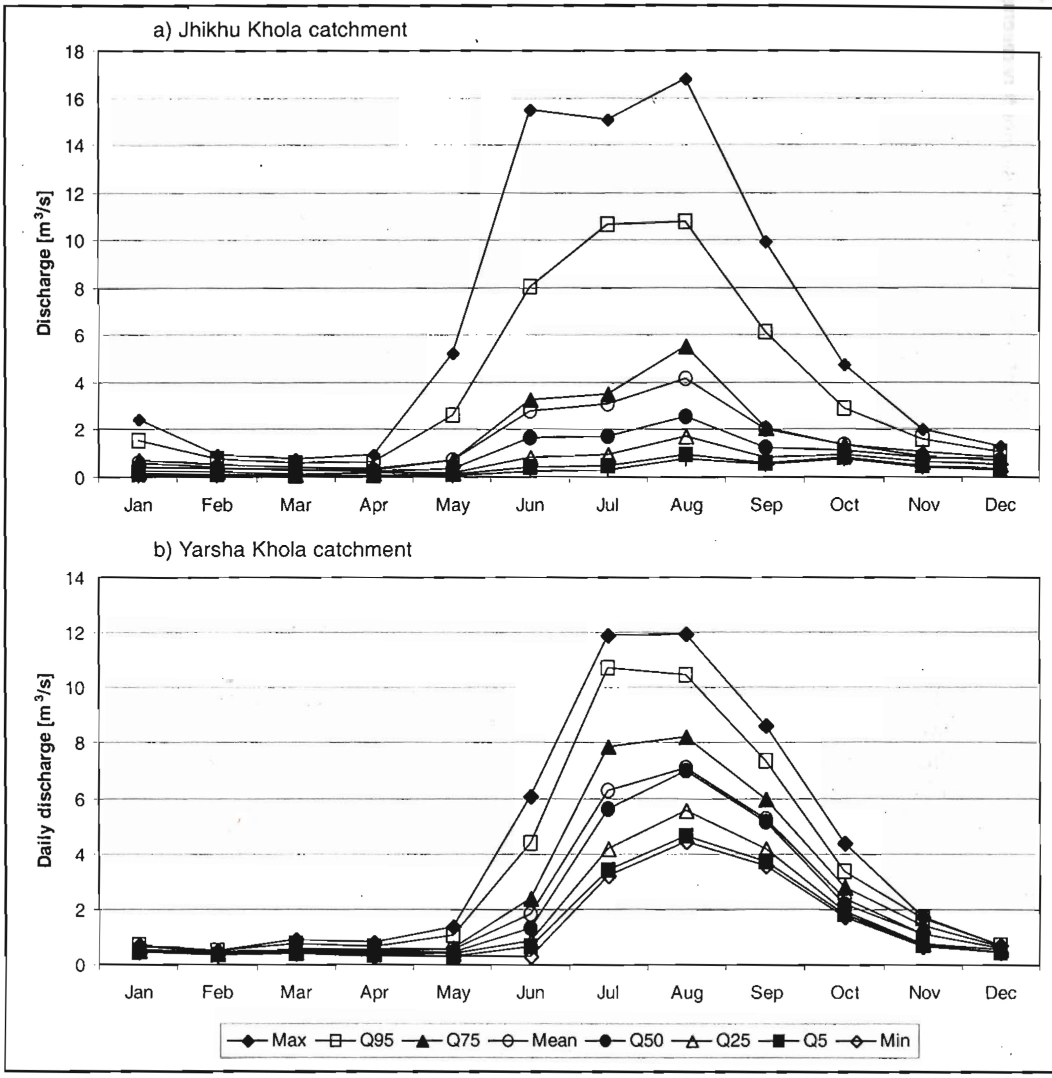

Figure 9.3: **Runoff regime at main stations in the Jhikhu Khola and Yarsha Khola catchments**

The monthly flows in the Jhikhu Khola catchment are generally variable (Figure 9.4). The least variability happens in the monsoon season in July and August. The February flows also have low variability – they were consistently low throughout the measurement period. Generally the pre-monsoon flows in March, April, and May have the highest variabilities as rainfall during this time may be plentiful in some years and erratic in others. They can also be high when intense pre-monsoon rain and extended showers occur.

The highest flow at the main station at the Jhikhu Khola catchment outlet during the year is on average 16 times higher than mean annual flow. The highest daily discharge was on

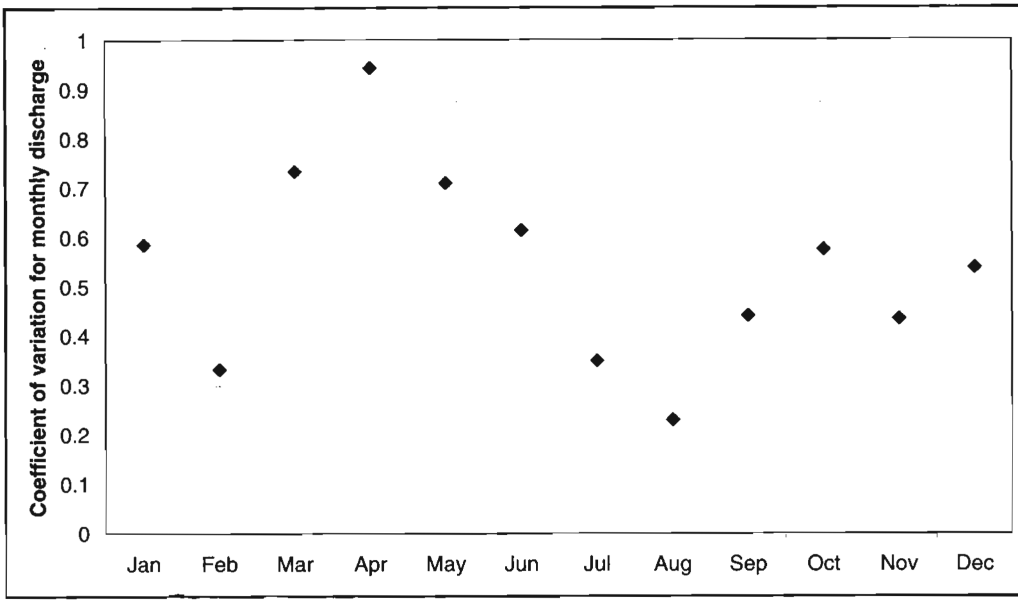

Figure 9.4: **Temporal variability of monthly flows for the Jhikhu Khola catchment**

average about 1500 times larger than the minimum daily flow throughout the study period and the mean flow was 83 times larger than the lowest annual flow.

Data monitoring in the Yarsha Khola catchment started in 1997 and complete annual data is only available from 1998 to 2000. In this period the mean discharge ranged from 1.9 to 2.9 m^3/s and the maximum discharge from 11.6 to 14.3 m^3/s. The minimum recorded value was below 100 l/s in 1998 and about 250 l/s in the other years. The same reservations regarding extreme low flow data quality have to be made here as for the Jhikhu Khola data.

The mean specific yield in the Yarsha Khola catchment (area 53 km^2) was considerably higher ranging up to 50 l/s*km^2 in 2000 and 40 l/s*km^2 in 1998 and 1999. This matches the values observed in the Rosi Khola that has a similar size and similar elevation, but more human activity.

The absolute minimum flows in the Yarsha Khola happen in May (Figure 9.3b). However, when there are strong pre-monsoon rains or the monsoon started early the smallest range of flows happened in April and February. Flows were consistently low from December through to the onset of the monsoon. The maximum flows were recorded in July and August followed by September and June, with irregular flows in October and November. The observed flows during August ranged from 4 to 12 m^3/s. The lowest flows were recorded in February with a range of annual values from 0.36 to 0.52 m^3/s.

The variability was not assessed for the Yarsha Khola as three years of data is not enough to carry out a variability analysis. The intra-annual variability can however be shown in terms of the ratio between the highest, lowest and mean flows at the outlet of the catchment. The highest flows were on average about 6 times bigger than the mean flows and about 64 times bigger than the lower flows. The lowest flows were on average only about a tenth of mean flows.

A comparison of the daily runoff at the hydrological stations at the outlets of the two catchments shows that the Yarsha Khola catchment generally carries much more water per unit area than the Jhikhu Khola (Figure 9.5). The baseflow – the flow derived from ground and soil water storage – in particular is higher in the former catchment.

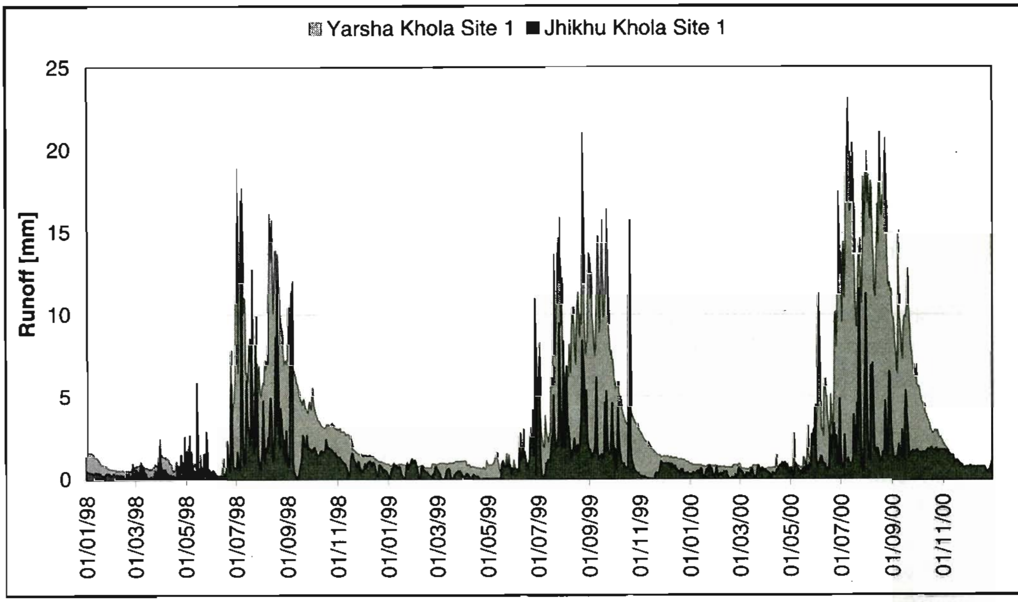

Figure 9.5: **Comparison of daily runoff at the outlets of Yarsha Khola and Jhikhu Khola**

The above analysis can be summarised as follows:

- both catchments have a distinct wet season-dry season regime with the lowest water flows in the pre-monsoon season (March/April) and the highest in July/August;
- the mean specific yields are about 12 l/s*km^2 in the Jhikhu Khola and 40 l/s*km^2 in the Yarsha Khola;
- annual runoff ranged from 300 to 500 mm during the 1993 to 2000 period in the Jhikhu Khola catchment and from 1200 to 1600 mm in the Yarsha Khola catchment for the period 1998 to 2000; and
- highest flow variabilities were recorded in pre-monsoon season flows.

Storage

While the flow during the monsoon season is governed by the distribution of rainfall, the flow in the post-monsoon and winter season, and often to a large extent also in the pre-monsoon season, is dependant on the emptying out of stored water from the catchment. These storages and their capacities are important to consider when assessing the potential availability of water. Some of the best forms of storage are glaciers, snow, and lakes. These delay the flow of water by a year or even years in the case of glaciers. None of the studied catchments contains any of these and so rainfall is stored as groundwater and soil water storage. In general these storage systems are believed to hold rainfall for up to one year. Kansakar (2001) mentions three main types of geological settings where groundwater can be expected in the hills of Nepal:

- thick unconsolidated fluvial, glacial and lacustrine sedimentary deposits in river and tectonic valleys;
- thick weathering mantles with coarse debris over bedrock; and
- fractured bedrock.

In the Jhikhu Khola the main valley is filled with alluvial deposits forming a potential aquifer of the first type. Adhikari et al. (2003) showed that spring yield is closely correlated with rock type in the eastern part of the Jhikhu Khola indicating a potential aquifer of the third type. They reported that 75% of the high spring yields were related to carbonate rocks such as limestone, dolomite and marble beds. These are highly fractured and contain interconnecting holes and fissures. In contrast the metamorphic rocks in the area such as phyllite, schist, quartzite and gneiss showed moderate to low discharge. The highest yields were further observed in the base of the syncline fold in the Jhikhu calcareous beds.

In the Yarsha Khola catchment, massive sedimentary deposits and thick weathered mantles are largely missing. Subsurface water that feeds base flows therefore probably mainly come from aquifers in the fractured bedrock and soil water storage.

In general the Yarsha Khola catchment shows a higher storage capacity than the Jhikhu khola catchment. This is reported in Dangol et al's paper in this volume (2005) as the base flow index (BFI). The base flow index is the proportion of a river's runoff that derives from stored sources. It varies from 0.1 for a river that is very prone to flash floods to near unity for a very stable river with a high proportion of base flow (Gustard et al. 1992). The base flow index for the 1998 to 2000 period was 0.46 for the Jhikhu Khola catchment and 0.68 for the Yarsha Khola showing a higher proportion of the annual runoff sustained by base flow in the Yarsha Khola.

To assess the storage capacity of the two catchments the flow recession curves were determined after the monsoon rains at the hydrological stations at both catchment outlets (Figure 9.6). For the Yarsha Khola the fit of a logarithmic curve with base e was very good with an r2 of 0.93 in the 1998/1999 dry season and 0.95 in the 1999/2000 dry season. Following the curve to the point of intercept with the x-axis, a theoretical storage capacity of about 310 days (304 days in 1998/1999, 321 days in 1999/2000) was determined. In the Jhikhu Khola catchment the fit was not as good. This was the case especially in 1999 when it was poor (probably partly due to a measurement error after a very large rainfall event). The theoretical storage capacity was determined at 299 days in 1998/1999 and 305 days in 1999/2000, with an average of about 300 days.

These values indicate that in both catchments the complete exhaustion of the groundwater has not occurred as in both cases the storage is refilled by the onset of the monsoon rains before it is exhausted. The longest possible theoretical dry season is 240 days.

Human Consumption

Water consumption by people in the rural catchments of Nepal's middle mountains comes from demands for crop production, livestock, and domestic needs. Industrial demands are negligible. For the Jhikhu Khola area demands from the tourism industry could become a major water use if this industry continues to grow.

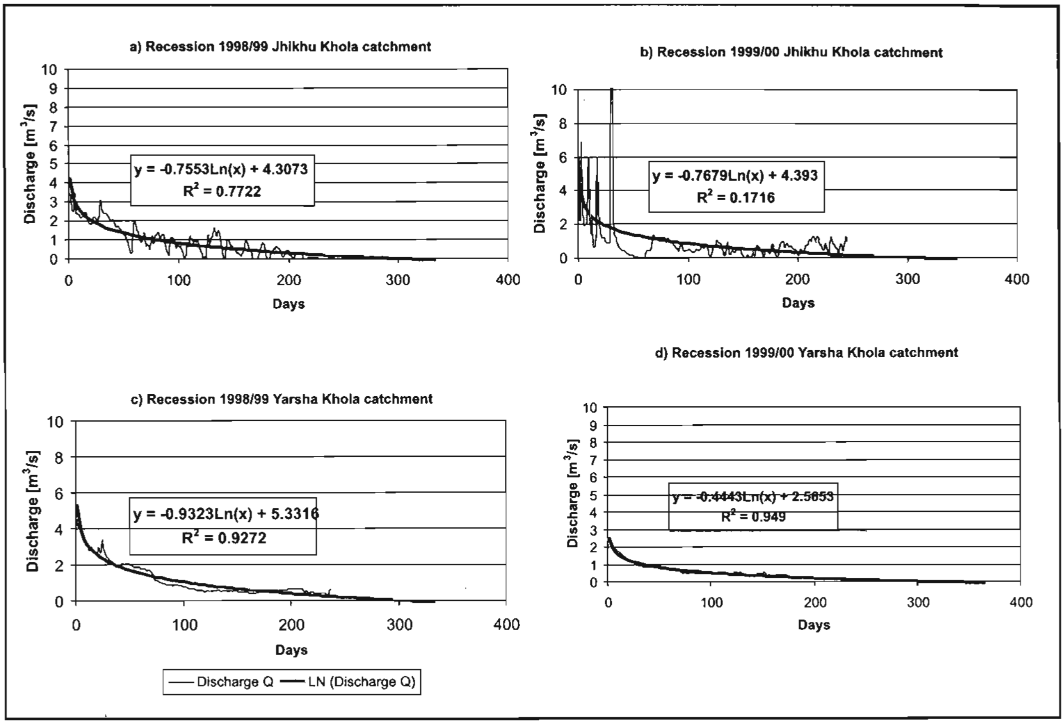

Figure 9.6: **Flow recession curves in the Jhikhu Khola catchment: a) 1998/1999 dry season, b) 1999/2000 dry season; and for the Yarsha Khola catchment: c) 1998/1999 dry season, and d) 1999/2000 dry season.**

Water demand for domestic use is low in the study catchments. On average respondents in the Jhikhu Khola only use 23.2 litres per day of water (Table 9.2). In the Yarsha Khola catchment water use was estimated at 21.1 litres per person per day. These demands are about half of the 45 litres of water per person per day as estimated by HMGN's Department of Water Supply and Sewerage (RWSSSP 1994). This value includes 20% for losses and wastage. On the basis of these water use values, overall water demand for domestic use per year was calculated at about 413,000 m³ (~4 mm) of water in the Jhikhu Khola and 159,000 m³ (~ 3 mm) of water in the Yarsha Khola catchment.

This amount of water use is above average in comparison with the estimated average figures for Nepal of 12 litres per person per day (Gleick 2000). These amounts mainly include water for drinking, cooking, and food preparation. Other water related activities such as washing and personal hygiene mostly happen directly at watercourses or taps. RWSSSP (1994) estimated the water demand at 45 litres per person per day for areas where piped water is available (usually at tap stands). The estimated amount of water used in areas with difficult access to

Table 9.2: **Annual domestic water needs in the Jhikhu and Yarsha Khola catchments**

Catchment	Population (1996)	Daily water use (litres/person/day)	Annual water use	
			(m^3)	(mm)
Jhikhu Khola	48728	23.2	412,629	3.7
Yarsha Khola	20620	21.1	158,805	3.0

water and collection times of more than 15 minutes is 25 litres and in local towns 60 litres per person per day. Gleick (1996) has calculated that individuals need 50 litres of water per day including 5 litres for drinking, 20 litres for sanitation, 15 litres for bathing, and 10 litres for cooking.

The quality of water is equally important as the amount. Schaffner (2003) and Merz et al. (2004) report that hardly any of the water sources in the Jhikhu Khola area are free from microbiological contamination. In addition nitrate and phosphate levels although still below World Health Organization guideline values (WHO 1993), are approaching levels of concern due to increasing fertiliser application.

The yearly cropping cycle in the two catchments are described in Merz et al. (2002). The following water demands were calculated on the basis of these cropping cycles. The theoretical water demand of different crops differs tremendously depending on climatic conditions. The following values assumed average climatic conditions based on the 1993-2000 data from the Jhikhu Khola and 1998-2000 data for the Yarsha Khola catchment. It is important to note that these water requirement values were calculated for maximum yields. It is therefore understood that crops may often use less water leading to lower yields. The impact of water stress on yields can be estimated by using a yield response factor to calculate the actual expected yield on the basis of the estimated yield at times of optimum water supply conditions (Doorenbos et al. 1979). Here optimum water conditions are assumed for maximum growth and yield.

Rice is by far the most demanding crop on irrigated land needing 1400 mm of water per crop. This value corresponds with the values of 1200 to 1800 mm/crop given by ILACO (1981). The impact on annual water resources availability is however limited as this crop is grown during the monsoon season. The recently introduced cash crop tomatoes is the next most demanding with 345 mm. The other main cash crop potatoes, however, requires less water – mainly due to its shorter growing season – than the wheat that was traditionally grown at the same time of the year. It is however important to note that potato crops actually use more water than wheat under the current management practices in irrigated land. This happens due to the drought resistance of wheat compared to potatoes' relative sensitivity to soil water deficits. This causes farmers to keep the soil moist for potatoes, whereas only one to two irrigations are applied to wheat (Doorenbos et al. 1979). On rainfed land the monsoon crop maize has the highest water demand followed by wheat and tomatoes.

A number of different crop rotations exist in the Jhikhu Khola. Pujara and Khanal (2002) identified 10 different crop rotations on irrigated land and 13 on rainfed agricultural land. All the rotations on irrigated land included a rice crop whilst all the rotations on rainfed land included a maize crop. Water use is therefore only given for the major crop rotations identified during this study's water demand and supply survey.

The calculation shows that 1898 mm water is required per $1m^2$ of irrigated land (Table 9.3). Given the 11,141 ha extent of the catchment area, the annual demand for the 1838 ha of irrigated fields is therefore about 313 mm/year. The water demand of the 4267 ha of rainfed areas was calculated at about 349 mm/year.

In the Yarsha Khola the main crops on irrigated land are rice, wheat, and potato. The highest water demanding crop is rice followed by potato and wheat. On rainfed land the traditional crops are maize, millet, wheat and potato with maize demanding the most water. Millet is

Table 9.3: **Water demand of main crop rotations in the Jhikhu Khola catchment**

Rotation	Annual	Monthly
1. Irrigated land		
Rice-potato-maize	1897 mm/12 months	158 mm/month in 12 months
Rice-wheat-maize	2018 mm/12 months	168 mm/month in 12 months
Rice-potato-tomato	1931 mm/12 months	161 mm/month in 12 months
Rice-wheat	1706 mm/10 months	171 mm/month in 10 months
Irrigated land average	1898 mm/yr	165 mm/month in 11.5 months
2. Rainfed land		
Maize-wheat	837 mm/10 months	84 mm/month in 10 months
Maize-tomato	848 mm/7 months	121 mm/month in 7 months
Maize-potato	808 mm/9 months	90 mm/month in 9 months
Maize-mustard-wheat	1050 mm/12 months	88 mm/month in 12 months
Rainfed average	912 mm/yr	96 mm/month in 9.5 months

relayed with the maize crop and requires about 340 mm per crop. The total water demand for the 742 ha of irrigated cropping land in the Yarsha Khola catchment is estimated to be 249 mm/year on the basis of the entire catchment area (Table 9.4). The demand for the 1996 ha of rainfed areas is estimated to be 295 mm/year.

Table 9.4: **Water demand of main crop rotations in the Yarsha Khola catchment**

Rotation	Annual	Monthly
1. Irrigated land		
Rice-wheat	1774 mm/12 months	148 mm/month in 12 months
Rice-potato	1801 mm/11 months	164 mm/month in 11 months
Irrigated land average	11.5 months = 1794 mm/yr	156 mm/month
2. Rainfed land		
Maize-millet	738 mm/yr in 8 months	92 mm/month in 8 months
Maize-millet-wheat	987 mm/yr in 11 months	90 mm/month in 11 months
Maize-potato	672 mm/yr in 10 months	67 mm/month in 10 months
Rainfed land average	789 mm/yr	83 mm/month in 9.5 months

Livestock are a very important part of HKH farming systems and an important factor in calculating water demand. Traditionally livestock were taken to water sources to drink. However, increased stall feeding, especially of buffaloes, but also sometimes goats and cows, means that they are now watered on-site (Merz et al. 2002). The water demand for the animals in Table 9.5 was estimated from a survey conducted in the Jhikhu Khola and the Kathmandu Valley of 23 farmers. The results were verified from the literature on the subject (ILACO 1981). In general the values arrived at are slightly higher than the values in the literature, which is appropriate given the hotter conditions in the Jhikhu Khola catchment than the places in the literature. The annual water demand for livestock in the Jhikhu Khola was estimated at 4.6 mm, while in the Yarsha Khola, where livestock plays a bigger role, water demand was estimated at 6.0 mm (Table 9.5).

Table 9.5: **Water demand for livestock watering in the Jhikhu and Yarsha Khola watersheds**					
	Water demand	**Jhikhu Khola**		**Yarsha Khola**	
	ltr/day	HH*no. [1]	m^3/day	HH*no. [1]	m^3/day
Buffaloes	61	8002* 1.2	585.7	4362* 1.1	292.7
Bullocks	49	8002* 0.8	313.7	4362* 1.5	320.6
Cows	23	8002* 0.9	165.6	4362* 0.9	90.3
Goats	12	8002* 3.5	336.0	4362* 3.3	1727
Pigs	10	-	-	-	-
Annual water use		511,365 m^3		319,849 m^3	
Annual water use		4.6 mm		6.0 mm	
[1]Number of households (HH) from PARDYP aerial photograph analysis times average number of livestock per household (no.) from Merz et al. (2002)					

Working out the domestic, agricultural, and livestock water requirements allowed the study to come up with an overall figure for the amount of water needed in the two catchments. The combined totals give a water demand of 671 mm per annum in the Jhikhu Khola catchment and 553 mm in the Yarsha Khola (Table 9.6). The difference is mainly due to the higher evapotranspiration rates and thus higher crop water requirements in the Jhikhu Khola with a greater demand of about 60 mm/year for its irrigated land and 50 mm/year for its rainfed land. The other components are comparable in the two catchments.

Table 9.6: **Summary of water demands for human consumption in mm**					
	Domestic	**Agriculture**			**Total**
		Irrigated land	**Rainfed land**	**Livestock**	
Jhikhu Khola	4 (1%)	313 (47%)	349 (52%)	5 (1%)	671
Yarsha Khola	3 (1%)	249 (45%)	295 (53%)	6 (1%)	553
Note: All values are rounded and therefore may add up to more than 100%					

Synthesis

The hydrological water balances of the Jhikhu Khola and Yarsha Khola catchments at the catchment outlet points are presented in Figure 9.7. The area monitored at the outlet of the Jhikhu Khola received about 1295 mm rainfall per annum on average during the study period. This amount is depleted by about 869 mm of evapotranspiration and 411 mm of runoff. This means that about 67% of the rainfall is lost through evapotranspiration and 32% by runoff. The balance of 15 mm was probably due to inaccurate measurement of precipitation or runoff, inaccurate interpolation of rainfall or evapotranspiration, or the inaccurate calculation of evapotranspiration. However, the balance only amounts to 1% of the entire rainfall.

In the Yarsha Khola catchment, which receives nearly double the rainfall of the Jhikhu Khola, 2206 mm rainfall was measured on average at the outlet point during the three-year study. Of this input 34% (767mm) was lost through evapotranspiration and 62% (1349 mm) through runoff downstream. The error due to measurement, calculation, or interpolation was 90 mm or 4% of total rainfall.

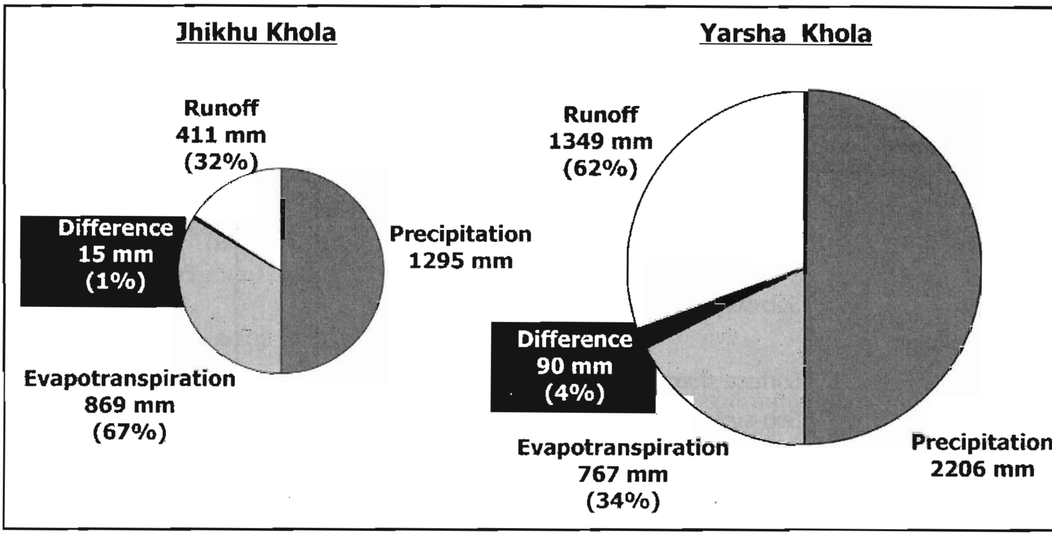

Figure 9.7: **Hydrological water balance of the Jhikhu and Yarsha Khola catchments**

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The study found that precipitation accounts for the entire gross inflow in both catchments and it was therefore assumed that there were no ground or soil water storage changes over a one year period.

The results of the water accounting analysis are shown in Table 9.7. Note that the data in this exercise is derived from measured data. Also, the 'available water for agriculture' figure in the calculation is derived from the total water available in the catchment minus the water that is depleted in various ways. Note Box 9.1 provides some useful definitions of the terminology used here.

Box 9.1: **Some water accounting definitions**

- **Gross inflow** is the total inflow into the catchment from precipitation, surface, and subsurface sources.
- **Net inflow** refers to changes in storage in addition to gross inflow.
- **Water depletion** refers to the use or removal of water from the catchment that renders it unavailable for further use, such as through evaporation, flows to sinks, pollution, and incorporation into a product. The water can be process-depleted such as when it is used to produce agricultural crops, energy, or industrial products. Non-process depleted water is the water lost through processes other than for the process it was diverted for such as evaporation from soil and water surfaces and deep percolation in irrigated land.
- **Non-depleted water** is water that is not lost after it has been diverted for a use such as hydropower or for in-stream uses.
- **Committed flow** is the water committed for certain uses such as for fisheries or to downstream rights for irrigation.
- **Uncommitted flow** is water that is neither depleted nor committed and thus available for use within the catchment or for downstream users.

Table 9.7: **Water accounting in the Jhikhu Khola and Yarsha Khola catchments**					
Description		**Jhikhu**		**Yarsha**	
		Total	**Parts**	**Total**	**Parts**
1. Gross inflow:		1295		2206	
	Surface diversion		0		0
	Precipitation		1295		2206
	River inflow		0		0
	Sub-surface flow		0		0
Storage change		0		0	
	Surface storage		0		0
	Sub-surface storage		0		0
2. Net inflow		1295		2206	
3. Depletion		886		776	
Process		493		365	
	Irrigation-crop evapotranspiration		484		356
	Municipal and industrial use		9		9
Non-process, beneficial		38		63	
	Irrigation-flows to sinks		38		63
Non-process, beneficial		355		348	
	Home gardens, forest		355		348
Beneficial		848		713	
Low and non-beneficial		38		63	
4. Outflow		411		1349	
	Committed outflow for downstream water rights		0		0
	Committed outflow for environment		0		0
	Uncommitted outflow	411		1349	
	Utilisable		411		1349
	Non-utilisable		0		0
5. Available water at catchment level (net minus committed minus non-usable)		1295		2206	
6. Available water for agriculture		931		1849	
Source: Merz 2004					

In summary the results reveal that:

- there is a net inflow (all from precipitation) of about 1300 mm into the Jhikhu Khola and 2200 mm into the Yarsha Khola catchments per year;
- crop evapotranspiration accounts for about 55% or 484 mm of the total process depletion of 886 mm in the Jhikhu Khola catchment;
- in the Yarsha Khola catchment crop evapotranspiration accounts for 356 mm or 46% of the total 776 mm of depleted water;

- about 40% or 355 mm accounted for non-process evapotranspiration by forests in the Jhikhu Khola and 348mm or 45% in the Yarsha Khola catchment. (Note that evapotranspiration is a beneficial depletion as this water goes to producing biomass);
- only 38 mm or 4% are non-process depleted meaning that it is lost without benefit to the users in the Jhikhu Khola catchment, mainly through evaporation from free soil surfaces and water bodies. In the Yarsha Khola this portion accounts for 8% or 63 mm; and
- all outflows from the catchments are usable and not committed to any downstream agreements. They provide a potential source of additional water for the people residing near the catchment outlets.

Merz (2004) gives a full account of these calculations.

The difference between the two catchments in terms of uncommitted flow as well as the percentage of beneficial depletion (the water required to produce biomass and crops) is evident. In the Yarsha Khola catchment more than 60% of the gross inflow is contributing to uncommitted flow suggesting that ample water is available in the catchment for further development of agricultural or other business activities that use water. In the Jhikhu Khola uncommitted flow amounts to only about 30% of the gross inflow. It is however important to note that these are annual values and include monsoon flows. During the dry season the uncommitted flow is reduced to a minimum in the Jhikhu Khola catchment and accounts for only about 7 mm in the driest months of March and April. In the Yarsha Khola catchment the uncommitted flow in February, the driest month is 20 mm.

The results of this water accounting exercise show that in both catchments there is more water available to be used and it could be used more efficiently. However, during the dry season there is little scope to improve water use efficiency in the Jhikhu Khola as there is already a high degree of beneficial depletion mostly for biomass and crop production accounting for 85% of the available water and hardly any uncommitted outflows. There is scope to better use monsoon waters. In the Yarsha Khola catchment, even during the dry season months there is scope to increase the beneficial depletion with increased biomass and crop production as there is a high outflow and low process depletion (productive use of the available water resources). This could be achieved by increasing the irrigated area or applying more irrigation water to more demanding crops.

Future Water Availability

Increasing water demands from the growing world population and higher per capita water use are putting ever greater demands on the world's limited water resources. The uncertain effect of global climate change is another important factor with potentially serious implications for the world's water resources. For example, Lal (2002) projects decreasing winter rainfall and increased monsoon rainfall during the monsoon for the Indian sub-continent (Table 9.8). Lal projects a decrease of 10 to 20% in winter rainfall by the year 2050 leading to an about 25% decrease by 2080. The same author projects an increase of 30% or more in monsoon precipitation over India. He further suggests that there will be an increased variability in the onset of the monsoon. However,

Table 9.8: **Projected climate change parameters for the Indian sub-continent, 1980- 2080**

	Temperature	Precipitation
Annual	+5.6 °C	+9.9%
Winter	+6.3 °C	-25%
Monsoon	+4.6 °C	+15%

Source: Lal (2002)

there is conflicting information on the basis of different global circulation models (GCM). Lal et al. (1995) calculated a decline in mean summer monsoon rainfall of about 0.5 mm/day over the South Asian region by 2080. Experiments referred to in IPCC (1998) also suggest that a decline in summer monsoon rainfall will happen or may have already happened.

The Precipitation-Runoff-Evapotranspiration-Hydrotope (PREVAH) computer simulation model (Gurtz et al. 1997) was applied to assess the potential impact of the climate change scenario discussed above. The scenario was assessed on the basis of the data for 1997 to 1999. Overall the simulations show that, on a seasonal basis, runoff from the Jhikhu Khola catchment could well increase for the monsoon season and decrease in the remaining seasons, particularly in the pre-monsoon season (Figure 9.8). The PREVAH model predicts that potential evapotranspiration will increase by about 40% in the Jhikhu Khola catchment from 1990 to 2080 if climate changes according to Lal's projections. The actual evapotranspiration rates would change by about 10% annually. As these figures are only preliminary due to inadequate vegetation datasets no further disaggregation into different months or seasons can be worked out although this would be of particular interest for different areas of the catchments. It is notable that water availability is projected to decrease in the seasons when water is already scarce.

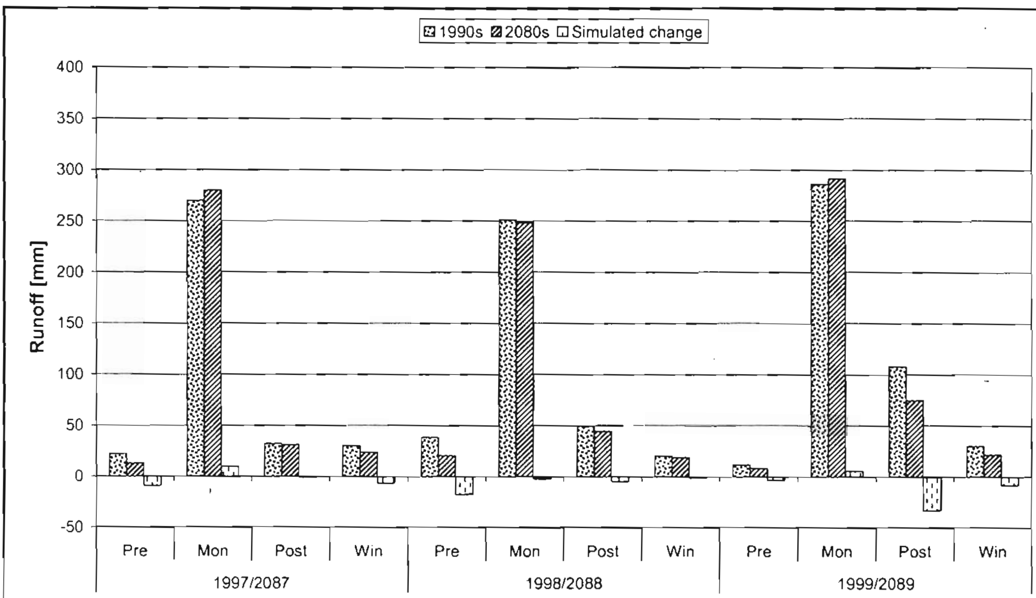

Figure 9.8: **Seasonal changes of runoff from the Jhikhu Khola catchment with global climate change determined by applying PREVAH model** (Merz 2004)

Lutz and Goujon (2002) have projected the population of Nepal according to high fertility and low fertility growth scenarios. Using these figures and an estimated daily water demand of 50 litres per person for basic domestic water needs (Gleick 1996), the forecasted water needs in the Jhikhu Khola catchment by the 2080s ranges between 14 and 25 mm (Table 9.9).

Village development committees (VDC) are the village level administrative units in Nepal. The disaggregated water demand information according to VDCs in the Jhikhu Khola catchment predicts the highest increases in water demand at VDCs along the main Araniko and

Table 9.9: **Projected population and water demand in the Jhikhu Khola catchment by 2080**

	1996	2080 Low fertility	2080 High fertility
Population	48,728	85,646	150,238
Population density [people/km^2]	437	769	1349
Annual water demand [mm]	3.7	14.0	24.6

Dhulikhel–Bardibas highways as the population grows and development happens there (Figure 9.9). In 1996 the water demand in all Jhikhu Khola VDCs was between 0-15 mm per year. The water demand to cover basic requirements under the low fertility scenario would shoot up to 15-30 mm in the VDCs that lie along the two highways and up to 15 mm in the other VDCs. In the high fertility scenario Rabi Opi, Paanchkhal, Patlekhet, Dhulikhel and Phoolbari VDCs would demand 30-45 mm per annum. Comparing these values with the annual precipitation values, or even the monthly precipitation values, would mean there would still be adequate water available for domestic purposes in 2080. However, so far in this area the local population do not generally use rainwater for domestic purposes and rely on surface water or shallow groundwater. In this respect the increasing pollution, as observed in the Jhikhu Khola catchment (Merz et al. 2004), would put further pressure on available water resources and local people would come to depend even more on the few clean and non-polluted water sources. In addition as mentioned above, the agricultural water demand is far more significant.

With the current high level of agricultural intensity in the catchment, agricultural expansion is only possible by bringing marginal lands under production.

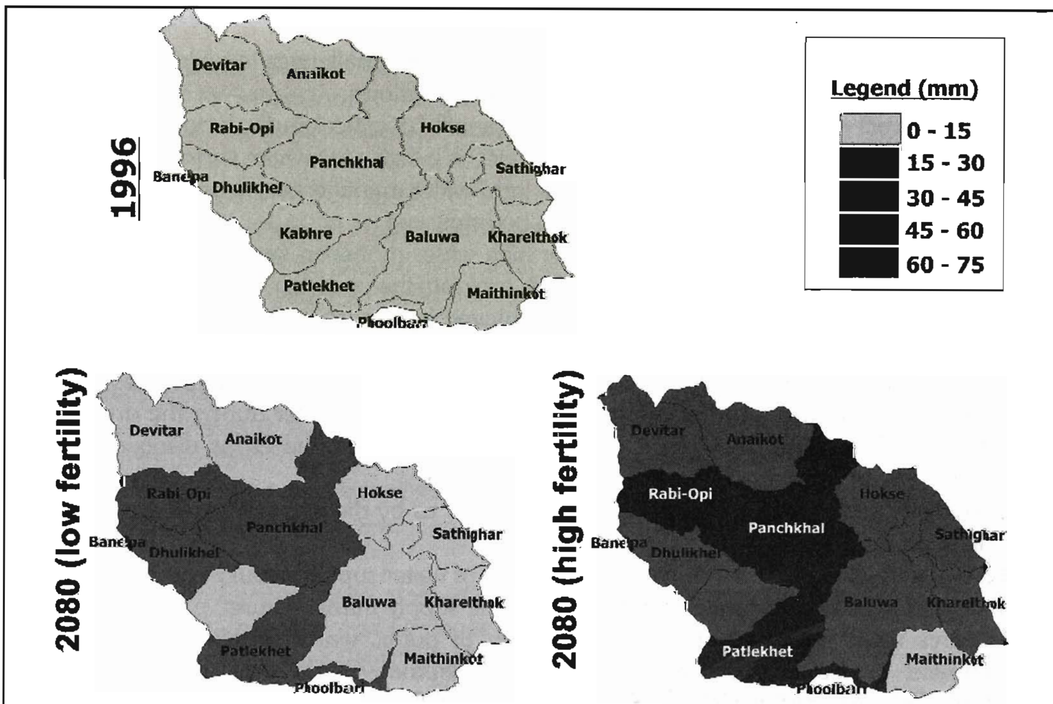

Figure 9.9: **Projected water demand 1996-2080 in Jhikhu Khola VDCs**

In summary:

- water demand for domestic purposes will increase with population growth;
- the main water demand increase is not expected from population growth, but will come about to meet Gleick's (1996) estimated basic water supply need of 50 litres per person per day; and
- the main water demand increase in the Jhikhu Khola catchment is most likely to come in the areas along the two highways that cross the catchment. The VDCs in the upper part along the catchment divide will have an important function as recharge areas and water supply for the valley bottoms and areas near the catchment outlet. This stresses the importance of local level planning and management of the water resources at the catchment level.

Conclusion

This study has found that the two middle mountain catchments have enough annual rainfall, as indicated by the high rainfall amounts and the considerable runoff that leaves the catchments. The accounting exercise showed that the current agricultural, domestic and livestock water requirements can be easily met. During the dry season water is sometimes scarce in parts of the catchments and sometimes even over the whole catchment areas. But, on average, even during this time, there is adequate water from groundwater sources to produce surpluses that leave the catchment as uncommitted flow. There are, however, pocket areas in the catchment that face considerable water shortages. These are the areas along the catchment divide and on spurs and river terraces. In addition, due to seasonal differences in water availability, there is not much scope to expand agricultural activities during the dry season months as long as approaches and technologies remain the same. This study has also shown that water demands are very likely to increase. Projected climate changes will reduce the amount of water available during the dry season.

The findings of this and other studies suggest that the main challenges in water management in rural catchments of Nepal's middle mountains are as follows.

- The improved management of water resources will be critical in the future. Although at present the overall availability of natural water is adequate, water shortages are being observed. This suggests that in some places local water management is not coping with the supply and demand situation and needs to be improved.
- Initiatives need to be taken to balance the high water monsoon surpluses with low water availability in the dry season. This would prolong the growing season and allow for increased food production. This could be achieved by monsoon water storage in the soil profile in cisterns or ponds. The artificial recharge of areas that do not get saturated during the monsoon is another option by artificially charging unsaturated soil profiles or other potential aquifers with monsoon runoff that can be extracted later during the dry season. Water stored into the dry season can be applied to high value crops using alternative irrigation methods such as drip or sprinkler irrigation.
- Alternative water sources should be explored, such as by digging wells and exploiting the shallow groundwater.
- The decentralised and community management of water supplies could improve access to water resources and improve maintenance of the supply infrastructure.
- Measures need taking to improve the quality of public water supplies. These include catchment protection, source protection, and alternative methods for making water suitable for consumption. PARDYP is testing the SODIS system of purifying drinking water by exposure to the sun (Wegelin and Meierhofer 2002).

- Overall, water resources should be managed catchment-wise rather than by administrative units that often cut catchments into different sections. This would promote the sustainable use of existing and seasonally replenishing water resources to satisfy the needs of upstream and downstream users.

Acknowledgements

The authors would like to acknowledge the support of their colleagues in the PARDYP Nepal team. The comments of Roger White, Suresh Chalise, and Richard Heggen were greatly appreciated and helped to improve the manuscript.

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10

Water Harvesting in Damaidi Village, China

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Abstract

Damaidi village lies in the Xizhuang watershed in the western part of Yunnan province, China. In recent times the local population has increased, family structure has changed, and livelihood strategies such as labour migration, tea cultivation, and livestock raising have become increasingly important. Improved water harvesting has reduced women's work, improved maize yields, and encouraged the establishment of tea plantations. However, struggles between power holders have led to conflicts over irrigation and drinking water. This case study shows that improved water harvesting can improve the livelihood security of poor people and reduce women's work.

10

Introduction

Water is a crucial natural resource for local livelihoods. It is also the main driving force behind soil erosion in Xizhuang watershed. The People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP) in the Xizhuang watershed has had two aims in relation to water. The first is to carry out scientific research by establishing a hydro-meteorology monitoring network to study the dynamics of water resources in the watershed. The second is to carry out action research on the building of water tanks, the establishment of local irrigation systems, and the building-up of local capacity to sustainably manage these resources.

The two main characteristics of Damaidi village's access to water is the seasonality of rainfall and the location of springs within the watershed. The amount of rainfall varies greatly between the wet and dry seasons. About 80% of each year's rainfall falls in the May to October season. Damaidi village has limited access to water resources as it is located in an upland area and most of the area's springs lie below at the bottom of the mountain.

The availability of water in this village improved greatly after PARDYP built four big drinking water tanks, four big irrigation water tanks, and 34 small irrigation water tanks in this village in 2000. These improvements led to greatly reduced time taken to collect drinking water, irrigate crops, and dilute pesticides. It also led to improved local agricultural productivity. This paper explains the impact of these projects. It also explains the impacts of water harvesting projects on local village governance and relates the water issue to local social, economic, and political aspects. This paper begins with a historical overview of the project site of Damaidi village, describes the water harvesting projects, and then analyses the benefits and conflicts arising from these initiatives.

Change in Damaidi Village

Major economic reforms began in China in 1978 with the establishment of the Household Responsibility System where farmlands were contracted out to individual farmers. The reforms in forestlands happened in 1982 by contracting out their management. These were turning points for local resource management in Damaidi village.

People and resource dynamics

Population growth and family structures

In 1983 Damaidi village had 58 households with 330 members and an average household size of 5.7 people. By 2003 the population had grown to 434 members in 94 households with an average family size of only 4.6 members. From 1983 to 2003 the population increased by 31% and the number of households increased by 62% (Figure 10.1). The average household size decreased by almost one person.

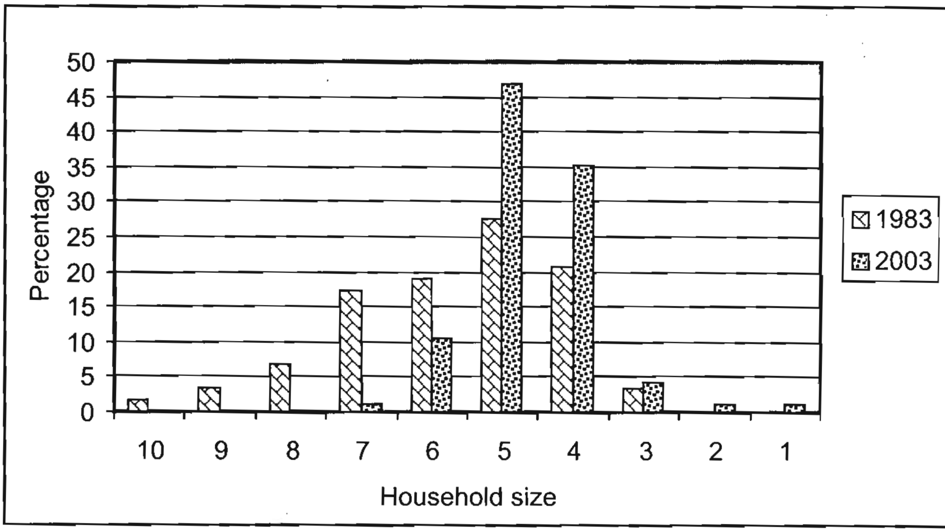

Figure 10.1: **Size of households in Damaidi Village, 1983 to 2003**

In Damaidi, population increases have resulted in a decline in the amount of cultivable land per person although this has not happened to all households. Since the government redistributed land in 1983 the total land of each household has remained the same regardless of the increase or decrease in the size of families. Hence, for those households whose members have decreased since 1983, such as those only producing daughters who leave the family home on marriage, the per person land area has increased. But, those families with more sons and therefore daughters-in-law have seen their per person land areas decrease. The total number of households has increased, but household sizes have declined. Some smaller households lack labour and land and some have become poor (see Table 10.1).

Land use change and labour migration

There are three types of land in Damaidi village. The best land (Type I) covers 14.2 ha. It mostly lies in the middle level parts of the village, in sloping areas, and on very fertile sloping lands at the bottom of the village. The secondary land (Type II) covers 5.3 ha in the upper parts of the village. The poor quality land (Type III) covers 6.5 ha in the high and infertile mountainous areas above the village. Before 1982, due to low agricultural productivity and the non-availability of other sources of food, the crops maize, wheat, buckwheat, and oat were planted on all these lands. Two crops per year can be planted on the Type I and II lands with maize in the wet season (May-October), and maize and wheat in the dry season (November-April). Type III lands only support a single crop of buckwheat or oats once a year. Even with all of these lands under agricultural production, the local people could only produce food to feed themselves for about 10 months of the year.

After the Household Responsibility System was introduced, the system of compulsory communal labour was abolished and individual households became responsible for managing croplands. This and increasing labour out-migration has seen land use change from subsistence to more cash cropping. This change is reflected in the turning over of much of the high altitude Type III lands to grasslands or forestlands and the establishment of 5 ha of tea plantations on lower altitude Type III lands in 1986. It was households with more land per capita that planted tea to improve their economic situation (Table 10.1).

Table 10.1: **Economic stratification in Damaidi Village, 2003**

Rank	No. of households	Indicator	Livelihood situation
Rich	12	2 floor cement house	4 households have government employees and 8 heads work outside the village
Above average	54	Have colour TVs and money invested	Some members employed as teachers. Most have areas of tea and some have livestock
Below average	22	1-floored mud-built house and black and white or no TV. No money to investment	Some households get income from tea, some from livestock, and some from working outside
Poor	6	Not enough food	Less labour, less land, or household member is handicapped

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Socioeconomic dynamics

The local economy of Damaidi village has changed from a largely subsistence economy in 1983 to a more diverse economy with a mix of livelihood strategies. Traditional agricultural production has lost its core position in local activities as outside work, tea cultivation, and livestock have emerged as new sources of income.

Labour migration started in 1983. Of Damaidi's 94 households 80 have members working away from home. Of the other households four belong to local leaders who receive regular salaries. In 71 households the menfolk spend the dry season working away on labouring jobs such as logging, building construction, and mining. These activities can yield US$242-363 per year per family. In seven households both men and women work outside the village the whole year. This gives them high incomes and they rent their village land out to others.

Local people planted 5 ha of tea in 1986 and 6 ha in 2001-2002. All village households have some tea bushes. Ten households have old areas of tea over more than 0.2 ha. One mu (0.06

ha) of tea plantation will normally yield 65 kg of tea leaves which can give a cash income of US$97-121 per year.

Fifteen households keep goats with a total of 902 goats in the village, and 28 households raise cattle with a total of 97 cattle. It is mostly old people and children who look after livestock. One goat can be sold for $24-36 and a cow for $97-121.

Before 1982, the communist ideology practiced in Damaidi village was based on the common life model of communal production. After that individual households became differentiated through their different livelihood strategies. Before 1982 local farmers produced food commonly and benefits were shared through the Gongfen which calculated people's share based on their labour inputs. In Damaidi village, male and female agricultural labour was given a nearly equal value. These benefits were distributed at the end of each year. After the introduction of the Household Responsibility System land was distributed to every household based on their population irrespective of their number of men and women. Households thus became the unit of demand, consumption, and production.

Almost all Damaidi men work outside the village during the dry season and return for the wet season to work on the fields planting and harvesting maize and then planting wheat. A local saying says goes, "When the hoar frost descends, every man leaves the village." After the men leave to work outside all household tasks fall on the shoulders of the women.

Initially all outside jobs were physical labouring jobs such as in logging, infrastructure construction, and mining. These are most suited to men and so many of them spend about half of each year working outside the village. In recent years women have also started to find outside jobs in restaurants and handcraft industries. However, they do not earn enough to provide the main income for their families.

In Damaidi tea is harvested three times from March to October. The harvesting and processing is carried out by women. Households with more tea than they can harvest hire in other women to help, paying them $0.06 per kg of fresh tea harvested or $0.96 per day. Raising pigs and collecting pine needles for livestock bedding are women's other major year-round tasks.

Social-political dynamics

The local socio-political system has changed since the Community Organisation Law was implemented in 1998. There are now two main competing power groupings inside the village. One is led by the new community administrator whilst the other is led by the former communist party secretary. They compete over the management of local affairs. At the higher level they both have support networks in Lijiashi Administrative Village. The local communist party secretary is in-line with his counterparts at Damaidi village and Lijiashi Administrative Village and represents the old authority of the community. The new community administrator is in-line with the administrative governor and represents the new generation of power holders. This power structure has had a significant effect on local water harvesting projects.

Water Harvesting Projects

Water has long been the scarcest resource in Damaidi. This meant that local people were restricted to growing opium, maize, and wheat. Although irrigation water was very scarce there was enough for drinking due to the dense forest cover and sparse population. Much forest was cleared for grain production after the Great Leap Forward in the 1960s. In addition, population increased rapidly and a shortage of drinking water began to be felt. Local people had to carry water from the top of the mountain or bring it the long distance from Wanjiacun village. At that time one family member had to spend about half of each day fetching water.

In 1976 Damaidi village was granted $726 to build a drinking water system. However, the money was not enough to complete the system. So, villagers prompted the communist party secretary to ask for more money from upper level government. The request was refused. The uncompleted system was made up of a big water tank by a spring and a waterpipe which led to the village, although not to individual households. Local villagers had to carry water from the end of the pipe.

In 1999, sponsored by the new community administrator and a local teacher, a few households wanted to build a small water system that linked the waterpipe to their houses. The previous twenty years of waiting in line to collect water from the pipe had inspired many villagers to become involved in this plan and 79 households joined in. The teacher's brother was the leader of the county water bureau. Due to this link the group of 79 households were given $3027 plus $14 per person to extend the water system. With these funds they rebuilt the spring water tank, built three drinking water tanks behind the village, and fitted a network of water pipes through the village. The first tank holds 5m^3 of water and supports eight households, the second contains 27m^3 and supports 38 households, and the third tank contains 29m^3 and supports 33 households. Three small individual tanks and one middle water tank were built for the 14 households who due to distance or high altitude were not in the group of 79.

In 2000, the PARDYP project began in Damaidi village. It identified the lack of irrigation facilities as a major problem. The project thus began to support the building of an irrigation system. This system includes one large tank holding 96m^3 and 34 small tanks to receive rainwater for irrigation. In 2002, the government gave further assistance for building a further two large irrigation tanks. These tanks together form Damaidi's water harvesting system irrigating a combined total of 9 ha of land (Table 10.2, Figure 10.2).

Table 10.2: **Area irrigated from different sources in Damaidi village**

	Irrigated land area (ha)
Irrigation system	4.66
Drinking water system	1.18
Small tanks	3.2
Total	9.05

Source: field household surveys, 2003

Benefit and Conflicts of Water Harvesting

These water harvesting projects have largely overcome drinking water and irrigation shortages in the village. The seasonal irrigation from the large tanks, supplementary water from the small tanks, and water from the drinking water tanks guarantees the growth of maize and the availability of water for pesticide and fertiliser application. As a result, local maize production has increased and less labour is needed. The water taps within the village mean that villagers no longer have to carry water in from outside. Land productivity has improved and local labour has been made available for other tasks such as tea production. However, conflicts have arisen between the old and new power holders and between men and women over managing the new water system. Figure 10.3 diagrams the impact of the changes.

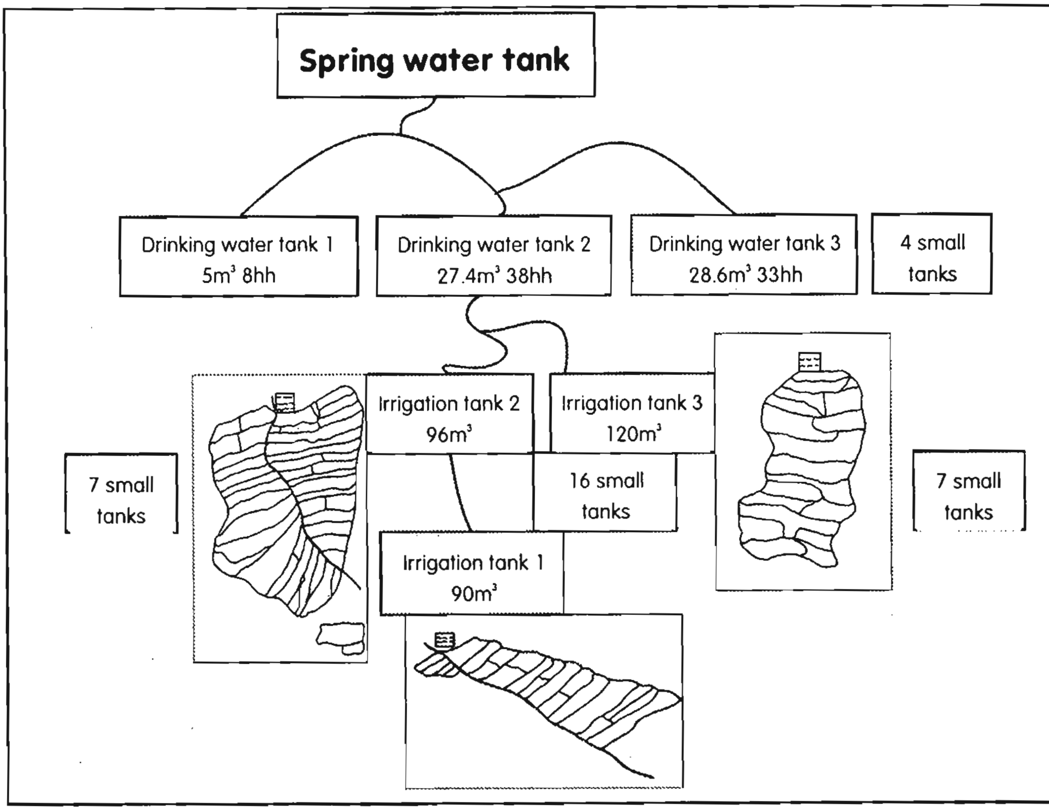

Figure 10.2: **Damaidi water harvesting system**

Benefits

Saving women's labour

The new water harvesting system has saved much labour that previously went to carrying drinking water. The group of 79 households used over 19,000m^3 of water in 2001 which would have needed more than 19,000 working days to carry from the traditional source. As most men work outside the village this task would have fallen to women for much of the year.

Previously it was the carrying of water to irrigate the maize fields which took the most labour. In the local system, where maize seedlings are planted out from nursery beds, it is crucial that they are irrigated immediately and thoroughly. On average, three working days are needed to plant and irrigate 0.06 ha of maize. Currently, one labourer is enough to finish the same work by irrigating directly from the water harvesting system. The water system irrigates 9 ha of land and therefore saves 271 working days every year. This means that 9,771 less working days are needed in a year. This does not include the labour cost of carrying water to prepare pesticide and fertiliser. It is the women who most appreciate the new water harvesting system.

Improving maize yields

There are two ways of growing maize in Damaidi village. The first is to directly plant seeds and the second is to grow-on seedlings in a nursery and then transplant them into the fields. On

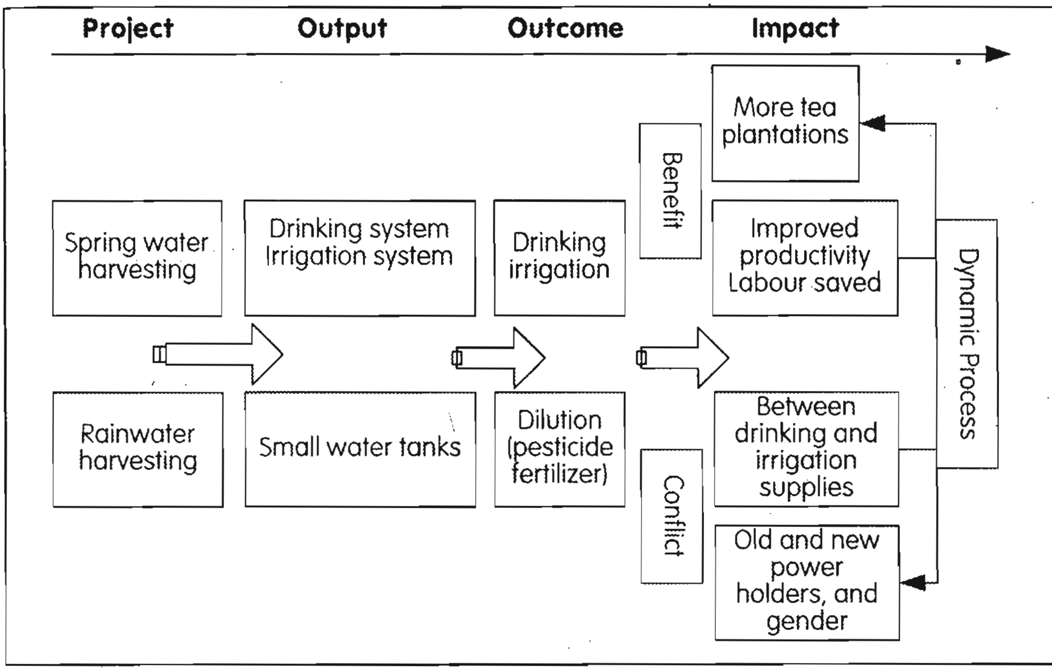

Figure 10.3: **Impacts of water harvesting projects in Damaidi Village**

average, 0.06 ha (1 mu) of maize planted by direct seeding produces 300 kg of maize, whilst transplanting them gives a higher yield of 350 kg plus. The transplanting technique relies on raising good quality seedlings. Previously most maize was grown by the seeding method as the lack of irrigation made it difficult to do transplanting. With the new system over 5.8 ha of maize is transplanted and only 1 ha of land is seeded. Since the building of the small tanks transplanting has replaced seeding on a further 3.2 ha of land. The transplanting of seedlings is now mostly used as it gives the highest yields.

Tea plantations

In Damaidi, tea cultivation is more profitable than growing maize as 0.06 ha of tea can yield 65 kg of tea which can be sold for $97-121 at the normal market price of $1.69/kg in 2002. In the same year the 350 kg of maize produced on the same area fetched only $42. Moreover, the costs of growing maize are more as chemical fertiliser and pesticides cost about $254 per ha compared to just $54/ha for tea. Many farmers have moved over to tea growing. This first happened in 1986 when large-scale labour migration meant there was less pressure on the land for providing for local livelihoods and 5 ha of tea was planted on the Type III lands. Maize continued to be grown on the Type I and II lands for livestock feed.

The second major planting of tea happened in 2001/02. This time most Type II lands and some Type I lands that had been used to grow maize (total 6 ha) were turned into tea plantations. The new availability of irrigation water improved maize yields on Type I and II lands giving sufficient production from a lesser area. The extra land was planted with tea. There is now competition for labour between tea and maize as they are both harvested between March and October. The labour saved by the new water system has led to the planting of tea.

The 34 small tanks were originally built for irrigating 3.2 ha of maize lands. However, 1 ha of this area has been planted with tea (Appendix 3). These small tanks are useful for diluting the pesticides and fertilisers that are frequently applied to the tea bushes.

The new supplies of irrigation water have encouraged the planting of tea plantations. This happened for a number of reasons. After 1982, local people developed strategies to deal with their difficulties in sustaining their livelihoods. These included labour migration, maize planting, tea cultivation, and livestock feeding. Following the implementation of the Household Responsibility System labour migration increased. The availability of irrigation water improved maize yields and saved much labour. Maize is grown in Damaidi just for feeding livestock. Local people's hopes for improving their living standards revolve around labour migration and tea plantation. Except for the seven households who gave up tea growing and work outside the village, most households feel that there is only a limited demand for their labour as they have limited literacy and are only suited for labouring jobs. For these people the growing of tea is their greatest hope. They have enthusiastically introduced a new variety of tea (Yunkang #10) into Damaidi. Four households now raise tea over all of their land. They intercrop tea and maize in the first and second years and do not plant maize at all once the bushes have grown up.

Conflicts

Conflicts often happen in Damaidi village in the dry season over demands for drinking and irrigation water. In the November to May period the amount of springwater dwindles. Before the irrigation system was built, water from the main spring was enough to provide drinking water all year round. However, since the irrigation system was connected through the drinking water tank for the main irrigation season at the beginning of May, almost all the water goes for irrigating fields. This conflict continues for about one month after the maize is planted.

To try and overcome this conflict, the 79 user households ruled that every person had the right to consume 12m^3 of water per year. Those who consumed more had to pay a fee. For using less than 0.5m^3 an extra \$0.24/m^3 was payable whilst for amounts above this \$2.42/m^3 had to be paid. Villagers were prohibited from wasting water or using drinking water to irrigate crops.

This regulation was later overruled by the local power holders led by the new community administrator and the teacher. These people are local leaders and retired government employees who live in the area and use a lot of water. Their water needs amounted to more than 12m^3 per person. For example, the local teacher's household had the highest consumption in the village using 524m^3. This group reduced the drinking water fee to only \$0.006 per cubic metre for everyone.

Most members of the other power group work outside of the village and have lower water demands. When they earn money and build new houses in the village they have to pay a \$0.84 per room water fee. They opposed this new regulation and got the support of the communist party secretary and the old community administrator to oppose it. But the other group countered that they had organised the building and funding of the drinking water system and the new regulation remained. This conflict led to the dismissal of the old community administrator from the post of water manager.

It is not easy for the water system manager to satisfy the different interests of the two groups. What has happened is that the current manager is almost powerless and more drinking water is being diverted to irrigating crops. This sometimes leads to drinking water tanks being emptied as the water flows to the irrigation tanks. Also, some villagers arrange with tap owners to pipe drinking water to their fields as drinking water is cheaper than irrigation water.

This conflict has a negative impact on local women. May is the busiest time of the year for them as they are busy harvesting tea and planting maize. They also have the added burden of having to go and fetch water before they can start cooking. It is mostly the men who divert drinking water to irrigate crops and the women end up having to negotiate for drinking water with women whose tanks still have water.

Conclusions

The establishment of a water harvesting system in Damaidi village has benefited the local community by saving labour, improving maize yields, and releasing land and labour for growing tea. However, a serious conflict has emerged between the new and old power groups over access to water. This has had a negative impact on local women. This has happened since 1982 as the population increased, household size decreased, and diverse livelihood strategies such as labour migration, tea cultivation, and livestock feeding were adopted.

The saving of labour and improvements in maize yields has most benefited the poor in Damaidi as they have the less labour and land. Many poor households have come to rely on tea growing for a large part of their incomes. In general, women grow the tea whilst men go to work outside and send money home. Now, in some households, the menfolk are returning home earlier than before to help their wives with the tea harvest.

11

Assessment of Rainfall, Runoff and Sediment Losses of the Bheta Gad Watershed, India

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Abstract

Rainfall, runoff and sediment loss data were collected from four natural experimental plots of 20 x 5m. These were established on the four most common land cover types on three sub-catchments and at one main outlet during 1999 to 2002 in Bheta Gad watershed, Kumaon Hills in the central Himalayas. Land use and land cover details, the quality of streamwater, and soil characteristics under different land covers were also analysed. Plots were established for rainfed agriculture, pine forest, degraded pasture land, and tea plantations. The study found an annual variation of total runoff of from 51.1 to 3593 m^3/ha, and of soil loss of between 0.06 and 5.47 tonnes/ha from the experimental plots. The range of runoff from the sub-catchments and watershed ranged from $2.51x10^8$ to $176.45x10^8$ litres with sediment loss of between 118.78 and 1605.15 tonnes/km^2). The paper quantifies differences in terms of concurrent rainfall and the other variables and compares runoff and sediment loss in the watershed.

11

Introduction

Complex meteorological, ecological, climatic, and geomorphological processes control water runoff and sediment discharge from a watershed. These processes are very important in the Hindu Kush-Himalayan region. The Himalayas are the youngest and most fragile mountains in the world and millions of tonnes of eroded fertile soil are transported downstream every year. Although they are the major source of water for the entire Indo-Gangetic plain area, tens of millions of upstream and downstream inhabitants suffer from serious water shortages.

It is therefore crucial to build a better understanding of the natural processes that cause runoff and sediment generation and to identify the influence of human activity on these processes. However, there is little reliable data to fully understand the processes involved.

The Bheta Gad watershed is a tributary of the river Gomti in the Ganga river system. It lies in the central Himalayas. The authors started an extensive study in this watershed in 1997 at plot, sub-catchments, and watershed level to investigate the relations between rainfall, runoff, and soil erosion.

Review

A number of authors have studied the dynamics of natural resources in the Himalayas and other mountainous areas of the world (Narayan et al. 1991, Singh 1999, Stewart et al. 1967). Negi (2002) has reviewed soil and water conservation studies conducted in the Indian

Himalayan region. Ram and Ramakrishnan (1988) and Bhatt et al. (1993) studied the plot runoff characteristics of terraced, shifting cultivation, forest, and barren lands in northeast India. Pathak et al. (1983), Pathak and Singh (1984), Loshali and Singh (1992), Negi et al. (1998), and Sen et al. (1997) studied the same for the central Himalayas in the Pinder and Pranmati catchments. Plot-scale soil conservation studies of the Shivaliks have been carried out by Lohan et al. (1996).

Medium-scale sub-catchment and watershed based runoff studies have been conducted by Joshi et al. (1996), Kumar and Satyal (2000), Valdiya and Bartarya (1989), Rawat and Rawat (1994a, 1994b), and Rawat and Rai (1997). These studies quantified the runoff and sediment losses from watersheds of the central Himalayas over different types of land cover — chiefly forest, agriculture, grass and wastelands. Similar studies have been carried out in the eastern and western Himalayan region by Rai and Sharma (1998a, 1998b), Singh (1997), Bahadur (1996), Rana and Subehia (1996), and Chaudhary and Sharma (1999).

Other relevant studies have included:

- Valdiya and Bartarya (1991) on the impact of land use, geology and anthropogenic pressure in the Gaula catchment, Kumaon, lesser Himalaya;
- Joshi and Kothyari (2003) on the influence of geo-hydrological features on the water chemistry of springs in the Bheta Gad watershed;
- Negi et al. (1998) on three high-altitude forested watersheds in the Nanda Devi Biosphere Reserve, central Himalayas;
- Malmer (1996) on the hydrological effects and nutrient losses of forest plantation in an experimental catchment in Sabah, Malaysia; and
- McGrath et al. (2001) who compared soil nutrient data from different land uses across Amazonia identifying patterns of nutrient concentration and variation with land use type.

These and other studies provide useful information for planning and managing cropping systems and for overall land use management in mountainous areas. However, there is little information available on the linkages of overland flow, soil erosion and nutrient losses that can be used in soil and water conservation for mountain land use planning. This paper aims to fill part of this gap by assessing overland flow and soil losses from different land uses in the Bheta Gad watershed at plot, sub-catchment, and watershed levels.

Study area

The Bheta Gad sub-watershed (Figure 11.1) drains an area of 23.5 km^2 in the central Himalayas in Uttaranchal state, India. It has a population density of 375 persons/km^2 and is typical of other watersheds in this region. It is characterised by a large altitude range (1,090-2,060 masl), and variations in slope aspect, forest cover, soil characteristics, land use and socioeconomic attributes (Bisht and Kothyari 2001). The area has a sub-tropical to temperate climate with three pronounced seasons of summer, monsoon, and winter. The mean annual precipitation is about 1400 mm and the mean monthly temperature varies from -2 to 38°C. Mica and chlorite schist, gneissic schist, biotite schist and gneisses, marble, granites and pegmatite are the area's major rock types (Valdiya 1979).

Chir pine (*Pinus roxburghii*) is the predominant conifer species and accounts for 69% of total forest cover. The important broadleaf species are *Quercus leuchotrichophora* (banj oak), *Alnus nepalensis* (utis), *Myrica esculanta* (kafal), and *Rhododendron arborium* (surans). They are found in mixed forests and in a few pure patches. Chir pine forests, tea plantations, upland agriculture, and grazing-cum-degraded lands areas are the most common land use types (Bisht and Kothyari 2001). The rainfed cropping land is fertilised with farmyard manure whilst irrigated agricultural fields receive light doses of inorganic fertiliser.

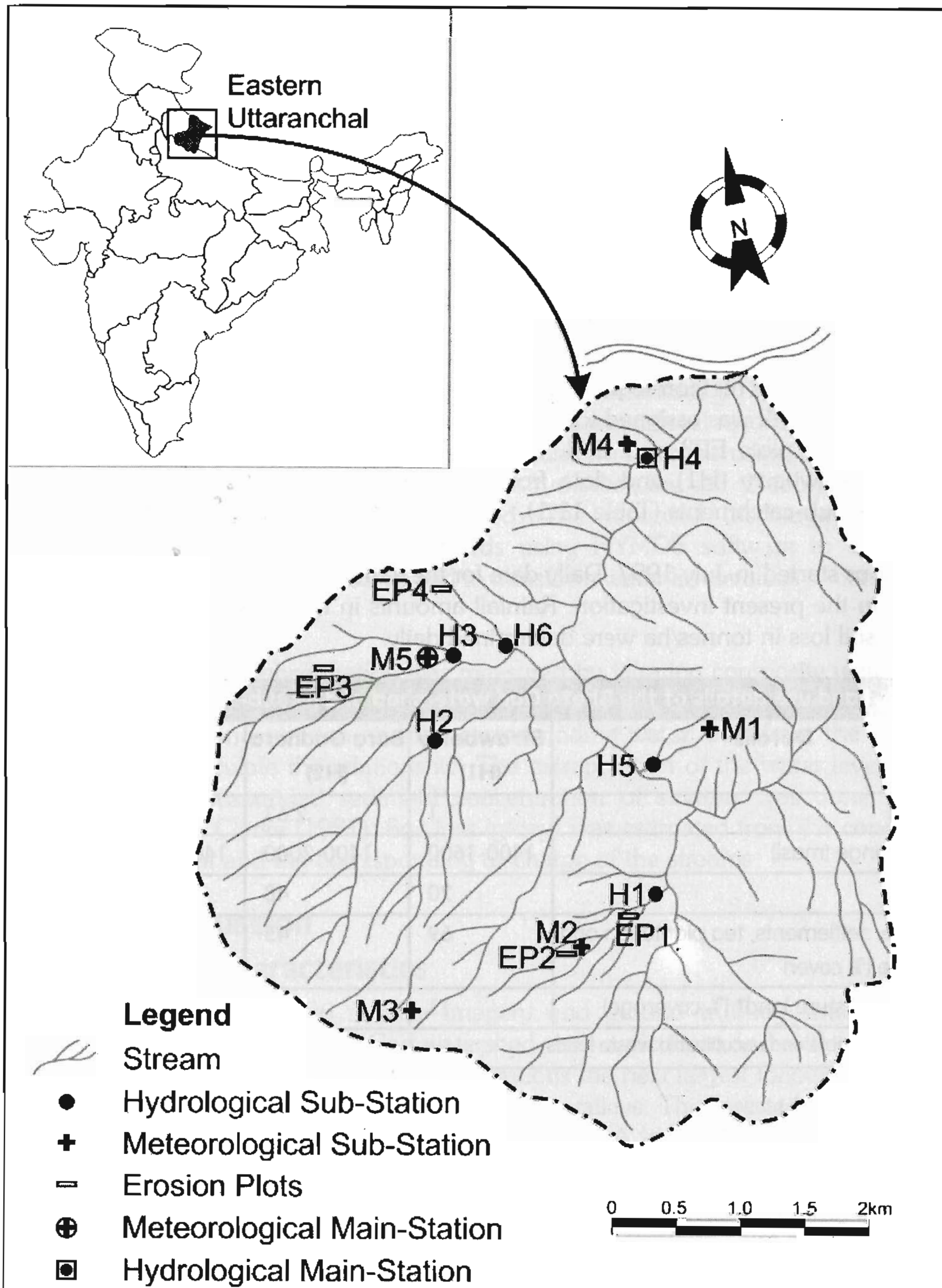

Figure 11.1: **Location of Bheta Gad watershed showing hydro-meteorological observation network**

Materials and Methods

Land use and land cover

Data on the land use and land cover characteristics of the watershed were collected from geographical information system (GIS) and remote sensing imagery, topographical maps, GIS software, and in other ways based on the study of Bisht and Kothyari (2001). The study's base map was based on the 1:50,000 Survey of India's topographical map, 1963. The GIS and remote sensing study of the watershed was carried out using ARC/INFO software backed up with ground truthing. Images from 1986 and 1996 satellite photographs (IRS-1A/1B, LISS-II bands 2, 3 and 4 at 1:50,000 scale) were digitised to assess changes over time (Bisht and Kothyari 2001).

Soil properties and precipitation

The chemical properties of the soil under the different land use systems where analysed as per Jackson (1962) and physical properties following Allen (1989). Meteorological stations were systematically placed in the watershed and were assigned to the nearest plots (Ramprasad et al. 2000). Precipitation was recorded with a tipping bucket rain gauge and a non-recording rain gauge at the five meteorological stations with data consolidated at a daily scale. Rainfall data from station M2 was assigned to plots EP1 and EP2, and data recorded from station M5 was assigned to plots EP3 and EP4. Rainfall data from M2 was assigned to the micro-catchment Strawberry (H1) and data from M5 was assigned to Bara Gadhera (H2) and Temple (H3) sub-catchments (Table 11.1).

Observations started in July 1997. Daily data for the January 1999 to December 2002 period was used in the present investigation. Rainfall amounts in mm, runoff volume in m^3/ha and litres, and soil loss in tonnes/ha were determined daily.

Table 11.1: **Land use details of the Bheta Gad watershed and its sub-catchments**

Details	Strawberry (H1)	Bara Gadhera (H2)	Lawbanj (H3)	Bheta Gad (H4)
Area (km^2)	1.1	2.63	1.7	23.5
Elevation range (masl)	1400-1600	1400-2000	1400-1800	1077-2000
Forest (%)	20	48	22	42
Agriculture, settlements, tea plantation and horticulture (% cover)	69	45	64	49
Barren and pasture land* (% coverage)	11	07	14	09
*: includes cultivable and uncultivable waste lands				

Experimental plots

The four 20m x 5m experimental plots (EP) EP1, EP2, EP3, and EP4 were delineated along the slopes of four common land use types with different slope aspects and soil types but similar slopes (18.5 to 28 degrees). Details of each plot are given in Table 11.2.

The percentage of surface vegetal cover and crown area, tree density, and the basal area of tree cover were measured (Mishra 1968) for the watershed's four main land use types. The infiltration capacity of each erosion plot's soil was measured using a double ring infiltrometer.

Only the agricultural plot (EP3) received significant amounts of external inputs with farmyard manure applied each year. No external inputs were applied to the other three land uses (EP2, EP3 and EP4).

The surface runoff from the erosion plots was collected in a tank which overflowed into a second tank via a seven–slot divider that allowed the overflow into the other tank. Volume of flow collected in these tanks {volume of first tank + (volume of second tank x 7)} was considered as the plot runoff for storm events. The total amount of eroded soil — including both splash and sheet erosion — was estimated by filtrating a composite sample collected from both tanks after thoroughly mixing the collected runoff and sediment (Heron 1990, Hudson 1993). The soil loss samples were collected daily at the same time and were filtered as quickly as possible on the same day at Lawbanj field laboratory in the watershed. The sediment retained after filtration (paper type: Whatman No. 1, pore size 1.2 μm) was dried at 40°C for 24 hours and then weighed and compared with the weight of a control filter paper that had filtered an equal volume of pure water. The calculated soil loss was converted into sediment yield in tonnes/ha.

Hydro-meteorological observations were made from a set of nested stations (Hofer 1998). Hydrological monitoring was carried out in three micro-catchments (H1, H2 and H3) and at the watershed's main outlet (H4). Continuous analogue water-level recorders were set up on the perennial streams. Discharge was measured at random intervals using the current meter method (using pigmy, price, and propeller-type instruments), the salt dilution method (using conductivity meters), and the bucket method. The recorded discharge values were extrapolated for the entire water level records using HYMOS software to calculate the regression equation and the rating curve and to transform water level values to corresponding discharge at hourly intervals.

The suspended sediment concentration was measured by filtrating composite water samples collected at random intervals (Heron 1990, Hudson 1993). A regression analysis of the suspended sediment concentration and the corresponding water level from the floater was then carried out to calculate the relationship. The extrapolation of the water level values to calculate the hourly suspended sediment concentration of streams was done using the regression equation in Clarke (1981). Soil loss (g/day) was estimated from the concentration of suspended sediment and the corresponding discharge of the streams.

Results and Discussion

Land use and soil characteristics

Preliminary studies of the 1996 satellite imagery and ground truthing showed that the predominant land uses in the Bheta Gad watershed were agriculture and settlements. Of this 49% was rainfed agriculture lands, with tea plantations the next largest followed by scattered settlements and areas of irrigated lands mainly in the valleys. The forested areas are mostly either chir pine forest or pine-dominated mixed forests. A large patch of pine-dominated mixed forest covers much of the Bara Gadhera (H2) catchment. The third major land use is barren and degraded lands spread through the watershed. During 1996-97, a large tea plantation was established over about 7% of the area that obviously did not appear on the 1996 satellite image.

The characteristics of the soil were measured for the watershed's major land uses. The study was carried out over three elevation zones. The lower part of the watershed (below 1200m) is mainly covered by pine forest, and agriculture and settlement land including a large area of irrigated land (Table 11.3). The middle part (1200-1600m) is covered with pine forest, new tea plantations, and rainfed agricultural land. The areas over 1600m are mostly covered with pine-dominated mixed forest and rainfed agriculture and settlement areas.

The soil is mainly brown coloured and the texture is sandy loam or loamy sand. The pH varied from 5.88 to 6.35, representing a neutral soil. Its water holding capacity varied from 24.2 to 36.8%, with higher rates in areas of tea plantation, agricultural land, and patches of mixed forests. The pH is lower in pine forests and degraded lands.

Organic carbon was highest in soils in patches of mixed forest due to the accumulation and gradual decomposition of the leaf litter of broadleaved trees. The next highest was on soils on agricultural land, due to the application of farmyard manure. Soils on degraded land had the lowest organic carbon.

The soils in mixed forest and agricultural lands had higher levels of total nitrogen due to the accumulation of dead biomass and the application of farmyard manure respectively. The higher levels of nitrogen on irrigated agricultural lands were due to applications of inorganic fertilisers. The levels of available phosphorus and potassium were also higher in agriculture, tea plantations, and mixed forest land, with the least in degraded land soils.

Experimental plot results

Rainfall-runoff relationships

Runoff volumes were greater from the pine forest EP1 plot, followed by the grazed or degraded plot (EP4), the tea plantation plot (EP2), and the rainfed agricultural plot (EP3). The maximum interception of rainwater occurred on plot EP3 which is an area of terraced agricultural fields with seasonal cropping. Most intercepted rain infiltrated into the soil in spite of the fact that the infiltration capacity of the soil there was not so high (Table 11.2). The runoff coefficient for the tea plantation plot (EP2) was comparatively less due to its all year round cover. Although the infiltration capacity of the grazed/degraded plot's soil (EP4) was very high it intercepted very little rainwater. The EP1 pine forest plot had the maximum biotic pressure and the least vegetation cover, and so unsurprisingly produced the most runoff of all four plots.

Runoff–soil loss relationships

There was a poor correlation between the monthly soil loss and rainfall values. A significant correlation was found between corresponding values of soil loss and runoff. This indicated that the process of sheet erosion is more dominant than splash erosion in these areas. The pine forest plot (EP1) showed the most soil erosion, followed by the tea plantation (EP2) and the grazed degraded (EP4) plots. The plot agricultural land plot showed the least soil erosion, probably because terracing encourages soil sedimentation rather than removal.

Annual rainfall, runoff, soil and nutrient loss relationships

The annual values of rainfall, surface runoff, and soil losses in different years for each of the plots are listed in Table 11.4. Quite a few storms happened in the study period of an intensity above the infiltration capacity rate. The maximum rainfall intensity ($I10_{max}$) recorded for the watershed was 157.2 mm/hr. Annual runoff varied from only 51 m^3/ha on the agricultural plot

Table 11.2: **Physiochemical characteristics of soil of experimental plots in Bheta Gad watershed**

Plot no.	Land use	Slope	Slope aspect	Elevation (masl	CEC (meq/100g)	pH	OM (%)	N (%)	P (kg/ha) as P_2O_5	K (kg/ha) As K_2O	Bulk density (gm/cc)	Infiltration capacity (cm/hr)	C:N ratio
EP1	Pine forest	18.5°	SE	1460	8.68	6.39	2.29	0.143	38.3	229	1.43	5.8	11.5
EP2	Tea plantation	20.1°	E	1620	14.56	6.16	2.55	0.167	38.3	286	1.15	8.7	7.44
EP3	Rainfed agriculture	22.5°	E	1390	11.79	6.24	3.04	0.236	22.9	315	1.05	4.2	6.28
EP4	Degraded land	28.0°	S	1350	12.16	6.84	1.64	0.102	11.8	137	1.31	10.6	9.34

Abbreviations: C = Carbon; CEC = cation exchange capacity; OM = organic matter; N = nitrogen; P = phosphorous; P_2O_5 = phosphorous pentaoxide; K = potassium; K_2O = potassium oxide

Table 11.3: **Soil and vegetal cover characteristics of experimental plots of Bheta Gad watershed**

Plot no.	Soil colour	Soil texture	Sand (%)	Silt (%)	Clay (%)	WHC (%)	Surface veg. cover (%)	Tree density (no./ha)	Total tree basal area (m^2/ha)	Crown cover (%)
EP1	Light grey	SL	63	22	15	30.8	47±12	240 *Pinus roxburghii*	32±0.42	52±03
EP2	Greyish-brown	SL	66	25	09	31.9	56±04	1800 tea plants	0.72±0.03	73±05
EP3	Light gray	SL	63	25	11	33.9	75±03	150 *Grewia oppositifolia* and *Pyrus pashia*	4.80±0.11	26±06
EP4	Reddish brown	LS	73	16	11	26.6	41±08	0	0	0

SL = sandy loam; LS = loamy sand; WHC = water holding capacity

Table 11.4: **Annual rainfall, runoff and soil losses from experimental plots in Bheta Gad Watershed**

Land use	Year	Rainfall (mm)	Surface runoff (m3/ha)	Soil loss (t/ha)
Open pine forest (EP1)	1999	103.2	1554.4	4.24
	2000	176.5	3593.1	4.39
	2001	114.7	1357.0	2.08
	2002	118.1	1101.9	1.90
Tea plantation (EP2)	1999	103.2	452.0	0.90
	2000	176.5	1022.0	1.51
	2001	114.7	202.6	0.56
	2002	118.1	157.7	0.18
Rainfed agriculture (EP3)	1999	101.1	147.1	0.20
	2000	198.9	155.2	0.13
	2001	112.5	51.1	0.06
	2002	108.4	60.8	0.10
Degraded/grazing land (EP4)	1999	101.1	522.3	0.56
	2000	198.9	2266.8	2.48
	2001	112.5	930.6	0.86
	2002	108.4	679.6	1.24

in 2001 to 3593 m^3/ha from the pine forest plot in 2000. Soil loss varied from 0.06 to 4.39 tonnes/ha during the study period. Rai and Sharma (1998b) reported relatively higher rates of soil loss (4.2 to 8.8 tonnes/ha/year) from the Mamlay watershed in the Sikkim Himalaya (northeast India) under agricultural land use. Nevertheless, both of the above mentioned values are within the range of 500–1000 tonnes/km^2/year reported for the Himalayan region by Milliman and Meade (1983). Collins and Jenkins (1996), however, reported soil losses in the middle hills of the Nepal Himalayas similar to those observed in the present study.

Micro-catchment and watershed studies

The annual total rainfall, runoff, and soil loss for all three micro-catchments and for the Bheta Gad watershed as a whole at its outlet point are presented in Table 11.5. This table also gives the calculated soil loss per km^2 area. The rainfall values considered for the whole watershed is taken as the mean by using Thiessen's polygon method, considering the weighted mean of values from the five meteorological stations.

The values of rainfall varied from 989 to 1946 mm. The runoff ranged from 55 x 10^8 to 176.45 x 10^8 litres and annual total soil loss varied between 4,814 and 37,759 tonnes. The loss of soil varied from 205 to 1605 tonnes/km^2. Similar values (616 tonnes/km^2) were reported by Rai and Sharma (1998b) from the 30 km^2 Mamlay watershed in Sikkim.

Soil loss values reported from other watersheds have been considerably higher. Soil loss values, have been reported from other watersheds as follows:

Table 11.5: **Annual rainfall, runoff and estimated soil loss in Bheta Gad watershed sub-catchments**

Sub catchments	Year	Rainfall (mm)	Runoff (l) x10^6	Soil loss (t)	Soil loss (t/km^2)
H1	1999	989.7	2.51	130.65	118.78
	2000	1810.9	7.88	1531.97	1392.70
	2001	1139.8	3.55	312.51	284.10
	2002	1181.1	2.74	178.22	162.02
H2	1999	1011.5	9.72	998.74	379.75
	2000	1946.5	26.90	3917.14	1489.41
	2001	1124.2	7.42	770.49	292.96
	2002	1083.9	5.36	483.95	184.01
H3	1999	1011.5	6.35	1007.72	592.78
	2000	1946.5	16.20	2648.72	1558.07
	2001	1124.2	4.45	477.80	281.06
	2002	1083.9	2.90	278.67	163.92
H4	1999	1012.9	97.62	11287.71	479.84
	2000	1796.6	176.45	37759.45	1605.15
	2001	1084.7	93.10	8998.17	382.51
	2002	1119.0	55.14	4814.42	204.66

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- 200 tonnes/km^2 by Rawat and Rawat (1994a and 1994b) from Nana Kosi catchments;
- 469 to 913 tonnes/km^2 by Rawat and Rai (1997) from two micro-watersheds in Garhwal Himalayas;
- 957 tonnes/km^2 by Chaudhary and Sharma (1999) from Giri catchments, Himachal Pradesh;
- 3596 tonnes/km^2 by Rana and Subehia (1996) from Bater micro-catchments, Himachal Pradesh; and
- 362 to 2250 tonnes/km^2 by Bahadur (1996) from Palampur.

Note that the quantity of soil and sediment loss from any watershed is also governed by factors other than rainfall intensity such as size of area, steepness, soil and geological characteristics, vegetation types and density.

Conclusions

Concurrent data on daily rainfall, runoff, total soil loss and estimated suspended sediment transport were observed from four natural experimental plots with different land covers from three micro-catchments, and from the overall Bheta Gad watershed. The study recorded the most runoff and soil loss from pine forest areas. The catchments data also shows the proportional increase of runoff and subsequent suspended sediment losses with amount of rainfall.

Acknowledgements

The authors extend their thanks to Dr Upendra Dhar, Director of the Govind Ballabh Pant Institute of Himalayan Environment and Development (GBPIHED), Almora for providing facilities. We are also grateful to the PARDYP India team for their cooperation and to ICIMOD, IDRC, and SDC for financial assistance. Last but by no mean least, the authors are indebted to all the inhabitants of the study watershed for their cooperation during the study.

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12

Interventions to Minimise Nutrient Losses from Bari Land (Rain-fed Upland) in the Middle Hills of the Western Development Region of Nepal*

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Abstract

Bari land (rain-fed upland bench or sloping terraces) in Nepal is increasingly becoming a focus of concern in terms of soil fertility decline and management. Understanding the circumstances leading to high erosion and leaching losses, and the areas particularly affected by high losses, are essential prerequisites for attempting to improve soil conservation. Participatory research was conducted with farmers in three contrasting agroecological regions: Nayatola (20-25° slope, l000-1500 mm annual rainfall); Landruk (bench terraces 0-5° slope, 3000-3500 mm annual rainfall); and Bandipur (bench terraces 0-5° slope, 1100-1500 mm annual rainfall). The research aimed to develop soil and water management interventions that control erosion without resulting in high leaching and so are effective in minimising total nutrient losses. Interventions tested include the control of water movement through diversion of run on, planting fodder trees and grasses on terrace risers on bench terraces in high rainfall areas, and strip cropping in non-terraced sloping fields of low to medium rainfall areas. The interventions were effective in reducing soil loss from bari in comparison with existing farmer practices, but no effect was observed on nutrient losses in solution through runoff and leaching.

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Introduction

Bari land comprises non-irrigated terraces on flat and sloping lands, and occupies most of the cropped area in the middle hills of Nepal. The function of the terraces is to maximise water availability within the physical constraints of the slope and the cropping pattern (Carson et al. 1986). The eastern part of the country has narrow bench terraces with low slope angles and the western part has large outward sloping terraces. Maize (*Zea mays* L.) is the main crop on bari and occupies 667,000 ha in the country, 192,940 ha in the western development region alone (Joshi 1998). However, soil fertility is declining in bari, thought primarily to be due to low applications of farmyard manure and soil erosion (Turton et al. 1995). Maize cultivation practices accelerate surface soil loss. Soil losses from rain-fed terraces and sloping farmland vary from 5 to 20 t/ha per year, with organic matter, nitrogen, phosphorous, and potassium losses of 150-600, 7.5 - 30, 5-20, and 10-40 kg/ha per year respectively (Partap and Watson 1994). In the study area, Gardner et al. (2000) reported that the greatest erosion was from bench terraces in a high rainfall area (Landruk, of Kaski District) and the least from sloping field cultivation in a low rainfall area (Nayatola, Palpa). They recorded soil losses in surface runoff of 2.5 t/ha per year, the losses of nitrate-nitrogen and potassium through runoff were comparatively low but losses through leaching were 45 and 180 kg/ha per year respectively.

* Paper previously published in 'Renewable Natural Resources Management for Mountain Communities', Michael Stocking, Hilde Helleman, Roger White (eds) Kathmandu: ICIMOD (2005)

A wide range of soil and nutrient conservation technologies are available that are appropriate to the Nepalese middle hills. Underseeding of white clover into maize fields considerably reduces surface runoff during May to June (when rainfall erosion is low) without decreasing maize yields (Goeck et al. 1989). Better soil cover in the crop fields improves water infiltration and increases crop yields by reducing erosion and stabilising soil minerals and organic matter (Barry et al. 1995). Grass strips are found to be useful for reducing soil loss in runoff (Lewis and Nyamulinda 1996). The adoption of technology depends upon the local farming environment. The intercropping of legume crops, mulching, and diversion of runon water from fields are practised in hill farming. Selecting technologies on the basis of local crop management could control soil erosion and lead to wide adoption. The main objective of this study was to investigate the effect of traditional cultivation practices on soil fertility and the effectiveness of locally appropriate technologies for maintaining inherent soil fertility of bari land in the middle hills of the western development region by controlling nutrient losses in solution form and in sediment movement.

Methodology

Site selection

Participatory research was conducted with farmers on bari land in three contrasting agroecological regions in the middle hills of the western development region of Nepal (Figure 12.1). On the basis of the survey results, Landruk was selected as a site representative for high rainfall areas with bench terracing cultivation systems. Nayatola was selected for low to medium rainfall with sloping land cultivation systems, and Bandipur was selected for low to medium rainfall with diversified cropping systems. The main features of these sites are given in Table 12.1.

Table 12.1: **Characteristics of the research sites**

Sites	Terrace slope angle	Rainfall (mm)	Common cropping systems
Landruk	0-5°	3000-3500	Maize/millet or maize + legume/wheat or barley + mustard
Nayatola	20-25°	1000-1500	Maize/wheat or barley + mustard + winter legume
Bandipur	0-5°	1100-1500	Maize-fallow-fallow or upland rice -blackgram and citrus orchard

Experimental design

Interventions were chosen by participatory rural appraisal and local knowledge acquisition. The interventions were designed to test basic principles of the relative influence of runoff and runon in causing nutrient loss and the relative merits of barrier and cover effects in the prevention of such losses in different conditions. A limited range of farmers were involved in the testing of interventions, because of the necessary costs and rigour of experimentation. However, a broader spectrum of interventions and farmers were involved in less rigorous farmer-managed trials (Shrestha et al. this volume). The interventions tested at different sites and crops are given in Table 12.2. Plots were 20m by 5m (long axis down slope) and replicated in 5 blocks at Landruk and Nayatola. *Setaria anceps* was planted in the terrace risers and *Flemingia congesta* was planted on the top of the riser in the second intervention at Landruk. *Flemingia congesta* did not perform well, because of its slow initial growth under Landruk's climatic conditions. Thus, in the next year only *Setaria* was planted across the whole riser. At Nayatola, strip crops were compared with the farmers' practice. Observations of soil and nutrient losses from different existing farming systems were continued in previous soil erosion research plots (Gardner et al. 2000) at Bandipur. The interventions were compared with the farmers' practices in which maize was grown without strips (Nayatola) and

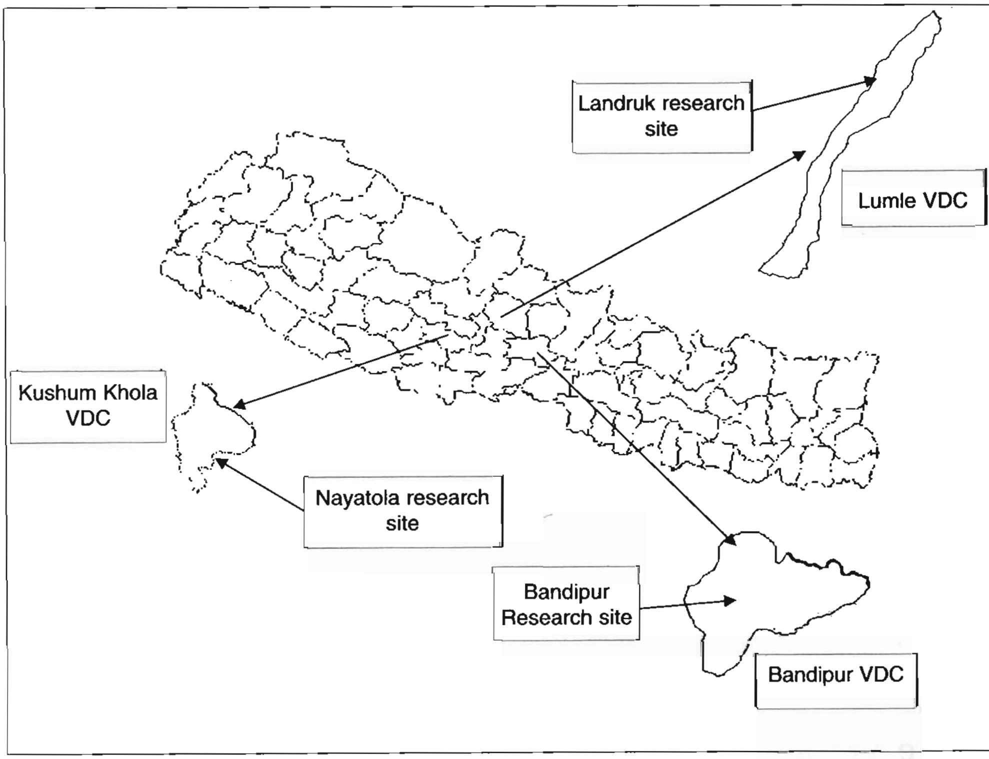

Figure 12.1: **Map of Nepal showing research sites**

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Table 12.2: **Treatment combinations studied at different sites**				
Sites	**Treatment**	**Crops**		
		2000	**2001**	**2002**
Landruk	Runon diversion	Maize/millet (*Eleusine coracama*)	Maize/naked barley (*Hordeum vulgare Var. nudum*)	Maize/millet
	Runon and grass planting in terr ace risers	Maize/millet	Maize/naked barley	Maize/millet
	Control (runon in farmers' practice)	Maize/millet	Maize/naked barley	Maize/millet
Nayatola	Maize + ginger (with mulch) Strip cropping	Maize and ginger (*Zingiber officinale* Roscoe)	Maize and ginger	Maize and ginger
	Maize + legume s trip cropping	Maize and cowpea (*Vigna ungulata*)	Maize and soybean (*Glycine max* (L.))	Maize and field bean (*Phaseolus vulgaris*)
	Farmers' maize practice (control)	Maize	Maize	Maize
Bandipur	Wide terraced	Maize-fallow	Upland rice fallow	Maize-fallow
	Young citrus orchard	Maize and soybean intercropping	Maize and cowpea intercropping	fallow
	Narrow terraced, maize based	Maize-fallow	Maize-fallow	Maize-fallow
	Narrow terraced, maize based	-	Maize-fallow + grass planted in risers	Maize-fallow + grass planted in risers
	Old citrus orchard	Fallow	Fallow	Fallow

maize was grown without diversion of runon and with native grass (not planted) in terrace risers (Landruk).

Measurement of rainfall, runoff, erosion, and leaching

Surface runoff volumes and nutrient content were monitored on a weekly basis in standard runoff plots. The experimental plots were enclosed by metal sheets on all sides to prevent lateral water movement (except for the upper border in the open plots at Landruk). The edge of the metal sheet was raised about 0.3m above and extended 0.2m below the surface of the soil. A 5m long trough was located at the lower end of the plot and connected with polythene pipe to a drum, in which total runoff from the experimental plot was collected. Eroded sediment was estimated in runoff samples of 0.5 l collected from each drum after vigorous stirring. A sample of clean solution from the last drum containing runoff was also taken for nutrient analysis. Infiltrated water was collected in lysimeters constructed and inserted in such a way as to collect leachate from the top 40 cm layer of the soil. They were constructed from polythene pipes of 11 cm diameter and 25 cm length and filled with soil. A leachate collection cup was fitted in the end of the pipe and 2 small, soft tubes of 5 cm diameter passed out through the pipe, remaining above the soil surface and allowing leachate to be pumped out. These lysimeters were inserted in the runoff plots (3 per plot) 15 cm below the surface of the soil. Rainfall amounts and intensities were recorded over the monsoon period (May-October) using both automated and manual recorders.

Results

Leachate and nutrient losses

At Landruk, the total annual rainfall was 3193 mm in 2000, 3691 mm in 2001 and 3440 mm in 2002 (Figure 12.2). The total leachate was higher in closed plots than in open plots, though the differences were only significant in 2000 (Figure 12.3).

In closed plots, the losses of nitrate-nitrogen (N) and exchangeable potassium (K) due to leaching were higher in all the seasons of 2000 (early, mid, and late) than in the farmers' practice (Table 12.3) (although not at a significant level [$P= 0.29$]). This was due to the fact that there was no control of rainwater in the farmers' practice, whilst the rainfall water is controlled and infiltration of water takes place in closed plots, which results in more leaching of nutrients in the infiltrated water. The total losses of nitrate-N (97.9 kg/ha) and exchangeable K (99.2 kg/ha) were higher in the closed plots than in the farmers' practice, where nitrate-N and exchangeable K losses were 73.4 kg/ha and 75.7 kg/ha respectively.

During 2001, the leaching of both nitrate-N and exchangeable K was higher in the mid and late seasons than in the early season (Table 12.3). No significant difference in leaching was recorded between treatments with grasses in the risers and the farmers' practice in early, mid, or late seasons. The total loss of exchangeable K was the highest (59.4 kg/ha) in closed plots followed by the farmers' practice and grasses in the risers. Similarly, the total nitrate-N loss was the highest (99.7 kg/ha) in the closed plot and more or less similar (61.3-61.6 kg/ha) in the grasses and the farmers' practice treatments. However, these differences were not significant as the grasses in the risers were poorly planted in 2001 and were still becoming established by the end of the monitoring period.

In 2002, intervention plots lost more N (18.3-28.6 kg/ha) than the farmers' practice (17.3 kg/ha) (Table 12.3). More nitrate-N was lost from the closed than the grass planting in terrace

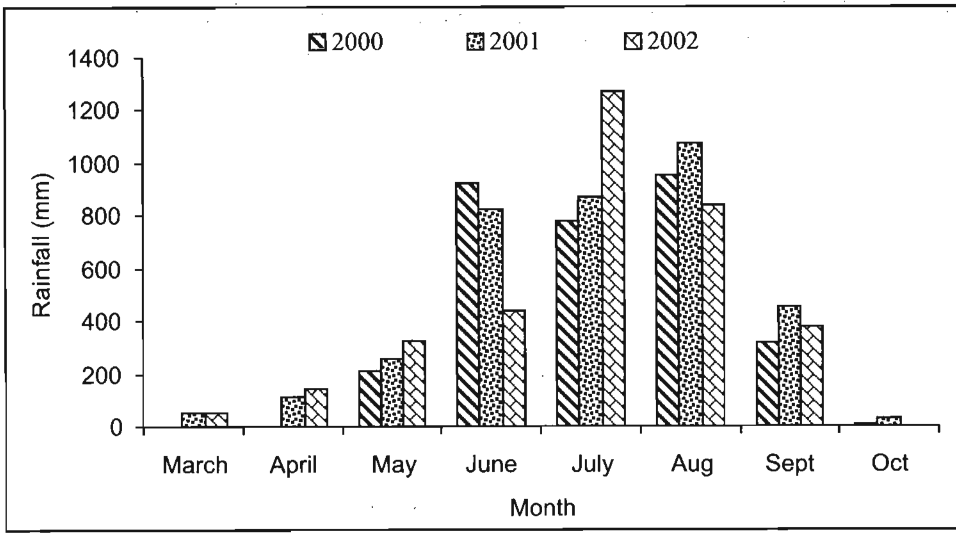

Figure 12.2: **Rainfall amount and pattern at Landruk during 2000-2002**

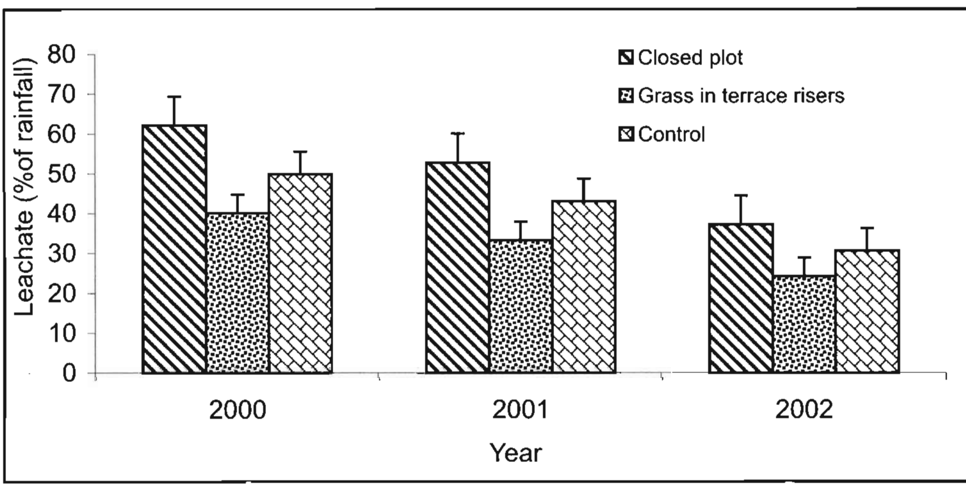

Figure 12.3: **Leachate (percentage of rainfall) at Landruk during 2000-2002**

riser plots. The loss of nitrate-N was more in the mid season and less in the early season for all treatments except the farmers' practice, which lost slightly more in the early season than the late season. The closed plots lost more K (35.3 kg/ha) than the farmers' practice (30.7 kg/ha) and the plot of grass planting in terrace riser lost least K (26.7 kg/ha). However, the differences among the treatments for the loss of K in leachate were not significant in any period of the season. K loss in leachate was most in the mid season, followed by the late season, and least in the early season for all treatments.

At Nayatola, the total rainfall was 1386, 1123, and 867 mm in 2000, 2001, and 2002 respectively (Figure 12.4). The total leachate in the strip cropped plots was lower in 2000 and higher in 2001 and 2002 than in the farmers' practice but the differences were not significant in any year (Figure 12.5).

Table 12.3: Effect on nutrient loss (kg/ha) in leachate at Landruk during 2000 -2002								
Treatment	Early season		Mid season		Late season		Total	
	N	K	N	K	N	K	N	K
2000								
Closed plot	21.2	3.0	61.1	63.0	18.7	33.1	97.9	99.2
Grass in terrace riser	5.7	3.8	73.6	38.4	15.0	20.8	95.4	61.1
Farmers' practice	7.2	3.6	48.0	45.0	17.4	28.9	73.4	75.7
p	0.36	0.87	0.29	0.86	0.84	0.88	0.46	0.87
2001								
Closed plot	4.0	4.0	62.0	27.0	31.0	29.0	99.7	59.0
Grass in terrace riser	3.0	2.0	33.0	22.0	23.0	12.0	61.6	35.0
Farmers' practice	21.0	4.0	24.0	27.0	21.0	19.0	61.3	48.0
p	0.80	0.69	0.45	0.89	0.50	0.74	0.59	0.78
2002								
Closed plot	3.5	3.5	19.9	24.0	6.6	8.8	28.0	35.3
Grass in terrace riser	3.0	2.1	10.8	18.4	6.1.	6.6	18.3	26.7
Farmers' practices	4.2	2.6	11.8	20.7	3.5	7.9	17.3	30.7
p	0.89	0.61	0.09	0.89	0.57	0.93	0.45	0.91

N = nitrate-nitrogen; K = exchangeable potassium; *p* = level of significance

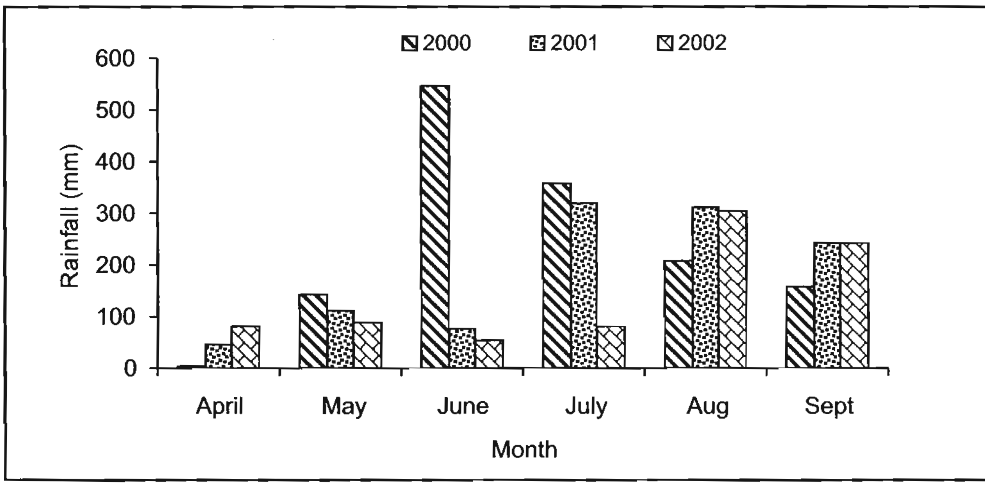

Figure 12.4: **Rainfall amount and pattern at Nayatola during 2000-2002**

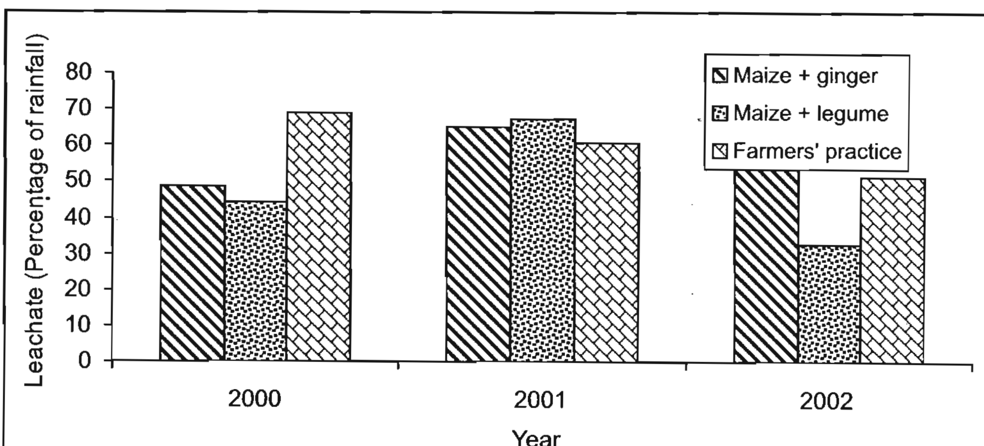

Figure 12.5: **Leachate (percentage of rainfall) at Nayatola during 2000-2002**

Both nitrate-N and exchangeable K leaching losses were slightly higher in the maize and ginger strip than in the farmers' practice in the early season 2000. Losses were reduced in the maize and ginger strip in the mid season because the maize and ginger plants established well and they covered the ground by the mid season. However, it was not so in the farmers' practice. As there was no rainfall in the late season of 2000, no samples of leachate were collected from the lysimeters. The total loss of nitrate-N was less (52.6 kg/ha) in the maize and ginger strip than in the farmers' practice (60.3 kg/ha) (Table 12.4). The total exchangeable K losses in both the interventions (maize and ginger strip as well as farmers' practice) were similar (22.5-23.0 kg/ha). However, leaching losses of both the nutrients were not significantly different between the interventions.

Table 12.4: Effect on nutrient loss (kg/ha) in leachate at Nayatola during 2000 -2002

Treatment	Early season		Mid season		Late season		Total	
	N	K	N	K	N	K	N	K
2000								
Maize + ginger	39.1	7.5	13.5	15.6	-	-	52.6	23.0
Maize + legume	41.5	7.9	23.1	17.3	-	-	64.5	25.1
Farmers' practices	37.3	4.3	23.0	18.2	-	-	60.3	22.5
p	0.94	0.25	0.12	0.94			0.54	0.96
2001								
Maize+ ginger	27.9	5.9	18.9	12.4	17.5	8.3	64.2	26.6
Maize + legume	29.3	6.0	33.9	15.7	20.4	7.8	83.6	29.5
Farmers' pract ices	32.6	5.0	14.0	9.3	15.5	7.4	62.1	21.7
p	0.84	0.75	0.21	0.36	0.64	0.74	0.35	0.38
2002								
Maize+ ginger	10.9	6.1	10.2	5.7	33.8	4.9	52.9	15.2
Maize + legume	0.4	2.3	3.5	4.0	16.1	4.5	21.7	10.7
Farmers' practices	8.2	2.6	4.4	3.6	23.2	4.2	34.8	10.2
p	0.30	0.20	0.13	0.27	0.63	0.84	0.40	0.35

N = nitrate -nitrogen; K = exchangeable potassium ; *p* = level of significance

During 2001, nitrate-N losses in the early, mid, and late seasons were lower in the maize and ginger strip plots than in the farmers' practice and maize and soybean strip. Nitrate-N leaching loss was greatest in maize and soybean most probably due to fewer soybean plants germinating in this treatment. Exchangeable K leaching loss was higher (15.7 kg/ha) in the maize and soybean strip in the mid season than in the maize and ginger and farmers' practice (9.3-12.4 kg/ha) but remained more or less the same in the early and late seasons. The total nitrate-N loss was higher (83.2 kg/ha) in the maize and soybean strip than in the maize and ginger (64.2 kg/ha) and farmers' practice (62.1 kg/ha) (Table 12.4). The same was true in the loss of exchangeable K, where the maize and soybean plot had 29.5 kg/ha and the maize and ginger and farmers' practice had 26.4 and 21.7 kg/ha respectively. However the results were not significantly different.

In 2002, nutrient losses were not significantly affected by the treatments. The loss of total nitrate-N through leachate was the highest (53 kg/ha) in the maize and ginger strip cropping, followed by 35 kg/ha in the control. The lowest loss was 22.0 kg/ha in the plot of maize and legume strip cropping. The seasonal distribution of N loss through leaching was the highest in the late monsoon period. Likewise, the total K loss through leachate was the highest (15 kg/ha) in the plot of maize and ginger strip cropping and its loss was 10.7 kg/ha from the maize and legume strip cropping and 10.2 kg/ha from the control plot (Table 12.4). The seasonal distribution of K loss through leaching was slightly higher in the early period followed by the mid and late periods.

At Bandipur, annual rainfall was 1250, 2043, and 1681 mm in 2000, 2001, and 2002 respectively (Figure 12.6). Leaching of nutrients was the highest in the old citrus orchard (36.4 kg of N and 32.0 kg of K per ha) and the lowest in the young citrus orchard (8.2 kg of N and 11.7 kg of K per ha) in 2000 (Table 12.5). The old citrus orchard lost more nutrients throughout all the years. The lowest loss of nutrients was 25.9 kg N per ha in the leachate of the wide terrace maize-fallow-fallow system and 10.5 kg K per ha in the leachate of the narrow terrace maize-fallow-fallow system with grass planting in terrace riser in 2001 (Table 12.5). In 2002, the lowest losses of both N and K were in the leachate of the narrow terrace maize-fallow-fallow (Table 12.5). The loss of total phosphorous (P) in the leachate was less than 1 kg/ha. This indicates that the loss of soluble P is negligible in leachate.

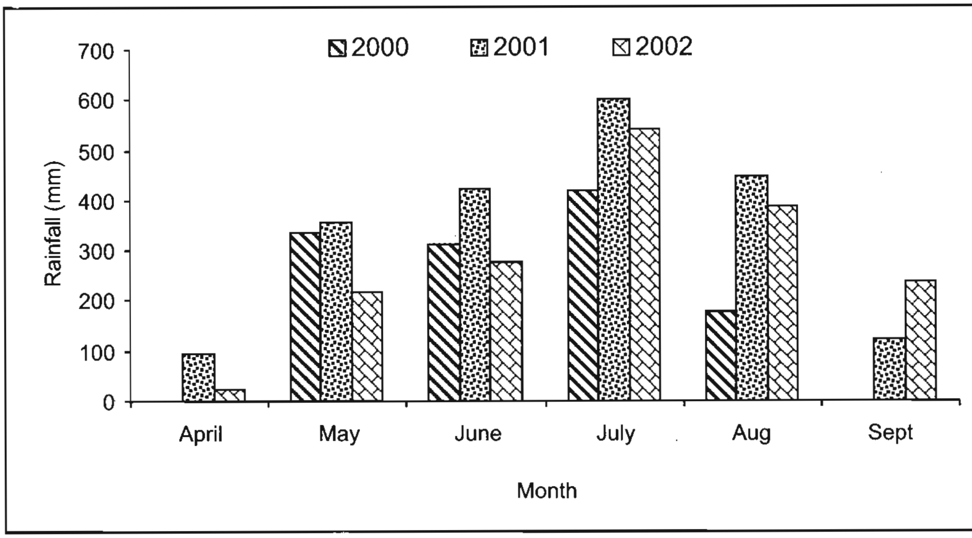

Figure 12.6: **Rainfall amount and pattern at Bandipur during 2000-2002**

Runoff and eroded sediments

Sediment loss at the high rainfall site of Landruk in 2000, 2001, and 2002 and average runoff from the different types of plot over the same period are shown in Figures 12.7 to 12.10. The total runoff from closed plots was significantly lower than from open plots during 2000 but it was similar during 2001 and 2002. However, the amount of runoff was very low in all years as compared to rainfall.

Sediment loss (Figures 12.7 - 12.9) was higher in farmers' practice (2229 kg/ha) than in closed plots (994 kg/ha) during 2000. Similarly, during 2001, the total loss of the sediment was the highest in the plots with grasses grown in the riser (1293 kg/ha) followed by the farmers' practice (886 kg/ha) and closed plots (478 kg/ha). In both years, low sediment loss in the closed plots was due to the limited area in which runoff water could not flow freely from the terraces above, and because runoff velocities were reduced, hence reducing erosion. The higher loss of the sediment from grasses grown in the riser than in the farmers' practice during 2001 was most probably due to first-year planting of grasses in the riser, where roots were not sufficiently well established to conserve soil. In 2002, the soil loss from the closed plots was

Table 12.5: Effect on nutrient loss (kg/ha) in leachate at Bandipur during 2000 -2002								
Cropping system	Early season		Mid season		Late season		Total	
	N	K	N	K	N	K	N	K
2000								
Wide terrace and M -F-F	0.9	9.8	8.4	4.8	6.5	6.1	15.8	20.7
Young citrus orch ard and intercropping	0.2	1.1	5.6	7.2	2.4	3.3	8.2	11.7
Narrow terrace and M -F-F	2.8	1.8	3.2	4.2	8.1	5.6	14.2	11.5
Old citrus orchard	9.0	3.6	14.5	13.1	12.9	15.2	36.4	32.0
2001								
Wide terrace and M -F-F	2.5	0.8	12.1	6.7	11.4	4.4	25.9	11.9
Young citrus orchard and intercropping	15.9	3.4	17.5	5.7	17.1	3.6	50.4	12.7
Narrow terrace and M -F-F	10.5	3.7	9.6	8.7	25.5	6.0	45.6	18.4
Narrow terrace and M -F-F + grass planting in terrace riser	10.0	3.4	2.5	3.0	14.1	4.2	26.6	10.5
Old citrus orchard	24.2	102	16.5	202	24.8	95	65.5	399
2002								
Wide terrace and M -F-F	15.9	4.9	12.5	11.5	4.2	7.2	32.6	23.6
Young citrus orchard and intercropping	19.1	26.6	23.0	5.8	6.8	1.7	48.9	34.1
Narrow terrace and M -F-F	12.9	3.7	8.9	9.5	7.6	4.3	29.4	17.5
Narrow terrace and M -F-F + grass planting in terrace riser	19.5	3.6	8.4	8.1	11.9	6.5	39.8	18.3
Old citrus orchard	38.7	8.5	12.8	6.9	3.3	1.3	54.9	167

N = nitrate -nitrogen; K = exchangeable potassium M -F-F = maize - fallow - follow

the lowest (4653 kg/ha) and it was the highest (7256 kg/ha) in the farmers' practice. The soil loss from the plot with grass planting in terrace risers was also less than the loss from the farmers' practice.

Sediment loss at Nayatola in 2000, 2001, and 2002 and average runoff from the different types of plot over the same period are shown in Figures 12.11 to 12.14. The total runoff from the strip cropped plots was less than for the farmers' practice (Figure 12.14); however differences were only significant in 2001. The total sediment loss (Figures 12.11 - 12.13) was higher in the farmers' practice (144 kg/ha) than the maize and ginger strip (58 kg/ha) in 2000. In 2001, the total loss of sediment was highest in the farmers' practice (867 kg/ha) followed by the maize and soybean strip (472 kg/ha) and maize and ginger strip (231 kg/ha). The maize and ginger strip was more effective than the maize and soybean as well as the farmers' practice for minimising sediment loss by runoff because in the maize and ginger strip the ginger was mulched with locally available materials at planting time, which acted as a cover to the soil as well as minimising the soil runoff. In 2002, 280.7 kg/ha of sediments were lost from the maize and ginger strip crop plots compared to 865 kg/ha from the maize and legume strip cropped plots and 1756 kg/ha from the control plots. Sediment losses were greatest in the early season irrespective of treatment. The losses of soil in the early season were 269.5, 843.0, and 1730.6 kg/ha from the maize and ginger strip plots, maize and bean strip plots, and control plots respectively. Insignificant amounts of soil were lost in the mid and late seasons, however the trend among the treatments was the same as for soil loss in the early season.

The total loss of soluble nutrients in runoff was not significantly affected by interventions at any of the sites. However, eroded sediments contain a high content of organic matter and P (Acharya et al. 2001). The results showed that a large amount of organic carbon was lost with sediment rather than other nutrients (Tables 12.12 and 12.13) in both Landruk and Nayatola.

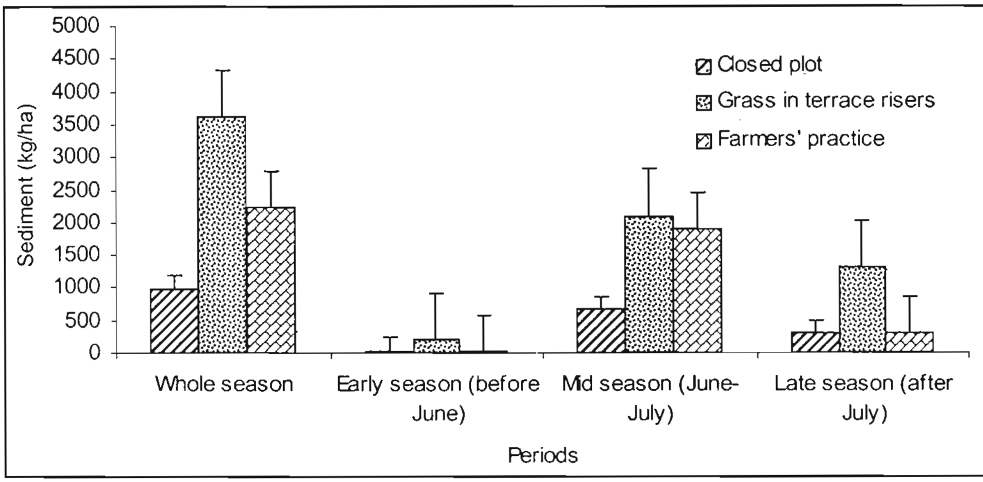

Figure 12.7: Soil losses at Landruk during 2000

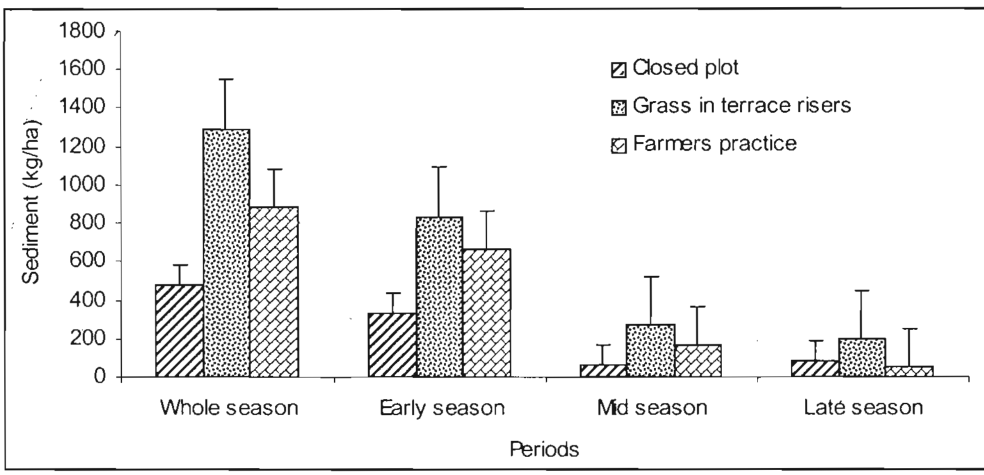

Figure 12.8: Soil losses at Landruk during 2001

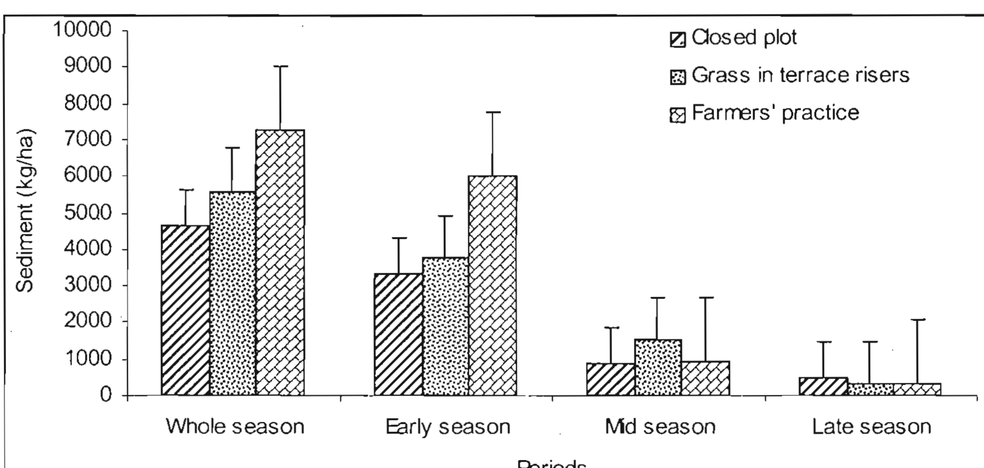

Figure 12.9: Soil losses at Landruk during 2002

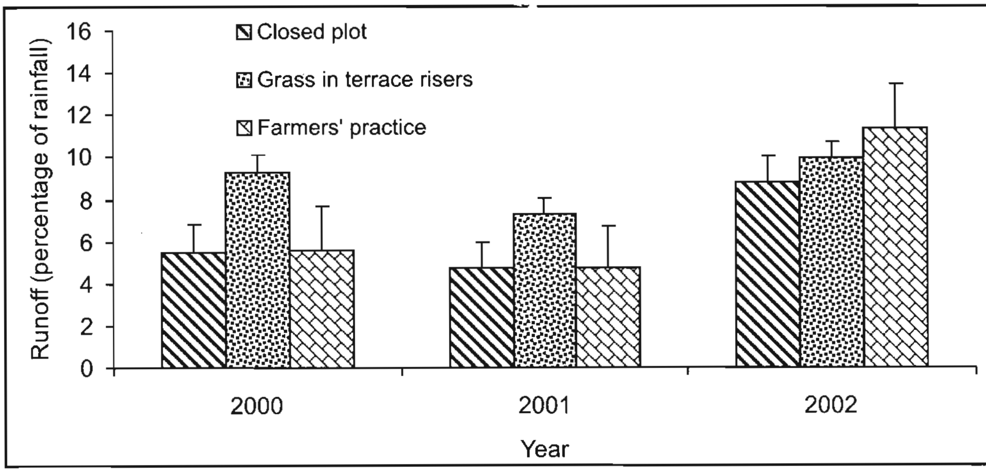

Figure 12.10: **Runoff (percentage of rainfall) at Landruk during 2000-2002**

Table 12.6: **Nutrient loss in eroded sediment at Landruk (3 years' average)**				
Treatment	**Organic C (kg/ha)**	**Total N (kg/ha)**	**Available P (kg/ha)**	**Exchangeable K (kg/ha)**
Closed plot	55.1	4.7	0.14	0.30
Grass in terrace riser	108.3	8.0	0.26	0.44
Farmers' practi ce	114.2	8.4	0.20	0.47

Table 12.7: **Nutrient loss in eroded sediment at Nayatola (3 years' average)**				
Treatment	**Organic C**	**Total N (kg/ha)**	**Available P (kg/ha)**	**Exchangeable K (kg/ha)**
Maize+ginger strip cropping	6.7	0.2	0.01	0.05
Maize+legume strip cropping	17.2	0.4	0.02	0.10
Farmers' practice	22.4	0.5	0.04	0.15

Organic matter is one of the most important sources of nitrogen and plays a major role in the improvement of the physical properties of soil.

Sediment loss at Bandipur in 2000, 2001, and 2002 is shown in Figures 12.15 to 12.17. At Bandipur, the highest sediment loss in 2000 was 1316.3 kg/ha from old citrus orchard and the lowest was 201.8 kg/ha from young citrus orchard, in 2001 the loss was the highest from the narrow terrace maize-fallow-fallow cropping system. Grass planting in the terrace riser had reduced soil loss from the narrow terrace maize-fallow-fallow cropping system indicating the riser planting could help to minimise soil movement along with runoff. In 2002, again the narrow terrace maize-fallow-fallow system yielded more sediment loss and the riser planting with grass did not show any reduction in soil loss.

Yield and economy

Total productivity of the interventions was compared with the farmers' practice. The interventions did not reduce crop productivity at Landruk (Table 12.14); maize and ginger

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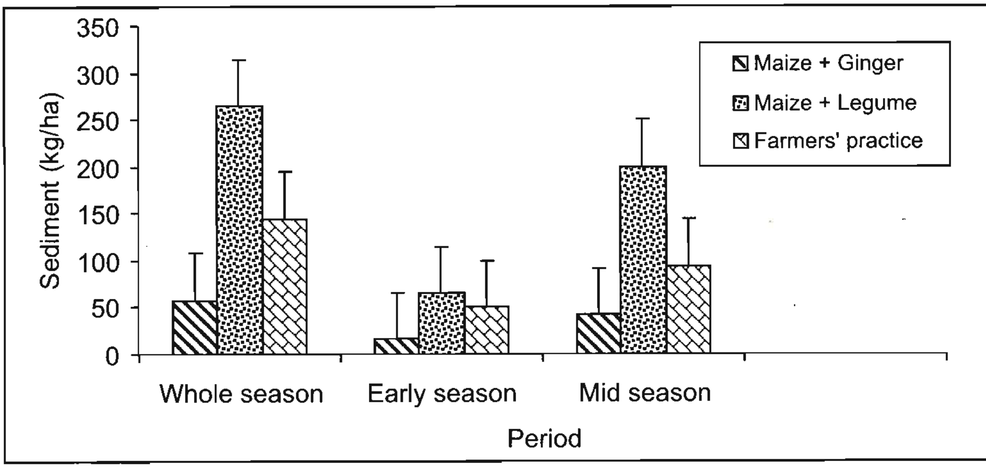

Figure 12.11: **Soil loss at Nayatola during 2000**

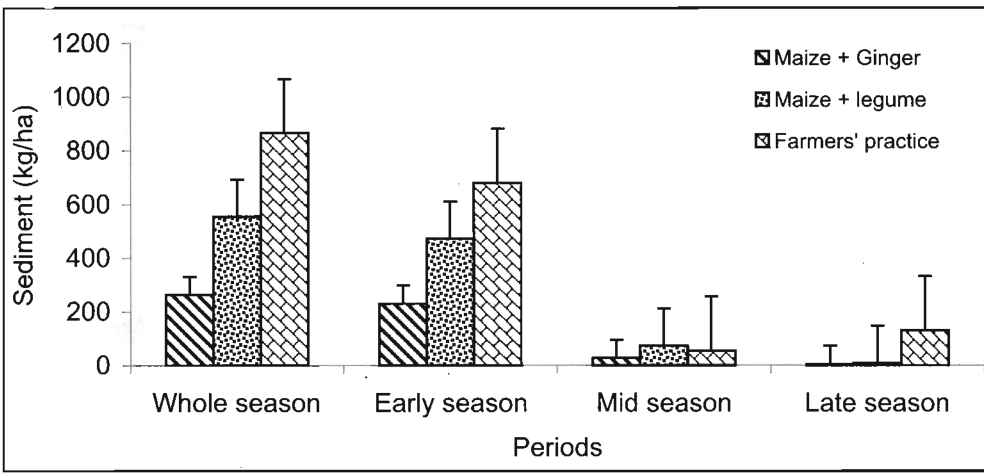

Figure 12.12: **Soil loss at Nayatola during 2001**

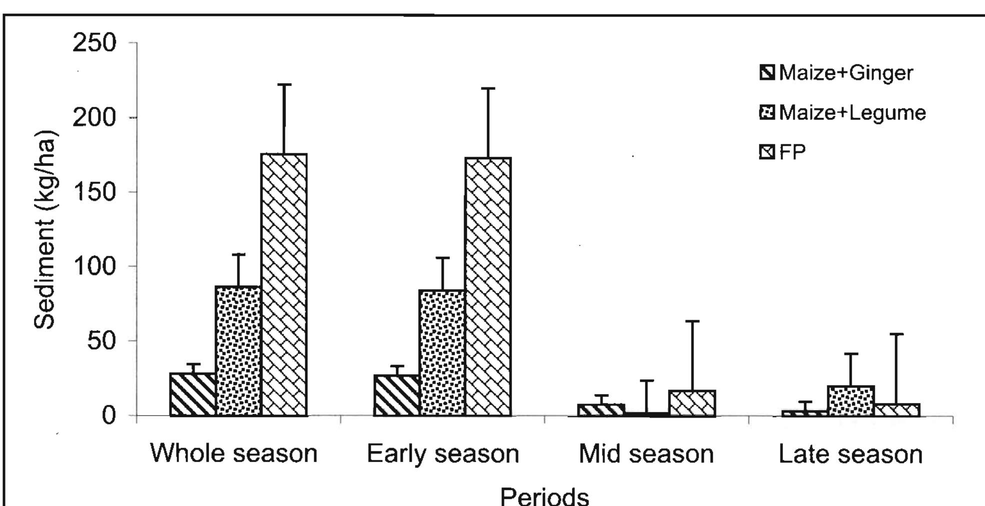

Figure 12.13: **Soil loss at Nayatola during 2002**

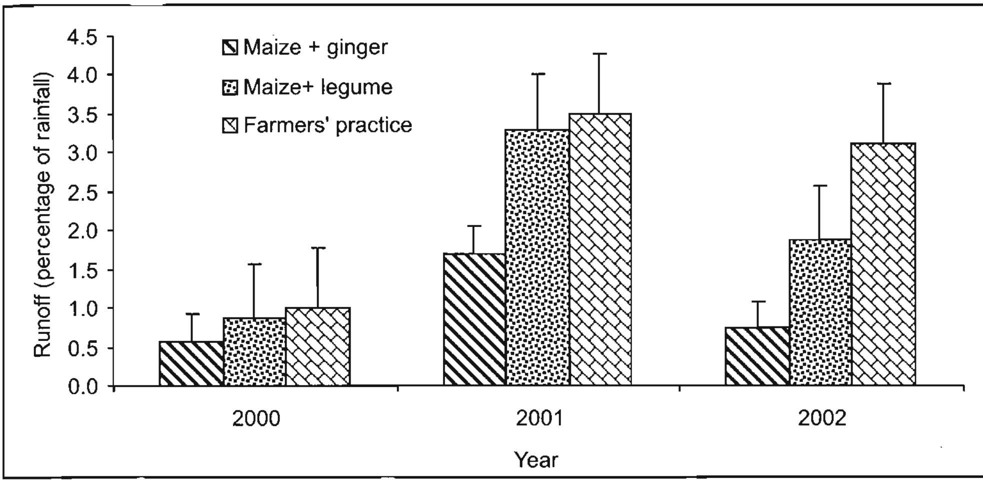

Figure 12.14: **Runoff (percentage of rainfall) at Nayatola during 2000-2002**

Table 12.8: **Effect on crop grain yields (kg/ha) at Landruk**

Treatment	2000	2001	2002
Closed plot	3929	3381	4778
Plot of grass planting in terrace risers	3715	3866	5248
Control (farmers' practice)	3160	3650	4516
P	0.18	0.76	0.76

Table 12.9: **Income (NRs*/ha) from strip cropping at Nayatola**

Treatment	2000	2001	2002
Maize+ginger strip	18,110	31,868	33,647
Maize+legume strip	9,236	18,820	6,420
Control (farmers' practice)	15,332	21,089	9,398
P	0.02	0.04	<0.01
US $1 = NRs 69, 76, 78 in 2000, 2001, and 2002, respectively			

strip cropping gave a higher income than farmers' practice at Nayatola (Table 12.15), mainly because of the high value of the ginger crop.

Discussion

The diversion of runon reduced soil erosion in the high rainfall area (Landruk, Kaski) without a significant effect on the loss of nutrients. However, diversion of runon enhanced water infiltration in which a great loss of nitrogen and potassium occurs. Grass planting in terrace risers showed a trend of reducing potassium loss in leachate. Landruk appears to be highly susceptible to runoff and erosion, which relates to its high rainfall and runon and red/brown type of soil (Tripathi et al. 1999; Gardner et al. 2000). The intensity of rain just after field ploughing (for crop planting and fertiliser incorporation) as well as intercultural operations accelerate the soil runoff causing about 50% of the total sediment loss in early June (Mawdesley et al. 1998) when the soil is bare. Gardner et al. (2000) further reported that the timing of heavy rain vis-a-vis the land management activities of ploughing, weeding, and mounding, all of which affect the percentage of ground cover (predominantly weeds) during the May/June/early July period, is an important, albeit random, determinant of the extent of

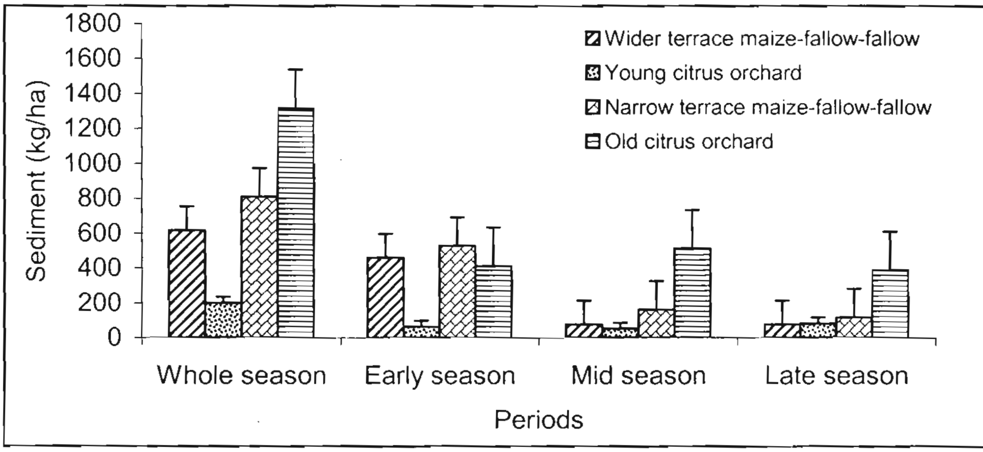

Figure 12.15: Soil loss at Bandipur during 2000

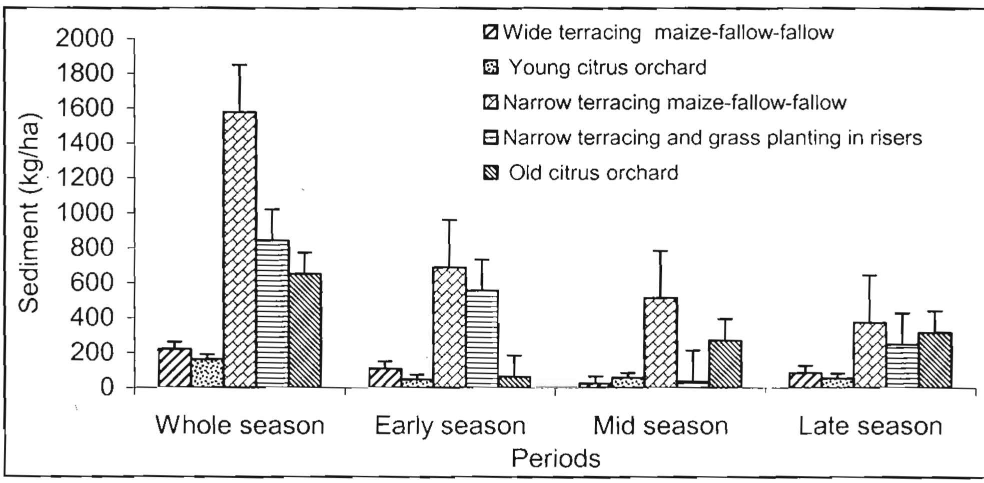

Figure 12.16: Soil loss at Bandipur during 2001

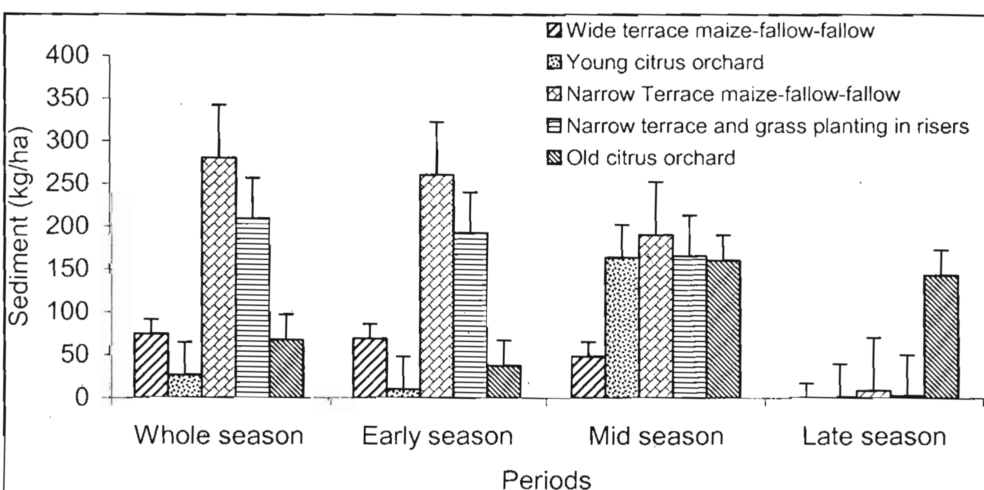

Figure 12.17: Soil loss at Bandipur during 2002

soil loss in a particular year. Soil losses by surface erosion, where run-on is controlled, were low (2.5-5.0 t/ha per year) in all the terraces studied, even where rainfall totals and erosivity were high. However, uncontrolled surface (runon) or sub-surface (piping) water input may result in higher volumes of soil movement on the hillsides and potentially to severe net losses (Gardner et al. 2000).

At Nayatola, the strips of maize and ginger reduced both runoff and leachate volumes under low rainfall and sloping field conditions as compared to the farmers' practice. However, the losses of soluble nutrients in runoff or leachate were not affected, only those adhered to eroded sediments. The ginger strips were mulched with plant materials, which effectively functions as a filter, slows runoff, and prevents the movement of soil particles with runoff water so that the loss of the soil was observed to be low in the maize and ginger strip-planting plot. Montoro et al. (2000) observed a marked reduction of runoff and sediment yields with light mulching of straw to the soil surface at 50% slope in a semiarid region (Smoliowski et al. 1998). Mulching is being used in the area on a small scale for a limited number of crops such as dasheen (*Colocasia esculenta* [L.]) and ginger. It can be extended to other crops provided the mulching material is available or the area under the farmers' traditionally mulched crops can be extended if markets are assured. The existing cultivation practice for the maize crop is the main reason for soil and plant nutrient losses from bari. The sloping nature of the terrace also contributes to increased runoff and soil loss (Vaidya et al. 1995). McDonald et al. (2002) reported that contour-tree-hedgerows are effective for soil and water conservation through the sieve-barrier effect and increased water infiltration and have the potential to enhance the sustainability of the land-use system at a plot scale. The improvement of the terraces is the best technology to reduce runoff from the fields, but it could result in increased leaching unless an appropriate combination of crops is used. Intercropping of legumes with maize is the traditional practice, but tending the maize accelerates soil movement. The modifications to traditional practice as tested in this study, such as inclusion of bushy types of legume crops (for example, cowpea) with maize as strips, reduce operation and control soil nutrient loss from the cropped fields particularly through runoff. Similarly, the use of mulch in ginger production is the usual practice of farmers in this area and the introduced modification of strip cropping of maize and ginger was shown to significantly reduce rates of soil loss through runoff and improve the fertility status of the eroded bari for sustainable crop yields. A maize-soybean rotation may reduce nitrate-N leaching loss as compared to continuous corn planting practices (Owens et al. 1995). Other potential interventions could be extended to include cover crops to protect the soil from erosion and to improve soil fertility through reducing the potential of nutrient leaching (Changkija and Yonghua 1997).

In the citrus-growing area of Bandipur, old citrus orchard showed higher nutrient losses in leachate than young citrus orchard. Intercropping in young citrus orchard reduced nutrient losses. Potassium leaching losses were much higher from old citrus orchard. This result differs from the findings of Ongprasert (2002) who observed that compaction of topsoils in mature litchi orchards results in lower infiltration of water and enhanced runoff.

Soil loss is high during early monsoon. The rainy season was divided into three parts to understand the factors that increase or decrease the erosion rate. In the early rainy season soil remains mostly susceptible to erosion (before June). In the mid rainy season the soil remains resistant to erosion (late June to early August). After that erosion depends on the time of the monsoon and soil cultivation for the next crop cycle.

The amount and nutrient content of runoff were very low compared to leachate but the associated sediment movements carry significant amounts of organic matter and available P. Therefore, further developments should maintain the focus of decreasing leaching and controlling sediment losses in runoff.

Besides N and K leaching, strip cropping at Nayatola and runon diversion and grass planting in terrace risers at Landruk increased productivity by reducing the losses of organic matter in the sediment.

Conclusions

From these findings the following can be concluded.

- The amount of nutrient loss through runoff is very low, but significant amounts of N and P were lost through leaching. Significant amounts of organic matter and available P were washed out along with sediment movements.
- Strips of ginger and maize minimised soil loss and maximised net income from the sloping bari land. This practice can be recommended to the farmers of other areas to minimise soil erosion.
- Young citrus orchard followed by leguminous crop intercropping is beneficial in reducing soil loss as well as nutrient loss in predominantly citrus-growing areas.
- Wide terraces are better for management of soil fertility as they have less runoff and nutrient leaching.

Therefore, technical efforts should focus on trapping nutrients that are lost in solution through leaching and the use of barriers to reduce soil movement and nutrient losses in eroded sediments.

Acknowledgements

The authors are grateful to R.P. Sah, Chief, Agriculture Research Station/Lumle, for his continued support and encouragement for conducting the study. We would like to acknowledge W. Stewart-Jones, ex-research adviser at LARS for the Hilll Agricultural Research Project (HARP); Tang Ya, one of the collaborators in this project from ICIMOD, Kathmandu; P.A. Stevens, Biochemistry and Land Use Section, Institute of Terrestrial Ecology, Bangor, UK; R. Gardner, Queen Mary and Westfield College (QMWC), University of London; and K. J. Mawdesley, collaborator in a previous soil erosion project from QMWC, University of London; for their suggestions and contributions at different stages of the present research work. We sincerely acknowledge the contribution of the team members of Soil Fertility Research, LARS, for their inputs and soil laboratory staff especially R.C. Tripathi (Technical Assistant) who we would like to thank for his continuous effort in the project. Cooperation of the recorders and farmers of the sites in Kaski and Palpa districts in implementing the field study are gratefully acknowledged. This is an output from a research project (R7412 Natural Resources Systemes Programme) funded by the Department for International Development (UK) (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID. The support of HARP by the British Government is gratefully acknowledged.

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Part Three

Common Property Resources

13

Potential Strategies for Rehabilitating Degraded Lands in the Middle Mountains of the Hindu Kush-Himalayas

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Abstract

Long-term action research on the rehabilitation of degraded lands in the middle mountains of the Hindu Kush-Himalayas (HKH) has been conducted under the Rehabilitation of Degraded Land in the Mountain Ecosystems Project (1992-96) and the People and Resource Dynamics in the Mountain Watersheds of the Hindu-Kush Himalayas Project (1996 to the present). These important regional initiatives of ICIMOD and its regional partners have sought solutions to resource degradation in the HKH. The on-site trials have taken a number of approaches. Some have been monitored for more than eight years and provide important information on potential measures to combat land degradation. This paper reports on the vegetative and supporting technologies tried out in China, India, Nepal, and Pakistan.

Introduction

Rehabilitating degraded land has many benefits for local people and the environment. It helps local people to meet their needs for food, livestock feed, fuelwood, and timber, and often increases cash incomes and land values. This in turn increases social stability. The environmental benefits include less soil erosion and the preservation of biodiversity by alleviating the need to convert remaining natural habitats.

In 1993, the six land rehabilitation case studies in Table 13.1 were initiated by the Rehabilitation of Degraded Lands in the Mountain Ecosystems Project (1992-1996) of the International Centre for Integrated Mountain Development (ICIMOD) in the mountainous areas of China, India, Nepal, and Pakistan. These studies were later taken over for long-term monitoring by the People and Resource Dynamics in the Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP). These initiatives led on from work carried out by the Mountain Resource Management Project that ran from 1989 to 1995 in Nepal (Schreier et al. 1995).

This action research on land rehabilitation tested soil and water conservation technologies and approaches to rehabilitating lands in the midhills of the Hindu Kush-Himalaya (HKH). This research recognised that the problems of degraded mountain lands in the different ecosystems of the HKH are many and varied and require different solutions. The approaches taken to rehabilitating degraded lands have been (ICIMOD 1996):

- carry out baseline surveys and rural appraisals to identify local bio-physical and socioeconomic conditions;

Table 13.1: **Land rehabilitation sites under ICIMOD's projects**

Country	Village	Area	Land tenure	Other details
China	Damai village, Baoshan district, Yunnan	45 ha denuded forest land and 7.5 ha farming land; 1370-1750 masl	Community forest belonging to 136 households	Field survey in 1992 and implemented in 1993. Implemented by Kunming Institute of Botany, Chengdu Institute of Ecology, and Kunming Institute of Biology Village community of 136 households
India	Arah, Bageshwar district, Uttar Pradesh (now Uttaranchal)	9.5 ha abandoned farmland; 1490 masl	Belonging to 86 individual households	Field survey in January 1993; started in July 1993. Implemented by G.B. Pant Institute of Himalayan Environment and Development Arah village community and ban panchayat
India	Khaderiya, Bageshwar district, Uttar Pradesh (now Uttaranchal)	4 ha abandoned farmland; 1400 masl	Belonging to 45 individual households	Survey and implementation in 1997 Implemented by G.B. Pant Institute of Himalayan Environment and Development Khaderiya, Laubanj, Puniamaphi village communities and Puniamaphi Ban Panchayat
Nepal	Godavari, Lalitpur, central Nepal	30 ha degraded forest with bushes, 1600 masl	ICIMOD test and demonstration site	Field survey in February 1993; site developed by ICIMOD from March 1993
Nepal	Bajrepare, and Dhaireni villages, Kavre Palanchok district, Central Nepal	6.7 ha and 16 ha, respectively; 890-1000 masl	Community forest land	Field surveys in March 1993; sites developed from July 1993 Implemented with Department of Forest, Ministry of Forests and Soils Conservation, HMGN Forest user groups in two VDCs
Pakistan	Tarbela and Mangal catchment, Sinkari valley, Mashera district, Abottobad Hill Division, NWFP	15 ha abandoned farmland; 1400-1550 masl	Belonging to 18 individual households	Field survey 1993; site developed from October 1993 by Pakistan Forest Institute, Peshawar Village community of 18 households

Source: Shengji and Karki 1994

- apply technical components that increase biomass and improve soil-water management;
- incorporate indigenous knowledge and locally used species and practices; and
- do environmental monitoring to assess impacts on local ecosystems.

The six types of sites provided a varying range of conditions. The Nepal sites, except for Godavari, are sloping degraded red clay (*rato mato*) dominated sites and involved working with local communities. The work at the Godavari demonstration site focussed on the natural regeneration of degraded ecosystems closed to human use. In China the village-level activities addressed issues to do with land management and economic and institutional constraints and installed vegetative and structural measures to overcome denudation (Box 13.1).

Box 13.1: **The rehabilitation of degraded lands in Damai village, China**

Existing problems:

- Forest denudation leading to surface erosion, mud and rock flows, flooding, and drought.
- Poor land management such as 'crude' farming practices, over-grazing and depletion of forest resources.
- Weak local institutions leading to weak regulation of natural resources.
- Low household incomes leading to increasing poverty and few farming inputs being applied.

Measures applied to overcome these problems:

- Engineering — building check dams and renovating degraded reservoirs;
- Revegetation — setting up local plant nurseries, community reforestation programmes, planting multipurpose hedgerow species, and promoting biogas stoves.
- Improving farming practices — introducing and promoting contour cultivation, alley cropping, organic fertilisers, improved crop rotations and soil-water conservation measures, and incorporating nitrogen fixing trees and crops in crop rotations.
- Improving incomes by introducing cash crops and trees and developing home gardens.
- Strengthening local institutions by addressing local people's land tenure needs and by involving communities in implementing the above measures.

Source: CAS 1995

13

In India the focus has mainly been on large areas of privately owned degraded and abandoned agricultural land. This work was facilitated by the local ban panchayats (village institutions for managing community forests). It involved extending a package developed by the G.B. Pant Institute of Himalayan Environment and Development for rehabilitating degraded lands called Sloping Watershed Environmental Engineering (SWEET; Kothyari et al. 1995). This includes recommended plant species and techniques for establishing them and for harvesting water. At the Pakistan site activities were carried out at sub-catchment level by establishing tree plantations on privately-owned abandoned farming land and on steep degraded community-owned areas. The strategy was to develop each land use under traditional practices keeping in mind the needs of local people and treating the watershed on a sub-catchment basis. The activities carried out in Pakistan have been:

- afforestation with *Pinus roxburghii* on steep slopes and ridges; and broadleaf species such as *Robinia pseudoacacia*, *Ailanthus alticima*, and *Eucalyptus camaldulensis* planted on mid-slope pasturelands; and

- improving agricultural land by incorporating perennial crops in the farming systems with robinia, hybrid poplar and fruit trees planted on terrace margins and grasses and legumes such as *Chlorus gyana*, *Lolium multiflorum*, *Sorghum almum*, *Pennisetum orientale*, and white clover planted on abandoned fields.

Lessons Learned about Rehabilitation

The outcomes of this work are presented here to document lessons learned and share PARDYP's experiences on the rehabilitation of degraded lands. This will be useful for land managers who work on rehabilitating degraded lands and researchers who measure and assess land degradation, particularly those working in the middle hills of the Hindu Kush-Himalayas.

PARDYP and its predecessor projects have found that rehabilitation should go ahead by:
- encouraging the participation of local communities and adopting approaches that encourage social cooperation and trust by way of participatory planning, execution and monitoring (Figure 13.1);
- transferring know-how to local people;
- strengthening local institutions;
- accounting for the inter-linkages between private, community and public land ownership in villages and the factors that cause their degradation; and
- monitoring the success of land rehabilitation measures.

Ground cover is crucial for stabilising slopes and controlling erosion. One particularly important area of concern in the HKH is the rehabilitation of the large areas of degraded red soils that occur extensively across the middle mountain areas in footslopes, furrows, and river terraces. Many such areas are found across Nepal (Figure 13.2). They are problematic to rehabilitate because of their low pH, low organic matter content, low available phosphorous,

Figure 13.1: **The opinions of land users govern whether new technologies and approaches are accepted (India)**

Figure 13.2: **Degraded red soil site in Nepal**

poor physical properties, and aluminium toxicity. The pronounced dry periods of these areas' climates makes them difficult to rehabilitate (Shah et al. 1995).

The rehabilitation of such sites should begin by assessing their soil characteristics and the existing vegetation cover. Stocking and Murnaghan's 2001 handbook provides many useful pointers for rapidly assessing land degradation. The following technologies and approaches have been successful in rehabilitating the project sites.

Vegetative measures for stabilising gullies

Gully stabilisation has been an important strategy for rehabilitating badly degraded land in all of PARDYP's watersheds. PARDYP and its predecessor projects have found the following to help stabilise gullies.

- The species *Agave americana*, *Dendrocalamus strictus/hamiltonii*, *Thysanolaena maxima*, *Pennisetum purpureum,* and *Vitex negundo* are good bio-engineering species for gully plugging.
- Establish nitrogen fixing trees such as *Alnus nepalensis* in combination with any of the above mentioned species on more shady and less compacted soils. These shade surrounding areas to reduce moisture loss thus encouraging natural regeneration.
- Where vegetative measures alone are not enough to stem degradation, build check dams made from soil-filled bags or stones (Figure 13.3) and then plant on them.
- Plant trees on sides of small gullies to conserve moisture and facilitate grass growth.
- Dig diversion drains, as shown in Figure 13.4a, and stabilise them by planting hedgerow species on their sides to reduce the amount of topsoil washed into gullies. This also allows runoff water to be harvested.
- Build earth-filled dams (Figure 13.4b) near the outlets of these drains and at other places to trap sediment and collect water for local use.

Figures 13.3a & 13.3b: **Gully stabilisation using bio-engineering and structural measures (Nepal)**

Figure 13.4a: **Diversion drains, Nepal**

Figure 13.4b: **A pond built to collect water diverted from a rehabilitation site, Pakistan (PFI 1994)**

Vegetative measures for rehabilitating degraded slopes

The following measures have proved successful for rehabilitating degraded slopes.

- Establish contour lines of hedgerow species (preferably nitrogen fixing) on exposed and bare sloping areas using a modified Sloping Agriculture Land Technology approach (Pratap and Watson 1994). This involves lightly cultivating the surface of a narrow strip about 30 cm wide and then seeding the area with a few of the species in Box 13.2.

> Box 13.2: **Recommended species for planting in contour lines:**
>
> *Flemingia macrophylla, Desmodium intortum, Tephrosia candida, Leucaena diversifolia, Crotolaria juncea,* n-fixing *Indigofera species; Stylosanthes hamata, Melinis minutiflora, Vetiveria zizanoides, Sorghum alum, Pennisetum orientale, Thysanolaena maxima, Medicago sativa, Amorpha fructicosa, Pennisetum purpureum* (NB 21), *Cajanus cajan, Agave americana, Cotoneaster spp., Ficus tikoua, Mucella laciocarpa, Pueraria lobata,* and *Vitex negundo.*
>
> Amongst species tried in Pakistan, *Sorghum alum* gave the best results. *Medicago sativa*, white clover and *Chlorus gyana* did not perform so well due to competition from naturally occurring grasses.

> Box 13.3: **Recommended species for planting on slopes:**
>
> *Cassia siamea, Diospyros kaki, Phyllanthus emblica, Punica granatum, Zanthoxyllum bungeanum, Betula alnoides, Camptotheca acuminata, Melia azedarach, Schima wallichii, Toona ciliata, Toona sinensis, Trachycarpus fortunei, Trema orientalis, Acacia richii, Albizia mollis, Atylosia scarabaeoides, Bauhinia variegata, Bauhinia faberi, Caesalpinia decapetala, Albizia lebbeck, Robinia pseudoacacia,* and *Ailanthus alticima.*
>
> *Dalbergia sissoo* often suffers from die-back problem at maturity in Nepal and is no longer considered suitable for large-scale planting;

- Plant a mixture of some of the tree and shrub species listed in Box 13.3 alternately at one metre intervals throughout degraded areas.
- As much as possible, plant locally occurring species that are suitable for the sites and preferred by local people. For example, in the PARDYP watershed in India where the land degradation problems were not so severe, villagers preferred *Grewia optiva*, *Bauhinia retusa*, *Thysanolaena maxima*, *Quercus incana*, *Quercus glauca*, *Ficus macrophylla*, *Ougenia delbergioedes*, *Debregeasia longifolia*, and *Diploknema butyracea* as they find these most useful. Their fast rate of growth is shown in Table 13.2. Table 13.3 shows the high success rates of the tree planting at the Damai China rehabilitation site.
- Select species for planting on degraded sites according to, and in order of importance, species that: 1) grow on poor sites, including hot, exposed and dry conditions; 2) grow fast and establish quickly; 3) require less inputs; and 4) are preferred by local users.
- Encourage the natural regeneration of vegetation on degraded sites. The results of studies at Arah in India (Table 13.4) and Godavari in Nepal (Figure 13.5) show how sloping areas that are not too seriously degraded can be re-greened by natural regeneration. The data from Arah shows how 26 new species came in to the site between 1993 and 2000. Although the pioneer species *Imperata cylindrica* – a C4 pioneer species – remained dominant, its dominance had decreased by 2000 and the proportion of C3 type species that prefer better soils and moist conditions had increased. The species richness and

Table 13.2: **The growth of trees planted at Arah, Uttaranchal, India**		
Species	**Height (cm)**	
	1993	**2001**
Quercus incana	12	245
Quercus glauca	19	296
Grewia optiva	28	389
Ficus macrophylla	21	369
Ficus nemoralis	25	356
Debregeasia longifolia	25	396
Ougeinia delbergiodes	25	345
Bauhinia retusa	40	421
Albizia lebbeck	36	369
Dalbergia sissoo	30	496

Table 13.3: **Survival and plant canopy area of species planted at Damai, China two years after planting**		
Species	**Survival (% in 1995)**	**Canopy area (cm^2 in 1995)**
Flemingia macrophylla	100	1,525
Crotalaria assamica	90	758
Tephrosia candida	95	141
Cajanus cajan	95	8,153
Cassia siamea	90	14,427
Acacia richii	95	2,057
Acacia mangium	20	not available
Acacia meansii	70	364
Albizia mollis	95	1,398
Leucaena leucocephala	95	1,612
Eucalyptus robusta	90	286

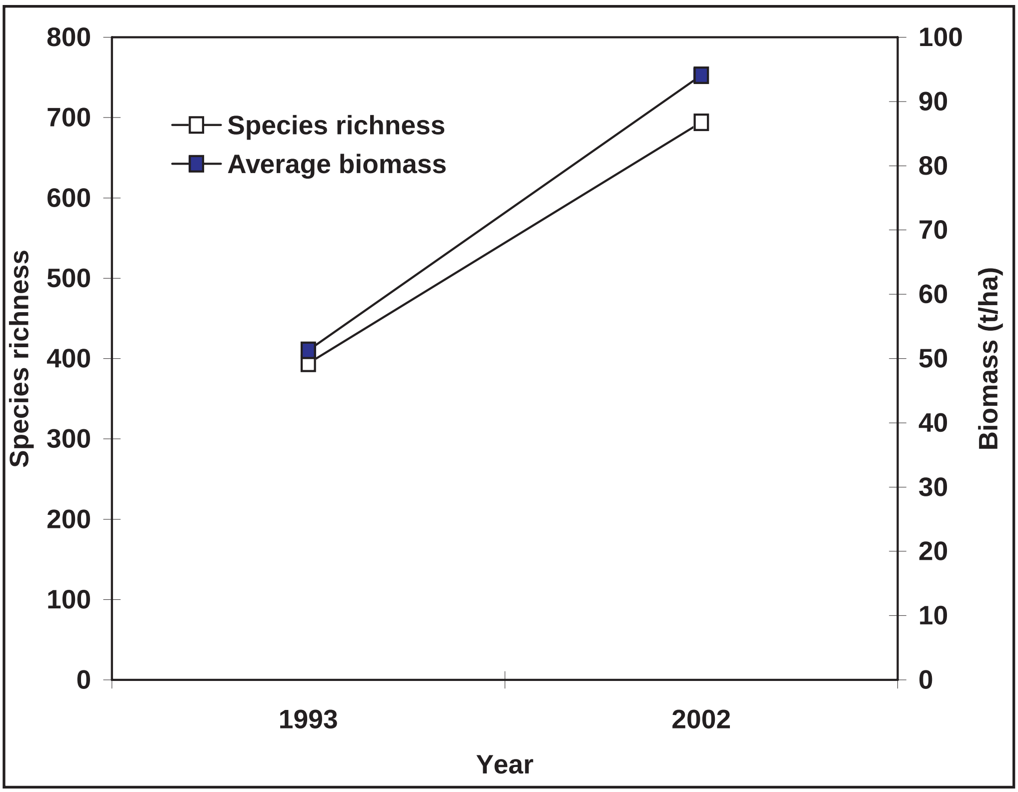

Figure 13.5: **Change in average biomass and species richness through natural regeneration of a degraded forest site, Godavari, Nepal** (Joshi 1994, 2002)

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Table 13.4: **Changes in the importance of species growing naturally on the Arah rehabilitation site (India)**

Species Names	Importance value index	
	1993	2000
Imperata cylindrica	128.45	96.33
Indigofera dosua	38.76	45.60
Erianthus rufipilus	19.11	16.56
Chrysopogon serrulatus	21.27	9.67
Cassia mimosoides	7.60	9.56
Desmodium triquetrum	10.00	8.23
Oxalis corniculata	6.00	7.16
Micromeria biflora	8.00	5.63
Heteropogon contortus	0.00	5.20
Potentilla fulgens	4.06	4.86
Setaria glauca	0.00	4.57
Fimbristylis miliacea	0.00	4.12
Dicanthium annulatum	0.00	3.98
Begonia picta	3.56	3.78
Adiantum lanulatum	1.00	3.56
Crotalaria semialata	3.23	3.56
Polygala abyssinica	1.00	3.46
Bothriochloa pertusa	0.00	3.45
Erigeron canadensis	4.00	3.41
Scrophularia calycina	3.63	3.16
Arundinella nepalensis	0.00	2.93
Cyperus compressus	0.00	2.90
Calamintha umbrosa	3.00	2.65
Origanum vulgare	3.00	2.63
Valeriana wallichi	0.00	2.56
Zornia gibbosa	0.00	2.56
Barlaria cristata	0.00	2.52

Note: 1) only the 27 species recorded the most in 2000 of the total of 54 are listed here.
2) a 0.00 value for a species means that it was not present. 3) The importance value index is the sum of relative dominance, relative frequency, and relative density of a plant species in a community.

average amount of biomass almost doubled through natural regeneration over 10 years at Godavari. The low cost of this technique makes it appealing to communities.

- Plant tree species at intervals of at least 1m to avoid too much competition for water and nutrients. It is best to plant at least one-year-old saplings grown inside nursery bags to plant in 0.5 m^3 sized pits and to add farmyard manure or humus-rich forest soil into the pits.
- Set up on-site nurseries (Figure 13.6) to ensure a supply of healthy seedlings. This also helps generate a local pool of native and potential exotic species. The growth of nursery plants can be increased by raising them inside polypits (Vyas et al. 1999).

Figure 13.6: **An on-site nursery in Bheta Gad watershed, India**

- Install low-cost water harvesting technologies such as simple polythene-lined ponds (Figure 13.7), to address short-term water needs. These ponds and the mulching of seedlings can overcome water scarcity problems. Where water is available all year round these ponds can be used for other purposes such as irrigating off-season vegetables and fish farming (Kothyari et al. 2002).

Figure 13.7: **Polythene lined water harvesting tanks in (a) Arah rehabilitation site (India) and (b) a rehabilitation site in Nepal**

- Make contour ditches or eyebrow 'terraces' (pits) (Figure 13.8) to help harvest surface runoff and conserve soil and increase the infiltration potential of land. Material planted along the bunds of these 'terraces' have a better chance of survival and good growth rates as they exploit water from the pits. Eventually the pits become filled with eroded soil.

Figure 13.8: **Eyebrow terracing at a PARDYP site in Nepal**

Benefits of Land Rehabilitation

The main benefits of rehabilitating the degraded sites have been:

- reduction in soil loss and runoff (Figures 13.9, 3.10), and increased soil fertility thereby maintaining the total stock of soil nutrients available to future crops; and
- increased biomass production (Table 13.5; figures 13.11, 13.12) and plant biodiversity meaning that women have to travel shorter distances to collect firewood and fodder, and making it easier for livestock herders to find dry season pastures.

Next Steps

Table 13.5: **Changes in grass production (dry weight), Khaderiya, India**

Year	Quantity of grass produced	Market value (US$)
1999	1.2	31
2000	4.3	131
2001	5.3	161
2002	7.0	213

Kothyari et al. 2003. Note: US$1:IR 46

The findings from the projects and other rehabilitation sites in the HKH suggest that there is a need to:

- carry out further trials to investigate the preliminary findings of Shah et al. (1995) suggesting that planting nitrogen-fixing fodder trees and grasses and applying lime on acidic red soils is a potential technique for rehabilitating these difficult sites;
- carry out in-depth studies across the PARDYP region of species growing naturally on degraded sites to identify other potential species for growing on dry, exposed, and degraded sites;

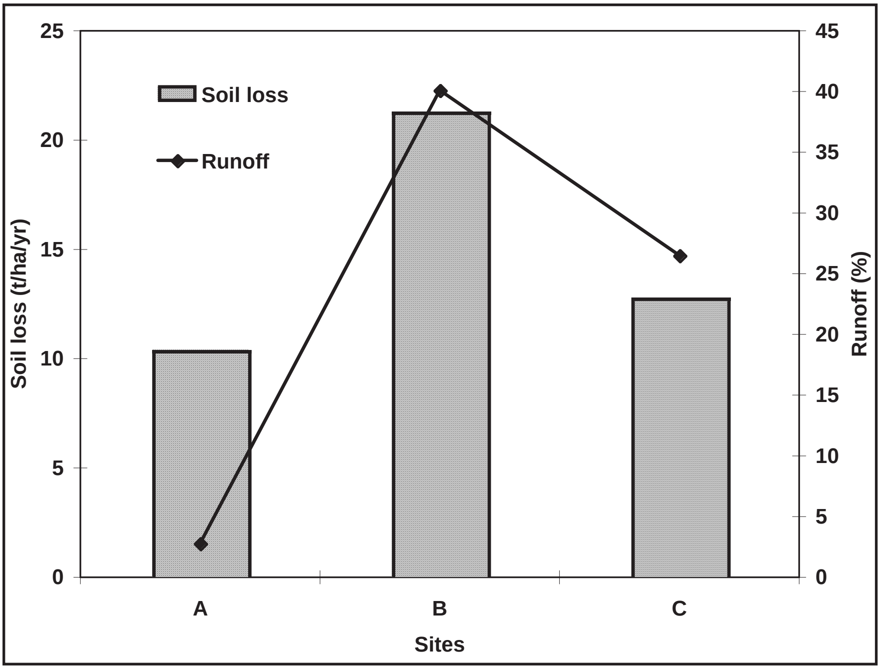

Figure 13.9: **Comparison of soil loss and surface runoff from three land use types in the Jhikhu Khola watershed, Nepal (A: sloping agriculture terraces, B: degraded red soils, and C: degraded plot in site B treated with broom grass)** (Mathema & Singh 2003)

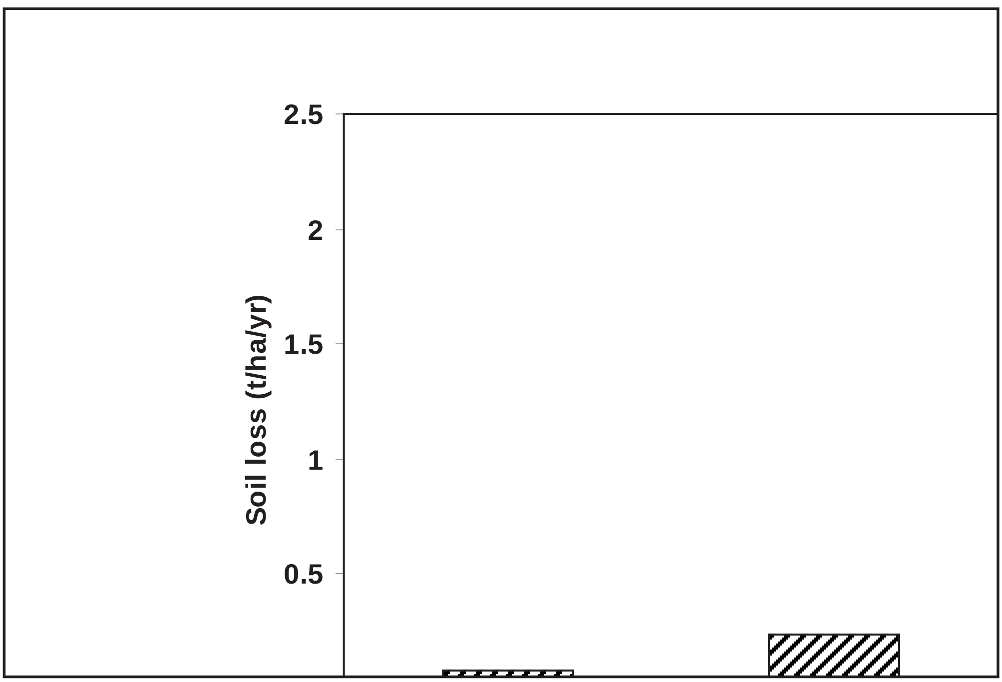

Figure 13.10: **Comparison of soil loss after 2 years of rehabilitation work showing treated and untreated (natural bare) areas, Damai, China** (Anonymous 1995)

Figure 13.11: **In Arah (India) the rehabilitated site produced 5.5 t/ha of grass in 2001 compared to 1.2 t/ha in 1993 before rehabilitation**

Figure 13.12: **In Nepal, grass harvested from the rehabilitated site in the centre of the picture was 10 times more than from untreated degraded areas as in the foreground**

- identify species most preferred by local farmers. A case study from Nepal (Baral et al. 1999) found that a species of *Cassia* that grew well on degraded slopes was not liked by local users;
- identify where forest regulations hinder the planting of certain species. Some countries limit the right to harvest certain valuable tree species which dissuades people from planting them;
- carry out further tests of farm-based technologies, such as polypits and biofertilisers, to see if they help plant establishment in degraded areas;
- carry out further research on how to reduce the large amounts of stream sediment that Merz's 2003 study identified as coming from degraded surfaces. This could be done by identifying potential soil and water conservation species;
- prepare lists of organisations working on the rehabilitation of degraded lands in the HKH region to facilitate networking and share experiences; an
- further investigate the following non-technical issues:
  - **land tenure** is of crucial importance as farmers and communities with clear title to land are more likely to invest in conservation measures as they are assured of benefiting. For example, the government owns Nepali community forestry sites and so users are not assured of their continued tenure and are sometimes reluctant to invest in their improvement (Karki and Chalise 1995);
  - **poverty** affects how land users manage and develop their land. Poverty-stricken people are unlikely to carry out conservation practices that need too much investment of time, land, labour and capital;
  - **economic incentives** can have a negative effect as conservation measures that attract direct financial inducements that are later withdrawn can dissuade farmers from practising conservation without payment later on;
  - **economic and financial returns** as decisions made by land users are sometimes based on their particular perceptions of economic rationality; and
  - **off-site versus on-site costs** as few land users living upstream will invest in measures that benefit downstream communities unless they receive incentives.

Conclusions

Many of the above findings are site specific and need further testing to assess the conditions where they can be applied. Species choice is in many cases dependant on local soil and climatic conditions. However, the common occurrence of similar types of degraded areas across the HKH provides good scope for replication. Areas of red soils in Nepal are of special concern as they have estimated erosion rates of up to 200/t/ha/yr (Biot 1990). China also has many areas of degraded red soil (Zhang 1991). In the Indian central Himalayas large tracts of rainfed agriculture fields are abandoned and degraded. There is therefore a great potential for applying PARDYP's findings and more attention needs to be given to disseminating them to the main target audiences of community users and land managers.

Acknowledgements

The authors wish to thank PARDYP country coordinators and research staff for their help during this review. The authors are particularly thankful to the PARDYP teams for providing information and photographs, and to Samma Shakya for technical help. Financial support from the Swiss Agency for Development and Cooperation, the International Development Research Centre, and the International Centre for Integrated Mountain Development is gratefully acknowledged.

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14

Access to Forest Resources in Hilkot Watershed, Pakistan

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Abstract

This study analyses local communities' access to forest resources in Hilkot watershed in Pakistan's North-West Frontier Province. This area's forests are held under a variety of ownership arrangements. The deeply dissected land tenure system and conflicts between the government and forest users have led to a drastic degradation of the resource. Although legislation theoretically limits the rights of local people, in fact the majority of them have access to forest resources. They fulfil nearly all their requirements from these forests but contribute nothing to their protection and development. The existing forest legislation and management systems have failed to achieve their objectives and if nothing is done to check degradation then the forests will soon disappear. The study argues for the introduction of participatory forest management. It gives options and approaches for the sustainable development of the forest resource that will also improve rural livelihoods.

Introduction

The Hindu Kush-Himalayas are home to natural resources that provide life-support to mountain communities and tens of million of plains dwellers. Forests are the most important of these resources as they provide a wide range of economic, social, environmental and cultural benefits and services. Mountain people have always depended on forests to fulfil their basic needs for fuelwood, fodder, leaf litter, timber, fruit and medicinal plants and for other essential inputs into the farming system. These forests also protect the natural resource base for growing agricultural crops and protect the upland watershed against erosion, thus regulating waterflow in downstream areas.

Only 4.8% of Pakistan's 88 million hectares are forested. This is a very low coverage compared to the average of around 26 percent forest cover for other countries. Per capita forest cover presents a gloomier picture. Pakistan has only 0.03 ha of forest per capita while the corresponding figure is 1.07 ha for developed countries and 0.50 for developing countries (Government of Pakistan 1992, FAO 1995). However, Pakistan's forests play an important role in the country's economy by providing employment to about half a million people, and by providing 3.5 million m^3 of wood, and one third of the nation's energy needs (Government of Pakistan 2002). Most of the country's forests are in the northern areas with 40% in the North-West Frontier Province (NWFP). The NWFP forests are distributed over the Himalayas in Hazara division and in the Hindu Kush in Malakand division (Ahmed and Mahmood 1998; Poffenberger 2000, Suleri 2002).

Participatory forest management has emerged as a common strategy in the Hindu Kush-Himalayas to protect and manage forests. A key element of this approach is collaboration between government institutions, NGOs, and local communities. ICIMOD's People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP) operates in Nepal, India, China, and Pakistan. It is promoting participatory forest management and developing options for the balanced, equitable and sustainable development of natural resources.

PARDYP is investigating equity and poverty linkages and advocacy issues to promote more equitable access to the common property resources of the Hindu Kush-Himalayan region. This programme involves preparing a series of case studies on communities' access to common property resources. The present paper is the Pakistan case study.

Study Site, Objectives and Methodology

Hilkot watershed, in the NWFP's Hazara division is a mosaic of diverse ethnic, socioeconomic and plant communities. Forests are held under a variety of ownership arrangements broadly divided between state and private forests. In Hilkot, watershed forests are managed under the Hazara Forest Act, 1936, that emphasises protection and limits community access. However, this legislation has achieved little and the forests have been degraded and owners and users now benefit less from them than in the past. This has led to growing concern to find ways of sustainably managing these forests. This concern is most marked to conserve upland forests that provide so many of the daily needs of upland communities.

The objectives of the Hilkot case study were to:

- assess the status of community access to forest resources with respect to gender, ethnic, social and political issues;
- identify flaws and deficiencies in the local system of forest management;
- assess the local institutional capacity for decision making, planning and policy implementation and its response to field issues; and
- develop options and approaches to improve equitable access to forest resources that ensure better livelihoods for mountains communities and sustainable development of the resources.

This report analyses the institutional setup that regulates communities' access to forest resources in Hilkot watershed. Primary data was collected by asking set questions to local people and by holding focus group discussions across all of Hilkot watershed's communities. Secondary data on the institutional set-up, forest legislation, forest policies, and baseline information was obtained from PARDYP, the local forest department, government records, and other publications.

First of all a preliminary survey was undertaken. This allowed the questionnaire to be tested and refined and a list of all 800 village households to be built up. Individual sample household heads were selected by random sampling. In all, 80 household heads were interviewed with an equal number of men and women. Thus the sampling intensity was 10%. Besides, focus group discussions were held to include owner groups, tenant groups, and officials from the provincial forest department.

Guzara and Reserved Forests

Guzara forests

Hilkot's forests are divided into reserved forests (state forests) and guzara forests (private forests). The guzara forests are held individually by families or jointly by communities. Except for the period 1981-92, these forests have been managed by the forest department. For the 12 years from 1981 they were managed by forest cooperative societies.

Guzara forests were set apart in 1872 to meet the domestic, agricultural and pastoral requirements of village communities. They are divided into 'mahduda' and 'ghair mahduda' forests. Mahduda forests, also known as protected wastelands, were demarcated and it is prohibited to break them up for cultivation, house building or to enclose them as private property. Ghair mahduda forests do not have such restrictions.

The guzaras are managed under the Hazara Forest Act, 1936. Their management was the responsibility of the Deputy Commissioner, Hazara until 1950 when it was transferred to the Forest Department. The Guzara Rules, 1950 gave the conservator of forests of Abbottabad full responsibility for managing guzara forests.

The government admits the proprietary rights of villagers over guzara forests subject to the limitations that the government retains the rights to 1) receive a seigniorage fee of 20 percent of forest revenue for managing and developing these forests, and 2) to introduce forest conservancy measures as needed.

Section 12 of the 1936 act defines the rights of owners and government as follows:

> *Subject to the rights and powers of the Government in respect of seigniorage and forest conservancy as defined in this act, or in rules made thereunder, and subject also to the claims of right holders, not being owners of the soil, all wastelands (Guzaras) are property, held jointly or severally. As the case may be, of all the owners of the village in whose boundaries they are included and such landowners are entitled to use free of charge, for their own domestic and agricultural requirements, any trees and forest produce found in those wastelands. But they shall have no right or power to sell any trees or brushwood growing in such lands except with the permission of the Deputy Commissioner or other officers authorised by the Government and under such condition as the Deputy Commissioner may impose and all sales shall be subject to payment to the Government of seigniorage fees as provided by Section 27.*
>
> *The claims of right holders other than the landowners of the village shall be recognised to the extent defined and recorded at settlement, or in case of doubt or dispute, to the extent which may hereafter be defined by the Deputy Commissioner with the sanction of the Local Government, and the exercise of such rights shall be subject to the provisions of this Act and the rules made there under.*
>
> *All Deodar trees shall be deemed to be the property of Government and nothing in this section shall be held to affect the rights of the Government thereto.*

The 1936 act clearly defines how the guzaras should be managed and defines the powers of the forest department as holding the right to:

- demarcate and protect any part of the guzaras against erosion and degradation by prohibiting the practising of any right given to villagers in that part of the forest;
- assess whether or not the supply of grasses, shrubs and trees is adequate for villagers' basic needs and if it is not to set apart, by its own decision or at the request of the owners, a considerable part of the forest to provide for these needs;
- appoint a village forest officer to manage the guzaras and to issue orders directing any such officer to improve the management and conservation of the guzara;
- punish any offender with imprisonment of up to six months or a fine of up to five hundred rupees (female offenders can authorise any person to appear before the government for inquiry on their behalf); and
- recover the cost of management of guzaras from all right-holders and landowners from land revenue.

Reserved forests

Local people have no rights in reserved forests. The rights of passage, water, and grazing are only allowed as concessions by the government. The responsibility for management rests with provincial forest departments as per Section 3 of the Hazara Forest Act, 1936. Section 4 states that reserved forests are government property:

> *Subject only to the rights defined and recorded at the time of settlement and to the payment to the village land owners of seigniorage fees as provided in Section 27, the reserved forests shall be deemed to be the property of the Government and the forest income accruing from them shall be credited to Government as forest revenue.*

The act specifies a punishment of imprisonment up to six months, or a fine of up to 500 rupees, or both, plus compensation for the following types of damage done to a reserved forest:

- setting fire to a reserved forest or kindling any fire or leaving any fire burning in such a way as to endanger;
- kindling, keeping or carrying any fire;
- grazing or driving cattle or permitting cattle to trespass;
- cutting, lopping, tapping, or burning any tree or brushwood or stripping off their bark or leaves from or otherwise damaging them;
- causing any damage by negligence in felling any trees or cutting or removing any forest produce;
- quarrying stone, burning lime or charcoal, or collecting or removing any forest produce;
- cultivating any land or cleaning or breaking up any land for cultivation or any other purpose;
- erecting any building or making any enclosure;
- entering a fenced enclosure;
- shooting or fishing in contravention of any government rules; and
- setting snares or traps, or poisoning water.

Forest Disputes

The documented forest history dates back to the middle of the nineteenth century at the start of British colonial rule. Little is known about the pre-colonial pattern of land ownership except that it was predominantly communal. Singh (1986) estimates that at least 80 percent of the total natural resources of India were commonly 'owned' by those living close to them (Azhar 1993).

After colonisation the British started their land settlement process. The state extended its control to forest lands through the Indian Forest Act, 1878 and in the process nationalised a fifth of India's land area. This provoked local people because it limited their access to forest resources. No significant changes were made after independence in 1947. With the passage of time conflicts over forest use have increased with the following three main types of conflict prevalent in Hazara civil division.

Between government and local people — In many places local people have never recognised reserved forests as government property and still consider that they hold the rights over them. They do little to protect and develop these forests and so there has been considerable encroachment on guzara and reserved forests.

Between government and guzara forest owners — Although the government recognises guzara forests as private property it still holds control of them in the name of forest management. This has disgruntled owners who mostly oppose government control. They want complete control of their property to manage, protect, use, and develop.

Between owners and tenants — There is a complicated land tenure system in Hazara. The big landholdings mean that owners are not able to manage their agricultural and forest land and so they let it out to tenants. Most of these tenant families have lived on these lands for centuries and believe they have rights over them. State law says that owners can only evict tenants after following lengthy legal procedures. Tenants demand a substantial share of forest resources, which they consider as common property resources. The owners' refusal to accept their demands has led to tenants violating the law to meet their needs for fuelwood, timber, and fodder from these forests.

Forest Policies and Laws

National forest policies

The forest resources of the Hilkot watershed are managed and controlled under national forest policies. The Government of Pakistan enacted forest policies in 1955, 1962, 1975, 1991, and 2001. The 1955 and 1962 policies emphasised the management of public forests and were particularly concerned with expanding the forested area to generate revenue and maximise yields. Environmental and social issues were not considered. These policies took a top-down approach and reinforced the notion that communities had no role in forest management and no stake in preserving public forests.

The 1975 forest policy was formulated in response to the widespread loss of forest resources after the separation of East Pakistan in 1971. The policy drafting committee included representatives from government and non-government institutions. This was the first people-friendly policy enacted in the forestry sector. It recognised that the management of guzara forests should be entrusted to the owners with the state taking on only supervisory responsibilities. The policy recommended the formation of owners' cooperatives societies, but stated that harvesting should be carried out entirely by public sector corporations.

The 1975 policy soon fell prey to political expediency. The government that had formulated the policy was removed in a coup in 1977 and the new government, which had not wish to continue with its predecessor's initiatives, started to reconsider the policies for managing natural resources. From 1977 to 1988, forestry was considered a subsidiary part of agriculture, and forest policies were enacted as an appendage to agricultural policies.

The 1991 policy represented a turning point. It was influenced by donor agencies and Pakistani NGOs involved in implementing forestry programmes at the grassroots level. The most significant contribution of these grassroots programmes has been to demonstrate the participatory approach to forest management. The 1991 policy recognised the importance of participatory forest management and placed greater emphasis on social forestry and biodiversity conservation. But, due to political instability this policy remained confined to the files and shelves of government offices and hardly any implementation was carried out.

Recent debates about governance, poverty, and environmental sustainability have emphasised a rights-based approach in which equitable development is strongly associated with individual and communal rights. The draft National Forest Policy, 2001 has the improvement of livelihoods as its fundamental goal. It calls for involving local communities in implementing projects, managing forests, and implementing joint forest management.

NWFP forest policy

Although policy formulation is mainly the responsibility of the federal government; due to its rich forest resources, diverse ecosystem, and unique cultural and socioeconomic conditions, the government of the North-West Frontier Province promulgated its own forest policy in 1999. This focuses on meeting the domestic needs of local communities, increasing income opportunities, conserving and developing natural resources, rehabilitating rangelands, and generally improving the environment. The policy is based on the principles of integrated resource management, people's participation, the promotion of the private sector, equity, public awareness, incentives and cross-sectoral linkages. It also calls for updating forest legislation and the institutional transformation of the forestry sector.

Forest legislation

The Forest Act, 1927 is the prime forestry legislation in Pakistan. It was promulgated to support the forest service to conserve and protect public forests from human and animal damage. This has led to the forest service almost exclusively relying on the force of law to achieve its main policy objective of forest conservation.

The forest legislation is regulatory and punitive. Section 75, Chapter 11 allows the government to invest any forest officer with the power to (a) enter upon any land and to survey, demarcate and map it, (b) to compel the attendance of accused persons and witnesses and the production of documents and material objects before a civil court, (c) to issue search warrants, (d) to hold an inquiry into forest offences, and (e) to try forest offence cases and to issue punishments. Section 82 makes every person living nearby forests responsible to help in controlling forest fires and preventing forest offences. Chapter 6 details penalties of up to six months imprisonment and fines up to 500 rupees, or both. Also, the government may confiscate any property (tools, boats, carts, and cattle) suspected of being used to commit a forest crime.

Most forests in Hazara civil division are privately-owned guzara forests. The Hazara Forest Act, 1936 details local communities' rights and the rights concerning management and control of forest resources in this area. The penalties and procedures are the same as specified in the Forest Act, 1927.

Implementation of forest laws

The enforcement of forestry legislation has not been effective. Local people cite corruption practised by forest officials as the main reason for non-implementation. Forest officials argue that their areas are too large to oversee and to prevent encroachment and the theft of forest products. Also, they claim it is difficult to detect forest crimes. The law relies on forest officers and local people detecting crimes, but the lack of cooperation and understanding between these two groups makes this impracticable.

Khattak (1994) makes the important point that the legislation says nothing about the obligations of the government and provides no mechanism to remedy forest depletion caused by government neglect. He also points out that the punishments for contravening the act have remained unchanged since 1865 while the profitability of illicit trade in timber has increased 500 times. The difficulty of proving an offender's guilt in court and the small punishments means that the law provides little deterrent.

Ashraf (1992) says that the effectiveness of forest laws is further undermined by two factors. Firstly, the judiciary and other law enforcing agencies hold matters relating to forest law in low esteem. They give a low priority to forest cases and often keep them pending for ages. Secondly, the misuse of their powers by some forest personnel invites public contempt of the law and instigates them to violate the law in protest.

Institutional set-up of forest department

The chief conservator of forests heads the Provincial Forest Department. There are several management circles in a province each headed by a conservator of forest. One circle comprises several forest divisions. The forest division is the basic unit for forest management and they are each divided into forest ranges.

Hilkot watershed's guzara and reserved forests are within Battal Forest Range which is headed by a range forest officer. He is supervised by the divisional forest officer of Siran Forest Division. The lowest tier in the hierarchy is the forest guard deputed to protect forest ranges. There are only two forest guards to protect Hilkot's large area of guzara and reserved forests.

Forest Cooperative Societies

Introduction and abolition

The guzara forests cover 1.39 million ha in Hazara Civil Division. They are owned by local landowners with management responsibilities resting with the forest department. Until 1950 the management of these forests lay with the district administration. The government of NWFP's Guzara Rules, 1950 transferred their management to the forest department.

The guzara owners became disgruntled with the managerial control of the forest department. They claimed that it was failing to protect the forests from the incursions of migratory graziers and from the mounting demands for forest products from the growing human population. They made several petitions to the government after which the Agricultural Inquiry Committee recommended that the management of these forests be transferred to the owners organised into cooperatives. Accordingly an experiment in the shape of the cooperative management of guzara forests was launched in 1981 under the Cooperative Act, 1925.

A total of 33 cooperative societies were formed in Hazara division to manage its guzara forests, with two formed in Hilkot watershed. These societies were made up of representatives of the owners and the forest department. They took over the management of the guzara forests in 1981. However, they carried out extensive commercial harvesting of the forests without considering the ecological consequences. This led to heavy losses during the floods of 1992, after which the prime minister abolished these societies.

Problems and challenges

The following factors led to the failure of the cooperatives system of forest management.

Departmental resistance — Most forest officers opposed the experiment. However, rather than addressing these objections the forest secretary took the whole process directly into his hands. This led to strained relationships between the forest department and cooperatives.

Hasty management transfer — The experiment was intended to start with trials in its first six years. However, by 1983, only three years after its introduction, 18 forest cooperative societies had been registered. The process was never allowed to evolve and the concepts were not tested and adapted before larger scale application. Furthermore, full management authority was entrusted to cooperatives before they were ready to handle these responsibilities.

Politicisation — The substantial influence of forest contractors and owners on provincial politics meant that it was very difficult for the provincial government to gain control.

Legal apparatus — The basic premises of the Cooperative Act 1925 were inappropriate for the management of natural resources in the hills of Pakistan as the legislation was orientated towards providing credit for agricultural development. This was one of the main reasons for the failure of the cooperative system.

The main operational weaknesses of the experiment included:

- the lack of real participatory resource management. The cooperatives were dominated by the leading forest owners often all from a single family. There was no participation by small owners, tenants, and seasonal grazers who were deprived of access to forest resources;
- the failure to manage adjacent non-forested land was contrary to the concept of integrated resource management and resulted in the depletion of forests as no steps were taken to improve adjacent denuded slopes;
- massive irregularities in the use of funds earmarked for operations and development. The owners' shares were often misappropriated and there were frequent cases of fraud and embezzlement by cooperative office bearers;
- the widespread malpractice of the sale of standing trees, which was concealed through fictitious record keeping, allowed for the re-entry of banned forest contractors into the system; and
- defective management plans prepared by the forest department that prescribed cutting volumes far in excess of sustained yield and that failed to prescribe appropriate silvicultural systems. This accelerated forest denudation.

One of the fundamental reasons for failure was that a supposed experiment was implemented on an operational scale from the beginning without going through an experimental phase. Its failure should not be blamed on its participatory approach. The concept is a valid one provided that responsibility is clearly delegated to owners, guided by clear regulations, controlled by owners' democratic organisations and assisted in technical and organisational management and regulated by honest and efficient government agencies.

General Situation in Hilkot Watershed

This section looks at the situation of forest management and use from the point of view of Hilkot's people.

The total area of Hilkot watershed is about 1600 ha. It covers part of the catchment of the Siran river, one of the major tributaries of the river Indus which drains into the Tarbela reservoirs, a crucial source of hydropower and irrigation water. The area's climate is humid temperate and the area ranges in altitude from 1342m to 2672m. The area has a population of 7500.

The population is divided into Swatis (28%) and Gujars (72%). The Swatis live in the lower watershed areas and own most of the forest and agricultural land rights. They have a relatively good socioeconomic standing and enjoy better education, communication and health care than the Gujars.

The Gujars are mostly tenants and are economically and socially 'backwards'. They live in the upper hilly areas. Most tenant the agricultural lands from which they take a share of agricultural produce. They fulfil their fuelwood, fodder and timber needs from the forests, but don't have any share in forest revenues. Their main source of income is livestock rearing and daily labouring. They have inadequate access to education, communication, and health care facilities.

Of Hilkot watershed's area 44% is forested with about half being guzara forest and half reserved forest. Blue pine (*Pinus wallichiana*) is the dominant species. On ridges it is mixed with deodar (*Cedrus deodara*) and fir (*Abies pindrow*). The total volume of wood in guzara forests is about 118,000m^3 and in reserved forests 112,000m^3 (Cheema et al. 2000). Table 14.1 gives estimated figures for the amount of timber in the watershed's forests.

Survey Findings

Access to forest resources

A sample survey was carried out to investigate local people's access to forest resources in the Hilkot watershed. It found that over two-thirds of Hilkot households had access to forest resources with 72% of households having access to guzara forest and 56% to reserved forest (Table 14.2). The lesser access to reserved forest is due to the greater forest department control over these forests and there distance from settlements.

Just over half of Hilkot households were found to fulfil their demands for timber, fuelwood, grass, and leaf-litter from local guzara and reserved forests (Table 14.3). Legally only forest owners are entitled to get timber from guzara forests and then only with written permission from the forest department. The forest department issues permits to owners to fell a maximum of four trees for building their houses and other local uses, but not for commercial sale. This

Table 14.1: **Volume of wood in Hilkot watershed's forests**					
Forest	**Forest area (ha)**	**Species**	**Volume (m^3)**		
			Timber	**Small wood**	**Total**
Reserved forests	332	Kail	69,838	3,020	72,858
		Deodar	30,639	8,456	39,095
		Sub-total	100,477	11,476	111,953
Guzara forests	378	Kail	45,673	8,190	53,863
		Deodar	11,583	4,669	16,252
		Fir	47,555	975	48,530
		Sub-total	104,811	13,834	118,645
Total	**710**		**205,288**	**25,310**	**230,598**

right is often misused by locals cutting more trees than permitted and selling them on. In the survey no forest owner admitted that they took timber from reserved forests. Most owners bought fuelwood as they do not have time to collect it from their forests. Also they consider it beneath their social status to collect fuelwood.

Table 14.2: **Access to forests, Hilkot watershed**		
Category	**Guzara forest (per cent)**	**Reserved forest (per cent)**
Access	72	56
No access	28	44
Total	100	100

Table 14.3: **Local people harvesting forest products, Hilkot watershed**		
Category	**Guzara (per cent)**	**Reserved (per cent)**
Timber	59	50
Fuelwood	55	56
Non-timber forest products	50	44

Table 14.4: **Local people buying forest products, Hilkot watershed**	
Category	**Percentage buying**
Timber	28
Fuelwood	34
Grass	15

Although tenants have no rights in guzara and reserved forests they said that they got timber, fuelwood, litter, medicinal plants and grass from them. Timber is collected as needed, whilst fuelwood is collected throughout the year and grass in August and September. They pay nothing to the owners or forest department, but when they are caught by forest guards they have to pay a fine usually of between Pakistani rupee 500-1000 (US$ 9-18). However, these fines are often taken without following the proper procedures.

Although there is no strict prevention of access to forests, some marginalised groups — mostly tenants and other non-owners — purchase timber, fuelwood and dry grass (Table 14.4). The survey found that 28% of respondents purchased timber, 34% purchased fuelwood, and 15% dry grass. The price of timber was PR 300/ft^3 for deodar wood, PR 200/ft^3 for kail, and PR 100/ft^3 for chir pine. For fuelwood the average price was PR 100 per 50 kg, and for dry grass PR 10-20 per 20 kg load.

In the lower forest-owner communities, women tend not to be involved in activities outside their households. In the upper tenant communities women are equally involved in collecting fuelwood, grass, and other non-timber forest products. They often spend 3-4 hours each day collecting grass and fuelwood from the forests.

Hilkot watershed is rich in medicinal plants with guchi, mameh, rathan jot and banafsha the most common species. Almost all local people know about these plants. Half of the survey respondents — mostly tenants and poor people — were found to collect them and 20% sold them locally (Table 14.5). About 30 percent of people use them to treat ailments such as colds, cough, fever, and stomach aches.

Table 14.5: **Local people collecting and using medicinal plants, Hilkot watershed**

Category	Percentage
Collection	50
Marketing	20
Use in local medicine	30

Grazing is viewed as one of the main causes of forest degradation in the Hindu Kush-Himalayas. In Hilkot the majority of people (68%) graze their animals in guzara and reserved forest without any restrictions. Almost all people from the upper communities graze their animals in the forests as livestock rearing is a main source of income and they don't have sufficient forage for stall feeding. Few lower community people keep animals.

The survey asked local people whether they thought grazing harmed the forests. Two-thirds replied that it was not harmful and a third that it did harm. These answers seem to reflect the desire of the two-thirds who graze their livestock in the forests to continue this practice.

Perceptions about forest management

Only 34% of respondents were aware of the forest department's work to plant Hilkot watershed's wastelands with trees in the 1980s. This reflects the poor involvement of local people in this initiative. The traditional top-down approach of the forest department gives little scope for the participation of local people in planning, managing and protecting local forest resources.

About 56% of respondents said that they were willing to participate in forest department activities such as afforestation and forest protection even under the present system of forest management. Undoubtedly more people than this would be willing to participate if incentives were provided for local people to get involved in managing reserved and guzara forests.

Almost all respondents felt that the condition of the area's forests had rapidly declined over the last ten years since the banning of the commercial harvesting of trees. Most of them cited illicit cutting and the corruption of forest officials whilst others pointed to population increases and the lack of alternate job opportunities as the major reasons for forest decline.

Overall most respondents were unsatisfied with the present system of forest management. They consider it to have completely failed to protect the forests and fulfil local needs. It is particularly the owners who oppose the system that has excluded them from managing and controlling their property.

Conclusions and Suggestions

Conclusions

This study found that the present forest management system has failed to safeguard the interest of locals and conserve forest resources. The gap between resource owners and managers has widened since the abolition of cooperative societies. In spite of it being illegal, local people continue to fulfil their needs for timber and fuelwood from these forests. As such they contribute nothing to developing and protecting the forests. On the other hand forest department officials seem to be little concerned about forest decline. According to local people they only seek their vested interests and are involved in illegal cutting.

The growing conflicts between the government and owners and between owners and tenants have led to much forest destruction. Tenurial uncertainties and inequalities are a major cause of forest depletion. The owners consider it unbearable that they are being deprived of the rights vested them in law. Tenants consider it inequitable for landlords to claim major benefits from forests even when they do not live in the area.

Current forest policy and legislation has failed to conserve forests and promote sustainable development. The resource is rapidly declining and the socioeconomic conditions of the owners and users are deteriorating day-by-day. There is an urgent need to change forest policies, legislation, and the institutional set up of the forest department.

Suggestions

The following suggestions are made for the sustainable development of the forest resources and the livelihoods of the people in Hilkot watershed.

- Decentralise and democratise forestry through organisational, legal, and political reforms to develop sustainable partnerships between stakeholders.
- Replace the current system of forest management with a participatory management system to improve the rural livelihood and manage the resource in a sustainable way.
- Promote close collaboration between government institutions, NGOs, and local communities.
- Gradually handover the management of guzara forests to owners with the forest department assuming a supervisory and technical role. At the same time allocate some share in revenues to tenants residing in forest areas with agreement from all stakeholders.
- Make owners and tenants responsible in law for protecting and reforesting their forests. Rule violators should be punished and their shares in the revenue suspended in agreement between stakeholders.
- Allow all owners and tenants residing near guzara forests to get timber and fuelwood from these forests for their domestic needs under an appropriate system devised by stakeholders.
- The government should give temporary ownership rights of reserved forests to people without rights in guzara forests. It should maintain strict control over these areas at first, but once stakeholders have proved their good intentions and abilities these rights should be legalised with forest departments playing a supervisory role.
- The forest department should encourage the participation of local people to protect and afforest reserved forest by providing them with incentives such as allowing them to harvest timber and fuelwood for their subsistence needs.

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Working with Communities in Hilkot Watershed, Pakistan

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Abstract

The more productive and sustainable use of the limited arable land and other natural resources is a key strategy to improve environmental conditions and local living standards in the middle mountains of the Hindu Kush-Himalayas. In late 1999 PARDYP began working to achieve this in the remote Pakistani watershed of Hilkot. It first carried out a socioeconomic survey and a gender and institutional analysis to see how local farming systems operated and how local common property resources were used and to identify improvement measures. PARDYP then began promoting a number of measures to improve local livelihoods and environmental conditions. It helped establish a network of separate social organisations for men and women that pool savings to spend on common problems. Skill development and income generating trainings have been run including on food and vegetable preservation, kitchen gardening, solar devices, and seedling nursery management. Women's community centres have been set up to run skill training courses. These initiatives have created awareness and motivated local women and helped them increase their earning power.

Background

Hilkot watershed lies in the remote hilly district of Mansehra in Pakistan's North-West Frontier Province. It has a population of 7500, an average literacy rate of 37%, an average household size of eight persons, and a per capita land holding of 0.05 ha (Khan and Shah 1998). It is a remote area where agricultural extension and outreach activities have only had a limited impact. Economic resources are few and most local people rely on agriculture, forest and local rangelands to meet their food and other livelihood requirements.

One of the area's main problems is forest degradation. The government owned forests are managed and controlled under the Forest Act, 1927 and the government's forest policy. These are considered to be oppressive and authoritative by forest users as they give local communities few rights over their forests. The lack of capacity of the forest department has led to the degradation of the vast tracts of forest under its jurisdiction.

The local population is made up of the two major tribes of the Khans (Swatis and Syeds) and the Gujars. The former are mostly agricultural landowners and the latter are tenants. Gujars make up all of the population or the majority in six of the area's settlements with Swati and Syed in the majority in the other two.

Socioeconomic Survey

In late 1999 PARDYP (the People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project) began work in Hilkot watershed to address the areas resource degradation and livelihood problems. The initial task was to survey the social and economic status of local people and local resource management institutions.

Table 15.1: **Distribution of ethnic groups in Hilkot**

Community	Gujar (%)	Swati (%)	Syed (%)	Total
Hilkot	-	100	-	100
Jolgran	100	-	-	100
Stangali	100	-	-	100
Kund	100	-	-	100
Mera	66	25	9	100
Kotani	76	20	4	100
Bojri	95	5	-	100
Syedabad	-	20	80	100

Source: Khan and Shah 1998

Table 15.2: **Land tenure status in various communities**

Community	Owner	Tenants	Owners cum-tenants	Total
Hilkot	90	5	5	100
Syedabad	70	10	20	100
Kandi	90	5	5	100
Jolgran	-	80	20	100
Kund	-	90	10	100
Mera	76	20	4	100
Kotani	20	60	20	100
Bojri	10	60	30	100

Source: Khan and Shah 1998

The survey mapped the distribution of the main ethnic groups (Table 15.1) and classified local households into income classes. The average land holding size for the poor class was taken as below 0.5 ha, middle class 0.5-1.0 ha, and rich class above 1.0 ha. Other sources of income than agriculture were found to be labouring jobs for poor class people, government service for middle class people, and government service, business, and income from overseas for rich class people. Forty four percent of households were found to be middle level, 34% poor, and 22% rich. In three of the eight communities, most people (60 to 90%) were landowners, whilst in Jolgran and Kund everyone was a tenant. In the other three communities between 10% and 25% of local people were landowners (Table 15.2).

The survey found that the local pattern of land ownership and the system of natural resource management has led to many conflicts. These usually take place between tenants, owner-cum-tenants, and right holders. They also sometimes arise between individuals within the same tenural class. The most common types of conflict happen over division of land, the demarcation of boundaries, the theft of livestock or grass and timber, the unjustified use of irrigation water, and the sharing of benefits from agricultural and grassland between owners and tenants. Conflicts between people of different socioeconomic groups over the violation of social norms were found to becoming rarer.

The survey identified the following user groups that exist for the local management of forests, grasslands, and irrigation systems.

Forest user groups — Forest user groups are made up of people who use the forests including owners and right holders, and those without any recognised rights. Hilkot's forest resources are either state owned or privately-owned guzara forests. The latter can be owned by several people. In state-owned forests informal user groups exist whose members have rights to grazing, and to collect fuelwood, timber, and water. For privately-owned forests, forest tenants pay owners in cash or kind to use the forests for grazing fuelwood and fodder and timber. Other people who use the forests are migratory herders, illegal timber harvesters, medicinal plant collectors, and local people who illegally cut trees, graze their animals, and collect fuelwood.

Guzara forest owners association — This group is made up of private forest owners. It operates at district level and its main objective is to safeguard the interests of forest owners by liaising with the district administration and helping resolve conflicts.

Grassland users — Areas that produce good quality grass are harvested by either owners or tenants. Tenants pay for the grass in kind with commodities like ghee or butter (on an annual or biannual basis), milk (on daily basis), or animals, chickens and goats (annual basis). Grassland that does not produce good quality fodder is usually harvested by several families who pay the landowner annually in cash or kind.

Water user groups — Water user groups include landowners and tenants who use streamwater for irrigating their paddy land in the lower watershed, usually near the main streams. Another type of water user group includes people who use streams or springs for drinking water. They either have access to a spring or get their water from nearby water pipes.

Gujar Youth Forum — This once active forum is no longer very effective. It was established by young Gujars to help in their struggles against the authoritarian powers of the Swati landowners.

Gender analysis

Following these investigations a gender analysis was carried out to identify the work that men and women do (Table 15.3) and the control of men and women over the area's natural resources (Table 15.4). This showed a clear division between the tasks carried out by men and women and between the control over the various forest, agricultural, and other natural resources. The aim was to see how local forestry activities could be adapted to improve how men and women can work together and share work and benefits. It was necessary to carry out this exercise because of the strict separation of men and women outside the family which means that interventions have to go ahead gender-wise with training programmes and interventions organised separately. This information was summarised and led to the identification of proposed action areas (Table 15.5) with targeted programmes for men and women.

PARDYP's Interventions

Improving forest management

Improving the condition of local forests and introducing sustainable management practices was identified as a priority intervention area. The factors affecting forestry development in the area were identified by the PARDYP team and local people (Table 15.6). Following this a proposal was developed to try out the decentralised management of Hilkot's natural forests by developing joint forest management on an area of government forest. This aimed to bring the forests under sustainable use and protect them against degradation and to demonstrate how local people could provide for their basic needs from the forests on an equitable basis.

Table 15.3: **Activities carried out by women and men in Hilkot Watershed**

Location	Activity	Gender involved	Time
Homesteads:	Provision of plants	Male	Seasonal
	Planting fruit and forest trees	Female	Seasonal
	Protecting trees	Male	Anytime
	Watering plants	Female	Weekly
	Collecting firewood, fodder and tree fruit	Female	Seasonal
	Processing non-timber forest products	Male/female	Seasonal
	Livestock and poultry care	Female	Daily
	Vegetable growing	Male/female	Seasonal
	Processing and storing agricultural crops	Female	Seasonal
	House construction and repair	Female/male	Occasional
	Cooking and caring for children and old people	Female	Daily
Forests:	Collecting firewood	Male/female	Weekly
	Collecting water	Female	As needed
	Collecting grass and fodder	Female	Seasonal
	Grazing animals	Male/female	Seasonal
	Timber collection	Male	Occasional
	Collecting non-timber forest products	Male	Seasonal
Farmland:	Providing planting stock and planting trees	Male	Seasonal
	Plant protection	Male	Anytime
	Collecting firewood, fodder and tree fruits	Female	Seasonal
	Harvesting and transporting timber	Male	Occasional
	Land preparation for crops and sowing	Male	Seasonal
	Weeding	Male/female	Seasonal
	Crop harvesting and transportation	Male	Seasonal

Table 15.4: **Women and men's access to and control over resources in Hilkot watershed**

Resource	Benefit	Used by	Controlled by
Homesteads	Crops, firewood, fruit, vegetables	Men and women	Men and women
Agroforestry land	Firewood, fruit, fodder	Men and women	Men
Forest	Firewood, timber and grazing	Men and women	Forest owners/ government
Degraded lands	None	Men and women	Men
Non-timber forest products	Income and herbal medicines	None	None
Livestock	Dairy products, animal power and meat	Men and women	Men
Poultry	Eggs, meat	Women	Men
Agriculture	Food, fodder, fuel	Men and women	Women
Labour	Income	Men and women	Men
Cash	Household needs	Men	Men

Table 15.5: **PARDYP Pakistan's proposed action areas in Hilkot watershed**		
Programme area	**Involvement of men and women**	**Action needed to make improvements**
Afforestation on homesteads	Men and women both decide on growing trees on homesteads	Train women in afforestation techniques
Agroforestry	Only men make decisions about agroforestry	Target men through extension programmes to promote agroforestry
Management of existing forest	In private forests male tenants are the users but management decisions are made by owners and the Forest Department. In government forests men are the users and the forest is controlled by the Forest Department.	Men take all decisions in joint forest management committees for government and private forests
Livestock improvement	Men are the decision makers whilst women look after livestock	Train men in improved livestock breeding and women on better livestock care
Non-timber forest produce enterprises	Men take decisions and women do most processing	Involve men in enterprise development and train women in improved processing
Agriculture	Men are the decision makers whilst in some communities women help in agricultural activities	Involve men and women in on-farm improvement programmes.
Income generation training	Both men and women are involved	Train men and women

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Table 15.6: **Factors affecting forestry development in Hilkot Watershed**		
Factor	**Constraints**	**Support**
Physical	Forest clearance, erosion, and low availability of seedlings	PARDYP undertaking afforestation. Men and women's community organisations
Social	Local culture limits women's role in natural resource management and decision making, and women's workload	Kitchen gardening and planting fruit and forest trees in homesteads
Economic	Poverty and lack of training facilities	Introducing high yielding varieties
Political	Landowner-tenant conflicts, legal constraints, and the disproportionate power of a few influential people	The government is beginning to promote community participation in forest management

This initiative went ahead by reviewing NWFP forest policies to understand the current policy and decision-making hierarchies relating to the area's forests. Then, meetings were held with forest department officials in Hilkot and other areas where joint forest management had been introduced. PARDYP identified the forest advocacy group, Institutional Transformation Cell (ITC) as a partner to help introduce joint forest management. This organisation is involved in promoting decentralised forest management in the local province and is pushing the government to introduce a new Forest Act.

PARDYP, ITC, and the forest department discussed introducing joint forest management and agreed on a plan of action. The first step involved collecting data on the social, economic and biological aspects of forest and user communities and other right holders. Also, preliminary discussions were held with another advocacy group, the Forest Management Center.

This led to the formation of community organisations in 1999 with eight for men and the same number for women. More have since been formed. They play an important role in managing local natural resources and are also working to empower women and build up skills. Regular meetings are held to discuss problems and solutions. Working through these groups has reduced class and gender based conflicts. These organisations have great potential to work alongside government agencies and other rural development organisations to improve the living conditions of local people. The monthly meetings and PARDYP-facilitated interactions are raising awareness about natural resource management problems issues and solutions.

The local social organisations are involved in collecting savings and providing credit. The women's groups are saving more money than the men's. The women have used their savings for buying sewing machines, developing handicraft production, and producing better quality honey. By 2003 the eight women's community groups had saved PR 10,000 (US$ 172). These women's organisations have started to share ideas about how to overcome their problems.

On-farm and livelihood support

Discussions between the PARDYP team and local communities identified the main problems faced by farmers and local households. In response PARDYP, in association with local line agencies, promoted and introduced the following interventions.

Figure 15.1a & b: **A farmer tour underway and a local tree nursery**

New varieties — The introductions of new varieties of maize and wheat that give higher yields and mature earlier to allow other crops to be grown. Local farmers preferred Inqilab-91, Fakhr e Sarhad, Noshera-96, Suleman and Tatara varieties of wheat; the Super 3203, Azam and Kissan varieties of maize, and JP-5 and Dilrosh rice. The introduction of sowing crop seed in lines has also led to better yields.

Off-season vegetables — The introduction of new types of seasonal and off-season vegetables, especially in higher elevation areas and rice fallow fields, which previously remained unused for almost half the year. Onion seed is being successfully grown on the rice fallow fields with farmers getting about 40 kg of onion seed from 0.05 ha of land.

Farmer's field days — The holding of annual farmer's field day separately for men and women where experts are invited to farmers' field trials and new techniques are demonstrated. These events provide a good opportunity for mutual learning. Farmer to farmer visits are held for the same purpose. Gender issues are incorporated into these awareness raising activities. PARDYP's female social organisers have frequent contact with local women. They attend the meetings of local women's organisations. The confidence of local women has increased and they now often contact the project to inform project staff about their difficulties and needs.

Food preservation training — Training courses have been run on food preparation and preservation and clothes making. Communities have shown a strong interest in food preservation because of the abundance of local fruit and the difficult access to market. A number of women have set up small enterprises. This has improved their socioeconomic status and led to them playing an increased role in decision making. These successes led the PARDYP team to increase its female support staff. It now has a female social organiser and a horticulturist.

Other training courses — Training courses have been run on plant propagation and nursery management, beekeeping, fish farming, livestock and dairy development, plant pruning, modern farming techniques, and mushroom cultivation.

Kitchen gardening — The project has supported local women to grow vegetables by training them and providing them with motivation and support such as advice and pesticides. The project promoted the growing of tomato, potato, brinjal, and other vegetables in the summer and spinach, radish, lettuce, coriander, karam (local spinach), and turnip in the winter. It established local demonstration plots of off-season peas, radish, turnip and mung, mash beans and onions. Most families used to spend large amounts of money buying vegetables. These gardens now provide year-round fresh vegetables at little cost.

Seedling production — The local production of forest and fruit tree seedlings has provided a valuable new source of income and has overcome the local shortage of these plants. Men and women have been trained in nursery management. The project established eight nurseries in Hilkot watershed, providing most inputs and technical guidance. The project buys the seedlings and distributes them for local planting.

Tree crops — The project holds field days in all Hilkot communities to promote the growing of plums, peaches, apricots, apples and walnuts. Local people have also been encouraged to plant more trees on their land to provide firewood, fodder and timber and for environmental protection. The project has provided them with tree seedlings and guidance on how to plant them.

Recommendations

The main recommendations arising from PARDYP's experiences in the Hilkot watershed are:

- sustainable natural resource management is not possible without the involvement of local communities;
- awareness building, motivation, and skills are needed to improve the way that communities manage their local natural resources;
- farmer to farmer visits are one of the best ways of improving awareness among farmers;
- at first farmers need incentives to adopt new interventions;
- involve women's groups in natural resource management and other on- and off-farm livelihood activities to improve the socio-economic condition of remote communities; and
- communities should be trained how to get maximum benefits from their local resources.

Acknowledgements

The authors are very grateful for technical and financial support, guidance provided by SDC, IDRC, ICIMOD and the Pakistan Forest Institute.

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The Sustainable Management of Common Property Resources in the Indian Central Himalaya: A Case Study from Garur Ganga Watershed

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Abstract

This paper analyses the management practices of the three major common property resources of land, water, and forest through a case study from villages in the Garur Ganga watershed in the Uttaranchal Himalaya, India. The availability of resources in and around these villages and their effective management with the sharing of cost and benefits are helping to maintain and conserve these resources. A joint venture between the People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP) and a group of villagers has helped to resolve local conflicts that were preventing sound management. This paper advocates that any policies for the management and conservation of common property resources must be framed, implemented, and evaluated in terms of an area's specific needs, its socioeconomic characteristics, its bio-physical attributes, and the influence of external forces to ensure sustainable management and maintain harmony between man and nature.

Introduction

Common property resources play multiple roles in sustaining the livelihoods of mountain people. In the Himalayas most human population is located in the lower and middle hills with their livelihoods mostly depending on subsistence agriculture. The overall farming system of the Himalayan midhills is largely governed by the availability of the common property resources of forest, water, and land. Local people use these to meet their daily needs. The economy of this region is largely built around holistic systems involving the use and management of livestock, cultivable land, forests, and water. However, increasing population pressure and unsustainable harvesting has led to the deterioration of these resources which is leading to conflicts between man and nature (Kala 2004). Commercial forestry, the expansion of agricultural land, and demands for fuel and fodder are accelerating the degradation of natural resources. Academics and scientists have been raising concerns about the management and conservation of common property resources since the late 1960s. They have identified their importance to communities particularly in poor people's survival strategies (Jodha 1986 and 1992; Wade 1987).

The People and Resource Dynamics in Mountain Watershed of the Himalayas Project (PARDYP) works with local communities to identify and develop the best options for improving farming systems. It has worked in India since 1997 to improve the quality of life of mountain people by suggesting sustainable measures to improve the management of common property resources, improve access to these resources, and help in resolving conflicts and conserving resources. The present study examines the management of forests, pastures, and water resources in six Uttaranchal villages. This paper also describes activities to demonstrate the bottom-up approach to the management and conservation of natural resources.

Study area

The study was carried out in six representative villages of the Garur Ganga watershed in Uttaranchal India. The study watershed covers an area of 83 km^2. The Bheta Gad-Garur Ganga watershed has 63 villages with a total population of 14,524 in the 1991 census. The local people are from the Brahman, Rajput (higher castes) and scheduled castes. Between 1963 and 1996 the area under agriculture increased from 35% to 42% with a concomitant decline in forest area (Table 16.1).

Table 16.1: **Land use change in Bheta Gad Garur Ganga watershed, 1963-1996**

Land use categories	Area in 1963 (%)	Area in 1996 (%)	Change (%)
Agriculture/settlements	34.97	42.34	+ 7.37
Forests	60.65	55.58	- 5.07
Barren land	3.63	1.32	- 2.31
Others	0.75	0.76	+ 0.01

Source: Bisht and Kothyari 2001

Per capita cultivable land is 0.13 ha and there is an average of 0.7 units of livestock per person (Mishra et al. 2001). The six study villages have 0.12 ha of cultivable land per person and an average 0.53 units of livestock per person (Table 16.2).

The village economy is characterised by subsistence agriculture, mainly on rainfed fields. The adoption of modern agricultural practices such as using improved variety seeds, applying chemical fertilisers, cultivating high value cash crops, and the artificial insemination of cattle were taken as the main indicators of the presence of more scientific farming methods.

Table 16.2: **Changes in population, per capita cultivable land (ha) and livestock units in sampled villages in Bheta Gad-Garur Ganga watershed, 1991-2001**

Village	% population growth 1991-2001	Growth in no. of households 1991-2001 (%)	Changes in per capita:					
			Cultivable land (ha)			Livestock units		
			1991	2001	Change	1991	2001	Change
Lawbanj	37.38	16.49	0.13	0.08	(-) 0.05	0.12	0.51	(+) 0.39
Patli	36.66	16.13	0.09	0.08	(-) 0.01	0.47	0.52	(+) 0.08
Lohari Talli	1.77	5.0	0.22	0.24	(+) 0.02	0.54	0.42	(-) 0.12
Bhagartola	51.84	15.79	0.23	0.21	(-) 0.02	1.11	0.47	(-) 0.64
Kafaldunga	78.15	36.36	0.12	0.11	(-) 0.01	1.21	0.93	(-) 0.28
Bimola	47.93	25.93	0.12	0.05	(-) 0.07	0.40	0.37	(-) 0.03
Average	42.28	19.28	0.15	0.12	(-) 0.03	0.64	0.53	(-) 0.11

Source: 1991 – Office of the Block Development Officer, Garur; 2001 – primary sample survey

All agriculture operations are performed by the local breed of bullocks while buffaloes, cows, and goats are the major cattle types. Forests cover 61% of the watershed mostly made up of chir pine (*Pinus roxburghii*). Broadleaved species like *Quercus leuchotrichophora* (banj), *Q. glauca* (phalyant), *Alnus nepalensis* (utis), *Rhododendron arboreum*, and *Myrica esculenta* (kafal) are found in mixed and a few pure patches.

The local communities are traditionally characterised by *jajmani* relations based on the exchange of different socioeconomic services. These mostly involve landless and marginalised people providing services to landowners and upper caste people. The services include processing grain and playing music at festivals for which they are mostly paid with food grains. Most of the scheduled castes that provided their services to the upper castes in this way now prefer cash payments. Furthermore the tool makers prefer to sell their agriculture implements to the local market instead of providing it to upper caste in return for food grains and cloths. The traditional jajmani relations are weakening and being replaced by the market economy (Topal et al. 2000).

Preliminary surveys identified six villages for intensive study that were deemed to be representative of the watershed's 63 villages.

Results and Discussion

Community forests

In Uttaranchal community forests (*panchayat ban*), pasture, degraded land and water resources are the major common property resources. Panchayat ban make up about 7% of Uttaranchal's total forest area (Saxena 1995) and are crucial sources of fuel and fodder for Uttaranchal's 4808 villages. In the study watershed chir pine accounts for over 70% of forest cover. *Quercus leuchotrichophora*, *Alnus nepalensis*, *Grewia optiva*, *Quercus glauca*, *Bauhinia retusa*, *Bauhinia variegata*, *Ficus roxburghii*, *Myrica esculanta*, *Debregeasia longifolia*, *Celtis saustrades*, *Prunus cerasoides*, *Rhododendron arboretum*, and *Cedrus deodara* are other important tree species.

The area's panchayat bans are divided into the same number of plots as there are user households. The harvesting rights over these plots are allocated by a lottery system. A main product from these forests is leaf litter for cattle bedding and mulching. It is collected during May and June either for free or on payment of a nominal amount to the panchayat ban fund. One member from each household is allowed to go to the forest and collect a load of pine needles at a time. The panchayat ban committees that oversee the management of these forests can impose penalties on offenders who commit illegal acts such as felling trees without permission. Local users are allowed to cut timber at a nominal cost for house repair and for building new houses. Uprooted or fallen trees are sold by auction with the cost varying from Indian rupees (IR) 20 to 80 per tree (US$ 1= IR 46). Much of the revenue collected is spent on forest protection and management. A small amount goes for community welfare programmes.

Water resources

Until 1917, the water resources in this and surrounding areas were considered as common property. After that time the state government put water resources under state control. In 1950, the state government took over the management and development of irrigation systems with villagers having the right to use them. At present, the Garur Ganga watershed is governed by the Kumaun and Garhwal Water Collection, Storage and Distribution Rules, 1975. Farmers with irrigated land have to pay for irrigation water. However, the village of Kafaldunga in the study area is an exception as the irrigation system has not been taken over or developed by the state. This community has sufficient water available and follows their traditional water distribution regime of *sanchayati gool* (community canals) that are managed by the local pani panchayat (water council). Management and use is locally agreed. The proper functioning and maintenance of this traditional system is a common responsibility.

Natural springs and water piped to taps are the main sources of drinking water. *Naulas* (water stored in a traditional tank in the ground) and *dharas* (water flowing openly from a natural source) are the main traditional sources of drinking water in the survey villages (Table 16.3). Access to water is governed by two different mechanisms. Irrigation water use is governed by a common mechanism applicable to the entire community, while access to a particular source is governed by traditional rights. These traditional rights may be flexible or rigid depending on community structures and ownership of the land where water springs and *naulas* lie.

Table 16.3: **Common property drinking water and irrigation facilities in survey villages of Garur Ganga watershed**

Village	Common property resource land	Drinking water facilities*	Irrigation facilities** and percentage of irrigated to cultivable land
Lawbanj	8.1 ha pasture 6.4 ha wasteland	4 naula, 6 taps	Government canal 41.5%
Patli	5.3 ha wasteland	13 naula, 4 taps	Government canal 25.5%
Kafaldunga	0.9 ha pasture 5.1 ha wasteland	5 naula, 1 dhara	Traditional irrigation canal 89.1%
Lohari Talli	13.4 ha wasteland	2 naula, 7 taps	Government canal 11.8%
Bhagartola	1.7 ha pasture 4.5 ha wasteland	2 naula, 8 taps	Government canal 53.0%
Bimola	6.2 ha pasture	1 dhara, 5 taps	Government canal 79.8%

Naula = water stored in a traditional tank in the ground; dhara = water flowing openly from a natural source
Sources * primary survey 2001 ** Office of the Block Development Officer, Garur

Pastureland

In Uttaranchal, most land classified as pasture by the state government is moderately to highly degraded. It is difficult to classify the pastures because pasture and degraded land are open for livestock grazing throughout the year and no revenue is charged for grazing them. Over-grazing has led to degradation. This study found that some villages have developed a system for sharing community pastures for grazing their cattle. However, in other cases its use is dominated by socioeconomically dominant households for grazing cattle or other personal uses. This often leads to disputes.

Rules to govern benefit and cost sharing of common property resources can minimise disputes over the use of community lands. Such degraded lands could provide a vital source of income if planted with fodder grasses and multipurpose trees. The enforcement of rules and measures in some villages in this watershed, such as encouraging the stall feeding of livestock, has helped to conserve these resources.

Socioeconomic and biophysical factors influence the management of common property resources. The socioeconomic factors include the composition of village communities, levels of economic inequality, gender issues, the level of infrastructure development, levels of participation, cumbersome systems and policies, fund-driven programmes, lack of awareness, and institutional weaknesses. The main biophysical factors are land degradation, access to alternative resources, and the availability of resources within and outside village boundaries.

Scarcity of livestock fodder is a major problem for farmers in the central Himalayas. The total annual production of fodder from all sources has been estimated at 705,000 tonnes when the annual demand is 29,115,000 tonnes. This leaves a huge gap (Sharma and Kumar 2002).

Water scarcities have greatly increased in recent years. Two thirds of total rainfall occurs during the monsoon and the rest of the year is almost dry. This impacts the production of agricultural crops and fodder, as more than 80% of this region's agriculture is rainfed and too little or too much monsoon rain drastically reduces production or destroys entire crops.

Management and conservation strategies have a strong influence on access, potential use, and conflict management. Reductions in the discharge of irrigation canals and increased numbers of users are the major causes of conflicts between users and management in government irrigation systems.

PARDYP's contribution to managing common property resources

PARDYP has initiated and demonstrated the following measures to improve the management of common property resources in the survey areas.

- The introduction of nutritious and high yielding grass species that give green fodder year round. The grass species *Thysanoleana* and Napier grass have been adopted by many farmers.
- Areas of degraded community land have been rehabilitated to demonstrate its potential productivity. The introduction of community based natural resource management has led to increased biomass production and soil cover by planting useful tree and grass species and by more water harvesting.
- The protection of catchment recharge areas has increased the levels of water percolation and improved spring discharge. Communities are closely involved in this work and can now manage their springs, water storage tanks, and distribution and use mechanisms.
- The planting of quality grasses and fodder tree species in panchayat bans has made more fodder available and reduced women's workloads. The introduction of joint forest management in some villagers has helped to improve the availability of biomass and the understanding of community based natural resource management.
- The introduction of high yielding seeds varieties, bio-composting, vermicompost, improved irrigation measures, and high value grasses and improvements to terrace bunds have increased agricultural productivity.

Conclusions

PARDYP's people-centred approach is promoting the sustainable, balanced and equitable development of the study area. Local people need to follow up on its interventions and demonstrations. The following measures have good potential to counteract the degradation of common property resources in Uttaranchal:

- build up the capacity of local institutions;
- amend policy in a participatory way that incorporates community level concerns;
- improve awareness among villagers and local common property resource institutions by circulating policy documents and providing demonstrations of improved management techniques;
- recognise the strengths of traditional practices and indigenous expertise for the sustainable management of natural resources;
- encourage the increased involvement of women in local institutions in managing natural resources; and
- ensure that all development interventions are framed, implemented and evaluated in line with area-specific needs and conditions.

Acknowledgements

This work is an outcome of PARDYP. The authors are grateful to the Director of the G.B. Pant Institute of Himalayan Environment and Development, Almora for providing facilities for this work. The authors are also grateful to IDRC, SDC and ICIMOD for financial assistance and sincerely thank C.P. Kala of the G.B. Pant Institute for his valuable comments.

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17

State Simplification and Access Issues for Farming Land in Upland Communities in a Chinese Village

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Abstract

This paper reports the findings of an investigation into how government land policies and in particular the Sloping Land Conversion Program (SLCP) has affected farmers' access to farming land and how local people have responded to these policies. Access to land is unequal in most rural areas in China. Access is controlled by state land policies and local power relations. On the macro-level, the state initiates generalised (simplified) land policies; but it is often difficult to implement these policies in the widely varying conditions at the local level. The diversity of livelihoods in villages results in differing responses to the state's land policies, particularly SLCP. The state's generalised policies cause many conflicts about access to land.

The Sloping Land Conversion Program

Ribot and Peluso (2003) define access as "the ability to derive benefits from things". This paper discusses how access to the natural resources of land, water and forests is influencing the livelihoods of local people in one Chinese village.

Access to land is a controversial issue in many societies. As a major means of production, land is perceived as central to development in developing countries. It is often farmers' main capital and governs their livelihood strategies and so is a key determinant of human welfare (Scoones 1998). Any government that sincerely pursues development must institute viable land programmes and policies. The Chinese government has put land and its attendant issues at the centre of its development strategies. In fact, the beginning of the current great rise of the Chinese economy can be traced back to individual farmers being given access to farmlands under the Household Responsibility System in 1978.

In the past few decades, the Chinese Government has implemented new land policies. From the establishment of the People's Republic of China in 1949 to the present, many policies on land tenure and land use have been formulated (Selden 1993). Land reform measures introduced in the early 1950s provided poor people with access to farmland. From the mid-1950s the state pushed the 'collectivisation' of land. This aimed for equitable access to natural resources and mutual support for labour sharing and decision-making. During the collectivisation era (1950-1978), all farmlands and forestlands were nationalised, and the state was responsible for drafting land policies, land use planning, and decision-making about resource management. Private and customary ownership and access rights to forestlands were not legally recognised or respected. This changed after economic reforms in the agricultural sector in 1978 and in the forest sector in 1982. This securing of people's access to land and forest resources has contributed to increased food production and has enhanced the living standard of rural people.

China's rapid economic growth has, however, led to high levels of air and water pollution, a drastic loss of biodiversity and vegetation cover, and alarming rates of deforestation and soil erosion (Chai 2000).

The Chinese government began to pay more attention to environmental issues after the destructive Yangtze River flood of 1998. This disastrous event was blamed on the clearance of large areas of upland forests. The government responded by first introducing the Natural Forest Protection Program to ban logging. The logging of natural forests was banned in upstream parts of the Yangtze and Yellow rivers, including parts of Yunnan Province (China Daily 2000). Soon after, the Sloping Land Conversion Program (SLCP) was introduced. This SLCP (Tuigeng Huanlin Huancao in Chinese) aimed to persuade farmers to convert upland fields into forests or grasslands. Agricultural fields with a slope of more than 25 degrees were singled out for farmers to plant. A survey by the Ministry of Land and Resources, the National Bureau of Statistics, and the National Agricultural Census Office found that 28.4% of the total area of West China (including Yunnan Province) was cultivated land, with 76.5% of this having a more than 25 degrees slope (Beijing Review 2000). The aim was to reduce the erosion caused by the cultivation of steeply sloping land.

Recognising that farmers would sustain substantial losses in forgoing grain cultivation, the central government provided a compensation package (see details below) that it pledged to provide for up to eight years or longer if necessary.

The SLCP has been a large-scale complex undertaking and has encountered a number of problems. It has led to conflicts emerging, in particular between environmental conservation and people's livelihoods. The new policies have had a large impact on farmers. Almost 94 percent of Yunnan Province is covered in mountains with almost all cropland is on slopes of more than 25 degrees. This has made wholesale conversion very difficult. Farmers in these areas are getting adequate compensation for giving up cropping their sloping farmland.

There are three ways of looking at farmers' access to land:

- the simplified state view as embodied in its land policies;
- the expanded view of the local political authority; and
- the elaborate view of the villagers that see all the complex social, political, and economic aspects that relate to land.

James Scott's exploration of the concept of state simplification (1998) discusses how governments, to deal with the varied natural and social environments that they govern, attempt to make these environments legible or understandable. They achieve this by creating simplifications or generalisations to form the basis of broad policies and actions. The problem is that these simplifications often do not apply well in particular circumstances and so frequently lead to conflicts. Scott claims that

> *the necessarily simple abstractions of large bureaucratic institutions can never adequately represent the actual complexity of natural or social process… The simple 'production and profit' model of agricultural extension and agricultural research has failed in important ways to represent the complex, subtle, and negotiated objectives of real farmers and their communities* (1998: 262).

Study Methods

A qualitative research case study was carried out on Yangjia Village, Banqian, Baoshan Prefecture, Yunnan Province, southwest China to see the impact of the state's land policies. The main source of information came from interviewing local respondents. In-depth interviews were carried out with 13 key-informant farmers. These farmers were selected for their relevant knowledge and their willingness to share their knowledge. Other key informants included local government officials, extension workers, local teachers, and community leaders. They provided information on the changes that have occurred in the community, the processes involved in the implementation of state land policies, emerging land tenure and land use issues, and local people's responses to the policies.

Community Profile

Yangjia village lies in the middle stream of Xizhuanghe watershed five kilometres from the Dabao national highway, and 18 kilometres from Baoshan city. Shaba town with its post office and hospital is the nearest service centre. The office for Qingshui administrative village lies in the neighbouring Guangwanken village.

The village is in a very mountainous area with the intensive farming of corn during the summer and wheat during the winter. The climate is strongly influenced by the monsoon with wet and dry seasons. Geologically, most of the area is covered with limestone and a little sandstone. The upper land of the village is mostly forested, with the village settlement in the middle areas, farmland in the middle-lower areas, and degraded land on low elevations.

There are 55 households and a total population of 236 people all of whom are Han Chinese. The nearest clinic is in the neighbouring village of Guangwankeng staffed by a paramedic. There are two primary schools close by. Many local people are illiterate and only a few children graduate beyond primary level due to the high expense of higher education. Many local men work away and older people and women take the major responsibility for farming during winter time.

The main food crops are maize, wheat, soyabean, and rice. Rice cultivation is becoming rarer because of the lack of locally preferred varieties. The main cash crops are tea, tobacco and fruits. Livestock is an important source of income for some households with pig, horse, goat, sheep and chickens. Persimmons, apples, pears, walnuts, plums and peaches are grown.

The area has only 9 ha of rainfed farm land. The most productive and intensively managed crops are corn, which gives a yield of 4.5 tonnes per ha, and wheat which gives 3 tonnes per ha. The 8 ha of tea gardens provide a crucial source of income. This area is well known for its good quality tea.

Policy, Local Livelihoods and Access to Land

The main objective of the government's SLCP is to reduce erosion by converting private cropland on steep slopes and some degraded land to grassland and forest. Farmers are given grain, cash, and tree saplings as incentives. Official statistics reported that there was 6 million ha of cropland with a slope of more than 25 degrees in China at the time that SLCP was started. More than 70 percent of these areas were in the western region of China (Beijing Review 2000: 26).

SLCP was designed by the central government and is being implemented by local officials. The provinces are responsible for assigning programme tasks to lower levels of government. The provinces in turn assign tasks to lower-level local government. It is mostly county forestry departments in cooperation with township governments that conduct field surveys and assign tasks to be carried out by households. They develop grassroots implementation plans which are then presented to the state forest administration (SFA) for approval.

The main state policies for the implementation of SLCP are to:

- grant free grain to farmers who convert their cropland, amounting to 150 kg of grain per mu (2.25 tonnes per ha) of land per year in the upper reaches of the Yangtze River, and 100 kg in the upper reaches of the Yellow River for 5-8 years;
- grant cash subsidies to farmers who convert their cropland (US$2.40/mu or US$36/ha per year);
- provide tree and grass seedlings to farmers that convert their cropland;
- contract individual farmers to carry out the land use conversion;
- make farmers responsible for growing trees and grass on the converted cropland and also on 1 mu (0.067 ha) or more of barren hills and degraded lands that is suitable for afforestation; and
- make the forestry agencies responsible for checking the implementation of cropland conversion in terms of schedule, quality, and management and for approving compensation payments (SFA 2000).

The Department of Forestry is the main local actor for environmental protection. For SLCP the department has to cooperate with the government agencies responsible for allocating grain and cash payments and giving new land tenure certificate. Table 17.1 shows how the implementation of SLCP demands good cooperation between different agencies. A delay in one agency can hold up the whole programme. A major problem has been the Department of Forestry's lack of human and financial resources to administer the programme. Another problem has been the selection of land for conversion. It has proven impractical to ask farmers to convert all of their steeply sloping cultivated land. The strategy of the local Baoshan government has been to ask local village cadre to submit their proposals for sloping land conversion specifying that conversion should only take place on adjacent plots that together make up at least 3.3 ha to ease measurement and checking.

Table 17.1: **Agency responsibilities for SLCP**

Unit	Responsibility
Commission of Planning	Overall planning and compiling
Commission of Minority and Nationality Affairs	Ethnic affairs
Department of Finance	Overall budgeting, releasing compensation payments, reducing or exempting liability for agricultural taxation
Department of Agriculture	Releasing crop compensation
Department of Land and Resources	Policies on improving land tenure systems, releasing new land contracts to farmers during SLCP, and issuing cropland conversion task cards for upland conversion
Department of Forestry	Overall activity planning and implementation: selecting land to convert, measuring areas, providing seedlings, monitoring conversion upland, issuing certificates, etc.

Local Farmers' Responses

Based on the policy of not converting single areas of less than 3.3 ha, the land belonging to only 26 of Yangjia's 55 households have been included in SLCP. The response of local people has been in-line with their level of reliance on the land for their livelihoods. Households that only partly rely on it, or who have abandoned it, have quite willingly participated whereas those that rely on their land for most of their livelihoods, such as tea plantation owners, have strongly resisted. The land assigned for conversion in the Da-jia-yan area of Yangjia village, is cultivated by some households and abandoned by others. The local conservation plan had been submitted to the local government. The approval of conversion depends on how much quota of SLCP has been allocated from central government to local government.

The growing of grain in this area no longer makes economic sense as much cheaper imported grain is available. So, grain crops are no longer the first choice for planting and it is more profitable to grow tea, fruit, and upland vegetables. In most peasant households in Yangjia village, land degradation has led to the need to apply more fertiliser for growing crops. This makes them expensive to grow. Without fertilisers, decreasing productivity means that corn and wheat crops will only provide seven to eight months' worth of food. Almost 70% of households in Yangjia need to buy rice to supplement their own production. The main ways for these people to improve their standard of living is through off-farm working and by selling livestock, tea, fruits, and other crops.

Eleven of the 26 households taking part in SLCP in Yangjia Village are Group A households. These rely on their cultivated land for their livelihoods. They have smaller land holdings and significant surplus labour. Their main crops are corn, wheat and in some cases, tea. The growing of tea demands much work between March and October. When the market price of tea leaves is US$0.72-0.96 per kg, the income amounts to US$36-48/mu (US$540-720/ha).

Group A people tend to have sufficient available labour to grow tea in contrast to the other three groups. Tea brings good economic benefits, but is labour-intensive. Another characteristic of this group is the importance of livestock raising. They grow corn to provide much of their livestock feed. These farmers have the most productive sloping lands and most strongly oppose SLCP (Table 17.2).

Group B (4 out of 26 households) also put much effort into farming. However, due to their lack of labour they cannot grow tea and corn and instead grow soyabean as it needs less labour. It also needs only a small amount of fertiliser and can easily be exchanged for rice. A kilogram of soyabean is exchanged for 1 kg of rice, while 2 kg of corn is needed to get 1 kg of rice. The SLCP is threatening these people's livelihoods by preventing them from growing this crop.

Table 17.2: **Yangjia village household types and their responses to SLCP during planning stage**

Group type (no. of hh)	Land status	Livelihood strategy	Response to SLCP
Group A (11)	Cultivated land	Tea plantation, corn plantation and livestock	Strongly resisting
Group B (4)	Cultivated land	Soyabean and corn plantation	Resisting
Group C (7)	Abandoned land	Full-time off-farm work	Hesitating
Group D (4)	Abandoned land	Part-time off-farm work	Willingly participating

The Group C households (7 out of 26 households) have surplus labour. These households differ from Group A in that they have abandoned cultivation to engage in off-farm work. Many have family members with skills such as carpentry, plastering, and blacksmithing. Some have outside contacts that allow them to find construction work outside the village. Most households want to move away from farming to work in urban areas. However, Group C hesitates to take part in SLCP because they suspect the government will not keep its promises.

The Group D households (4 out of 26) find it most difficult to sustain their livelihoods. They have only limited labour to either produce more from their own land or to pursue off-farm work. Their food security is often threatened by low production from their land and the lack of cash incomes from off-farm work. The SLCP provides them with a valuable source of income from their abandoned lands and so they are eager to participate.

The amount of available labour and the types of crops are the key factors that govern farmers' livelihood strategies. This study worked out the impact and economic contrasts of different crops grown in the study area (Tables 17.3 and 17.4). The factors delineated in these tables account for most of the factors that farmers take into account when deciding which crops to grow. The study found that farmers see corn as a very useful crop but growing it is environmentally damaging compared to soyabean. The most profitable crop is tea (Table 17.4).

Impact of SLCP

The township government's decision to implement SLCP in Yangjia village has had a huge impact on this quiet upland village. Unlike other state land policies, the SLCP relies on the willingness of farmers to participate and local officials cannot force farmers to convert their sloping land. The programme is only at the planning stage and this research reports on local people's responses to the proposed programme.

Table 17.3: **Farmers' perceptions of impacts of crops in Yangjia village**

Crops	Social benefit	Economic benefit	Ecological impact
Maize	☑ Main crop, especially for fodder. Demands higher labour and time inputs	☒ The value of production almost equals the capital input. 2 kg corn can be exchanged for only 1 kg of rice. But corn is valued as livestock feed.	☒ Farmers use more chemical fertiliser and less manure to improve the poor soil fertility as fields are far from the village
Tea	☑ Main cash crop. But higher labour and time input, especially for women	☑ Important source of cash	☒ Farmers use chemical fertilisers and pesticide, one type of which is forbidden in food production
Soyabean	☑ Not a main crop but has lower labour and time inputs, and is simple to grow	☑ Lower capital inputs and higher productivity than corn. 1 kg soyabean can be exchanged for 1 kg rice	☑ Nitrogen fixation increases soil fertility and improves soil structure

Table 17.4: **Yangjia village farmers' estimates of economics of crop growing**

Crop	Labour input	Capital input	Average productivity (kg/mu)	Market price (yuan/kg)	Income yuan/mu
Soyabean	Medium (simple management)	Low (average less than US$4.80/mu, including seeds)	120	2.40	288
Corn	High (fertilising, weeding, etc.)	High (average US$8.40/mu)	100	0.76	76
Tea	High (applying pesticide, harvesting leaves)	High (average more than US$12/mu)	50	8	400

This study identified four types of responses to the conversion programme with Group D households being most likely to take part in conversion. This group appreciates the benefits from the little work of planting trees for the return of regular cash and grain payments from the government over five to eight years and beyond. Farmers in Group D feel optimistic about SCLP as they lack the internal and external livelihood opportunities compared to the other groups. One of them said that it is not possible to get that amount of grain from a whole year of working hard on the land. "Now we can get some cash and grain for doing nothing in the following years, so why not join the scheme?" Group D farmers benefit from planting up land that they no longer grow crops on. They have been encouraging other farmers to take part.

Similarly, the people in Group C have good reason to take part in SLCP as they are quite well off as they already have enough income from on-farm work. However, one farmer pointed out, 'If we provide free labour to plant trees for the government and lowland people in our own farming land, I might as well leave it abandoned'. He added that if he did this at least he would still be able to crop it, plant trees. or do anything else he wanted later. Bad experiences with other government programmes mean that these people are suspicious that they will not receive due compensation on time. This makes them hesitate to take part in SLCP. They always keep silent in SLCP planning meetings waiting to see others' responses.

Group B people resist SLCP and are not persuaded by the prospect of five to eight years of compensation payments. Having to use their 'useless' land for environment conservation for sustainable livelihood by certain officials enrages many of these farmers. A Group B farmer said, "We know how to produce enough food from our land. How can we agree to only get some grain for 5 to 8 years instead of for a life long period?" Many of these farmers have started planting soyabeans on their degraded land to improve soil fertility and get better returns.

These farmers, who have decades long experience of making a living from the land, have a better vision and plan for the future of their land. The study investigated how Group B farmers have experimented with growing improved varieties of corn and soyabeans (Table 17.5).

The farmers in Group B know in detail about the economics of crop growing. The average rice consumption per person per year is 350 kg in Yangjia Village. Planting corn in Yangjia,

Table 17.5: **Returns on corn and soyabean grown by group B farmers, Yangjia village**

Crops	Productivity on fertile land	Productivity on less fertile land	Equal value with rice
Old corn varieties	300 kg/mu	100 kg/mu	50 kg/mu
High yielding corn varieties	525 kg/mu	-	50 kg/mu
Soyabean	-	120 kg/mu	120 kg/mu

Note: The high yielding varieties of corn did not grow well on the less-fertile land, and soyabean isn't fit for fertile land which causes disease and pest infestations

where there are 9 ha of fertile lands and 27 ha of less-fertile lands produces 40,250 kg of corn which was exchanged for 20,125 kg of rice. However, this is not enough to meet local needs. Planting a combination of the new variety of corn on the fertile lands and soyabean on the less-fertile lands realises 83,437 kg of rice. This can meet the needs of the whole community. It seems that a combination of the new variety of more productive corn on the fertile lands and soyabean on the less-fertile land would meet local food needs. The village head belongs to group B and often asks SLCP officials whether they will still get compensation from the local government for food security issue after SLCP comes to an end after eight years. The people in group B don't want to take part in SLCP.

People in Group A strongly oppose SLCP. It will only give 150 kg of grain, US$2.40 for education, and US$6 for tree seedlings. The value of this compensation amounts to about US$24 per mu per year. This is less than the US$48 per mu profit they earn from managing their tea gardens. A farmer in Group A admitted that they had to work hard to earn that money, 'but at least it is under our control. We are not fools to give up US$48 to receive only US$24 in return'. Their productive land provides cash income from the tea gardens and agricultural products to feed their livestock. They will lose out if they join SLCP and strongly oppose joining it. They have asked the village head to make their position clear to SLCP officials and not to betray them under political pressure from high-level government officials.

The different priorities of local people with most villagers not in favour of taking part in SLCP, means that it was planned to postpone its implementation from 2001 to 2003.

Conclusions

State simplification is the strategy adopted by governments to initiate broad policies and actions often at the cost of local diversity and complexity. As a result it often leads to conflicts. This study has shown how SLCP does not account for the diversity of local conditions and the needs of different community people. SLCP gives little attention to local social dimensions. The people of Yangjia village have different household sizes, family composition, and socioeconomic status. The willingness to convert agricultural land is based on local people's differing livelihood strategies. SLCP ignores this diversity and proposes a single approach with one compensation standard. It shows how state policymakers are insensitive to rural communities social structures and processes. Of the four broad socioeconomic groups in this village only one welcomes SLCP.

Local officials and village cadre understand farmers' opinions about SLCP. They are in a dilemma whether to try and change state policies or to initiate new local regulations to make state policies more amenable. They are often able to predict the prospects of state policies introduced into their areas.

Future Implications

Centralised unilateral development approaches have often failed because they ignore local communities' interests. In China this has increased the problems faced by many upland communities. State policies need to account for local people's approaches to sustaining their livelihoods. A livelihood is sustainable only when it can cope with and recover from stresses and maintain and enhance its capabilities and assets while not undermining local natural resources (Scoones 1998). All these aspects need to be considered when drafting policies.

Farmers have communicated their objections to SLCP to local officials. This should make the government more aware of farmers' priorities and be seen positively as a chance to adapt policy to better address farmers' priorities.

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18

The Spatial and Temporal Dynamics of Land Use in Xizhuang Watershed of Yunnan, Southwest China

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Abstract

This paper documents the impacts of state-driven reforestation on land use, land cover, and the livelihoods of upland farmers in Xizhuang watershed, southwest China. An analysis of aerial photographs and ASTER satellite imagery from 1987 and 2002 showed that the area of forest has significantly increased and the amount of farmland has decreased. The monocultural reforestation of pine has had serious biophysical and socioeconomic consequences. This case study shows that the government's forestry agency and the local government authority have been implementing decisions for forest plantation and conservation that affect peoples' livelihoods with little local participation.

Introduction

Land use and land cover changes have been extensively researched (Lambin et al. 2001, Verburg 2000). These studies show that forests are rapidly decreasing as the area of cultivated land increases both worldwide and in China. For example, deforestation is estimated to have caused the loss of 1.16 billion hectares of forest worldwide while the area of farmland has increased by about 1.24 billion hectares in the past 300 years (Lambin et al. 2001). However, many areas experience forest transitions when economic development stimulates a decline in forest cover and later, through feedback processes, there is often a recovery in forest cover. A number of scientists (Rudel et al. 2005, Mather 1990, McNeely 2003, and Zhang et al. 2000) have assessed the potential of forest recovery for biodiversity conservation, the sequestering of carbon, and other environmental benefits. Increased afforestation can adversely effect agricultural intensification. Lambin et al. (2000) state that long-term population growth and economic development usually do not take place without the growth of agricultural production.

Forest ecosystems provide important environmental goods and services for local farmers and off-site and lowland dwellers. This case study analyses the underlying dynamics of land use change at the micro-watershed level as a contribution to the development of policies on conservation. It explores the spatial and temporal dynamics of land use in the Xizhuang watershed from 1987 to 2002. It addresses the questions of:

- where does forest recovery happen and at what rate does land-use change progress?
- what drives local afforestation?
- what are the social consequences of forest recovery to local communities? and
- what are local people's coping strategies for such forest transition?

The Xizhuang Watershed

The Xizhuang watershed lies 20 km to the northwest of Baoshan city in the western part of Yunnan province (Figure 18.1). It covers 3,437 ha and is a sub-catchment of the Nujiang river (Salween river). Its elevation ranges from 1750 to 3100 masl. It is located in the southern Hengduan Mountains. The climate in the foothills is subtropical and temperate in the mountain areas. The average annual precipitation is 1013 mm with clearly defined dry and wet seasons. The main soil type is red soil (Li and Sha 2002). The natural vegetation is semi-moist broadleaf forest that disappeared many decades ago and has been replaced by coniferous forest with a mix of alder (*Alnus nepalensis*).

The main settlement in the area is Damaidi village. Most farmers plant two crops per year with maize in the summer and wheat or barley in the winter. Tea is the traditional cash crop.

Xizhuang watershed covers the whole of the administrative villages of Lijiashi and Qingshui, and part of another village. The total population of the watershed is 4,273 with a population density of 124/km^2 in 2002. Population growth and urbanisation in nearby Baoshan has increased the importance of the Xizhuang watershed for the supply of water for agricultural, domestic, and industrial use. A drinking water company is located downstream and a cement factory also relies on water from this watershed. An irrigation canal provides crucial irrigation for Banqiao township. The Baimiao reservoir also has a water intake from the Xizhuang watershed.

Materials and Methods

The authors integrated socioeconomic and spatial information collected from household interviews, participatory social mapping, land use mapping, and a policy review.

Spatial data

Table 18.1 shows the land types found in the Xizhuang watershed according to the classification system adopted in 2002 by the Chinese Land Resources Ministry.

Spatial database — A spatial database was developed using aerial photographs taken in February 1987 at a scale of 1:40,000 by the Yunnan Land Survey Bureau. These were digitally scanned and geo-referenced, data was segmented in e-Cognition by using 'Segmentation' with the parameter of default 10. (Segmentation is the subdivision of an image into separated regions to automatically extract the desired objects of interest in an image for a certain task.) After the polygons were extracted, they were manually interpreted to delineate land cover categories and projected into Transverse Mercator projection (Krasovsky datum).

Satellite imagery — A December 2002 ASTER satellite image of the watershed with a resolution of 15m was rectified using 1:10,000 digital topographic maps. Then more than 20 ground control points were collected with a maximum root mean square (RMS) error of control within 1 pixel. Supervised classification of the image was completed by selecting training sites. GPS readings at more than 40 points were carried out to test the accuracy of the supervised classification. This showed a 90% reliability.

Classification evaluation — The classification of aerial photos and satellite image was evaluated by the researchers and local people. Draft maps were printed and the classification was discussed with local people in the field. Supervised classification of the image was

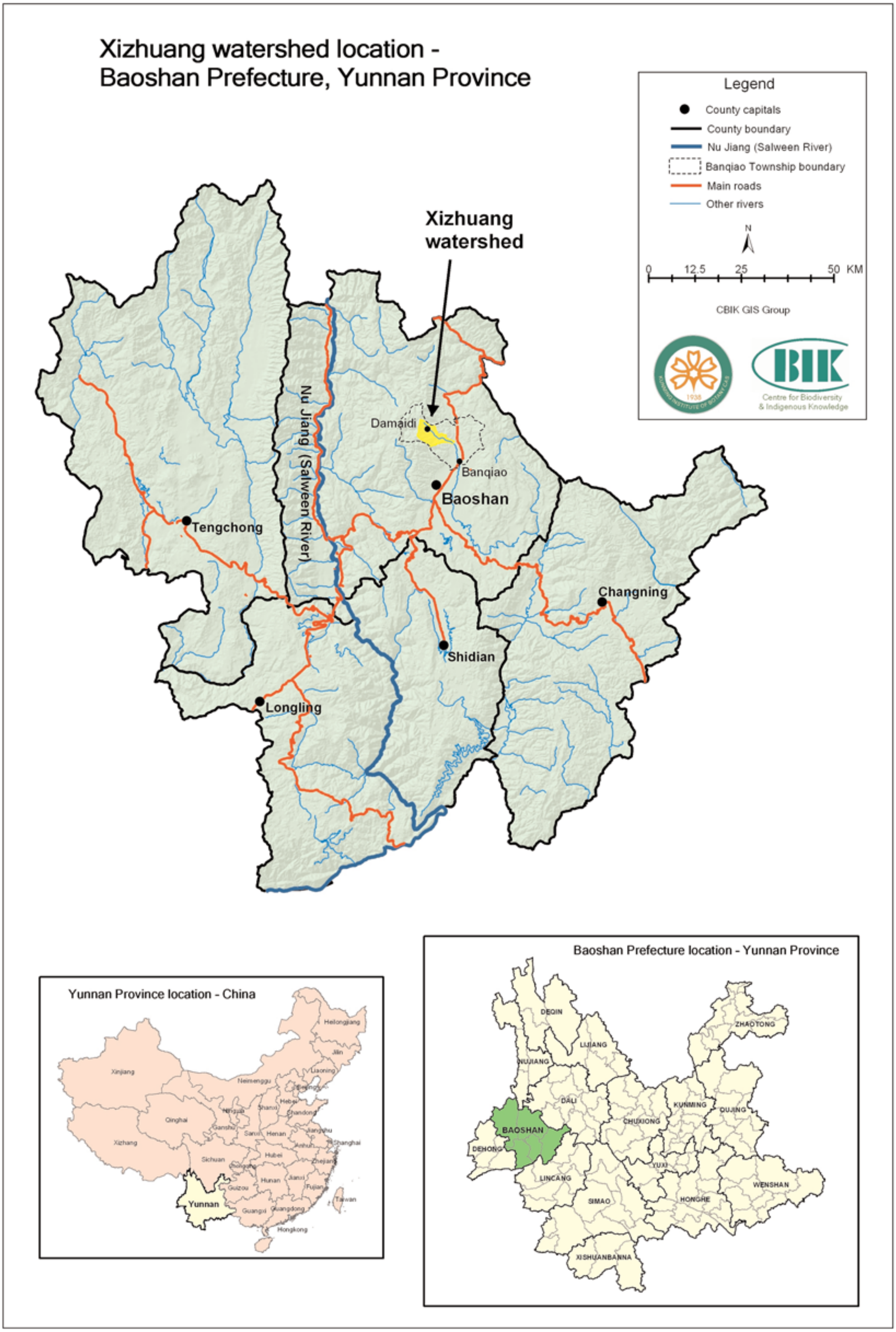

Figure 18.1: **Location of Xizhuang watershed**

Table 18.1: **Land types in Xizhuang watershed**

I. Agricultural Land	
	11. Paddy (rice)
	12. Upland fields (rainfed crops – in Xizhuang = wheat and corn)
	13. Gardens (in Xizhuang = tea gardens)
	14. Forest land (dense): conifer forest with crown density more than 20%
	15. Forest land (sparse): crown density of 10-20%
	16. Grassland
II. Construction land	
	23. Rural settlements
	24. Individual industrial use land (in Xizhuang = quarries)
	27. Roads
III. Unused land	
	31. Shrubland or young plantations
	35. Barren land
	36. Rivers

completed by selecting training sites. GPS readings at more than 40 points were carried out to test the accuracy of the supervised classification. This showed a 90% reliability in lieu of a statistically-based accuracy assessment. The final classifications for both dates were examined carefully and compared against all available reference data and the authors' extensive knowledge of the study area.

Analysis of the land use and land cover changes was carried out by comparing the 1987 aerial photos and the 2002 satellite image.

Socioeconomic survey

A socioeconomic survey was carried out for the study area by:

- collecting secondary data from government agencies on population, the area of cultivated fields, and food production;
- interviewing key informants, including government officials and local people, about historical events and land use change trends. The relations between the government and local people under different land tenure systems were analysed to show how tenure rights have affected villagers' access to forest resources; and
- participatory mapping where the survey team worked with local people to produce time lines, land use sketch maps, land use transects, and land tenure maps. Topographic and land-use maps were used in the field to facilitate these discussion with farmers, officials and community members on past land-use practices, land-use conflicts, and future plans.

Index of land use change

The degree of individual land use dynamics was calculated through the numerical change in particular land use dynamics multiplied by the length of time of the study. The following formula (Wang 2000, Yang 2001) was used:

In the formula LC represents the degree of land use change, Ua the amount of the particular land use at the beginning of year 'a' and Ub the amount at the end of year 'b', and T the

$$LC = \frac{Ub - Ua}{Ua} \times \frac{1}{T} \times 100\%$$

length of time. When the unit of T is set as a year LC indicates the degree of annual individual land use change.

The degree of integrated land use change is defined by the integrated numeric change of all the categories of land use during the length of time of the study in the area. The formula used to work this out is:

$$LC = \frac{\sum_{i=1}^{n} \Delta LU_{i-j}}{2\sum_{i=1}^{n} LU_i} \times \frac{1}{T} \times 100\%$$

LUi represents the area of category i at the beginning year of the study, DLUi-j represents the amount of land use category i converted to other land uses, and T represents the length of the study. When the unit of T is set as a year, LC indicates the degree of annual integrated land use change (Chen 1998).

Results and Discussion

History of the watershed

Baoshan has a long history. Many inland people migrated from eastern China to the Baoshan valley after the Yuan Dynasty (1279-1368). After this most of the natural forests were destroyed through shifting cultivation and were replaced by pine forests. Box 18.1 shows the main recent events. The field survey and interviews recorded the three major causes of deforestation in recent times as:

- shifting cultivation, the intensive planting of opium and buckwheat, and overgrazing in the early part of the twentieth century;
- logging for firewood to supply iron and steel production; and
- the pre-1980s granting of individual household rights to forest resource use.

The population in Xizhuang watershed has doubled in the past four decades. Population growth has been greater in upland areas because of less enforcement of the one child policy. These upland areas are the ones that have the least arable land. Table 18.2 shows that there is only 0.04 hectares of farmland per person in Lijiashi in the upper watershed, 0.03 hectares per person in Qingshui in the middle watershed, and 0.02 hectares per person on Xizhuang in the lower watershed. This compares with the average of 0.04 hectare per person for lowland farmers in the nearby Baoshan valley.

Most families depend on agriculture for between 50 and 60% of their livelihoods (Figure 18.2). Many local women spend around 15% of their working time collecting firewood, pine needles, leaf litter, and non-timber forest products. Leaf litter is used for fuel and fertiliser. It is put into pigstys for bedding and after mixing with pig manure is composted for fertiliser. Some families sell fuelwood, pine needle ropes (for lighting), and other non-timber forest products. Most households raise about US$200 per year from these products. Livestock, particularly pigs, provide a substantial income for local farmers. Higher agriculture outputs mostly depend on using expensive high yielding crop varieties, chemical fertilisers, and pesticides.

Box 18.1: **Historical events in Xizhuang watershed**

1942-1944	Much logging for house road and bridge building during World War II
Pre-1953	Practicing shifting cultivation (buckwheat 80%, potato 20%) with 3-5 year fallow cycle, and raising goats on pastureland
1957-58	Large areas of forest cut during the “Great Leap Forward” including to build Baimiao Reservoir
1962	First trial of aerial seeding of pine for large-scale afforestation
1965	Establishment of people’s communes, collectivisation and much terrace construction
1966-67	Pit-planting of 1000 kg of seeds of *Pinus armandii* per year
1968	Micro-hydro-power station established
1974	Forest survey carried out
1982	Introduction of household responsibility system; but more forest loss
1984	Big floods in Qingshui village
1985	Large-scale mud-flows and first aerial seeding of *Pinus yunnanesis*
1988	Road building gives access to outside
1991	Supplementary aerial seeding carried out
1994	Wasteland auctions where collective degraded lands were leased to the public
1996	Construction of new road
1998	Renewal of household responsibility system

Table 18.2: **Population and farmland resources in Xizhuang watershed (1998 census)**

	Lijiashi village	Qingshui village	Xizhuang village*	Total
Population	1533	2493	1818	5844
Labour	767	1262	904	2934
Arable land (ha)	66.5	81.5	39	187
Arable land per capita (ha/person)	0.043	0.033	0.021	0.034 (average)
Tea gardens (ha)	4.987	5.207	0.973	11.167
Grain production (tonnes/year)	1860	3393	671	5924

Note: Only one third of Xizhuang Administrative village is located within the watershed.

The importance of the Xizhuang watershed area for maintaining good quality water supplies has led to Baoshan municipal government and local communities making great efforts to reforest areas of the watershed. Logging operations have been greatly reduced since the early 1980s in state forest in the watershed’s upper catchment areas. Only 500m^3 of firewood is allowed to be removed each year. In 1985 and 1991 the Forestry Bureau carried out aerial seeding to replant a number of degraded areas. In recent years villagers in lower catchment areas have planted trees. The local village administrations, particularly Lijiashi, are regulating the collection of timber, fuelwood and non-timber forest products. Forest guards have been appointed to watch over the forests. They patrol twice a day and serve as a link between villagers and local forest stations. This link includes local people requesting their local forest

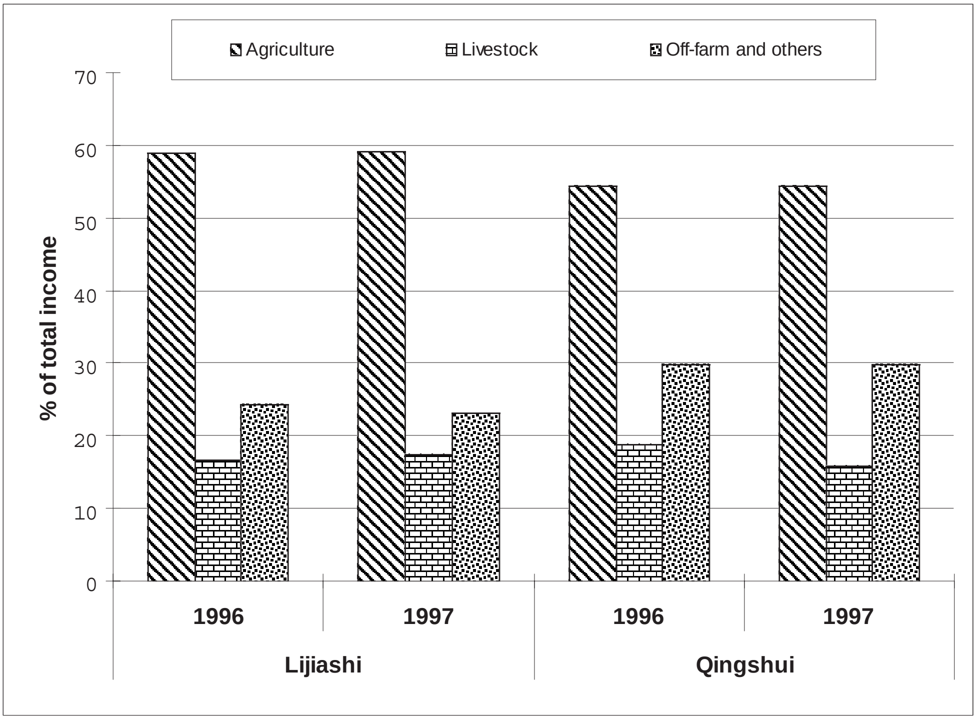

Figure 18.2: **Sources of income in Lijiashi and Qingshui villages**

office to provide them with seedlings for planting. The guards' salaries are paid by villages from forest tax revenues.

Land use dynamics, 1987-2002

Figure 18.3 shows the pattern of land use in the Xizhuang watershed in 1987 and 2002. Changes over the 15 year period show that land use has become more fragmented. Forest land remains the principle cover in the watershed increasing from 44% of the area in 1987 to 54% in 2002. The second most cover is upland fields which reduced from 29% of the area in 1987 to 16% in 2002.

The changes in land use from 1987 to 2002 have been quite diverse (Table 18.3). The change index ranges from only 1.0 for rural settlements to 36.6 for barren land. The most change was a 13% decrease in dry-land cropping land and a 10% increase in dense forest.

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Table 18.4, and Figures 18.4 and 18.5 show that 519 hectares of upland fields have been converted into forest land whilst the reverse has happened (forest lands to upland fields) over 160 hectares. Another significant change is the 46 hectares of forest land converted to grassland. Rice paddies have decreased to only one plot by the outlet of the watershed and have mostly been converted into upland fields, forest, and tea gardens. Housing has occupied upland fields and tea gardens.

So much land has become pine forest as many upland fields have been afforested through aerial seeding and by planting with pine seedlings. The analysis also shows that most of the tea in 1987 has been removed and most of the area under tea in 2001 has been planted since

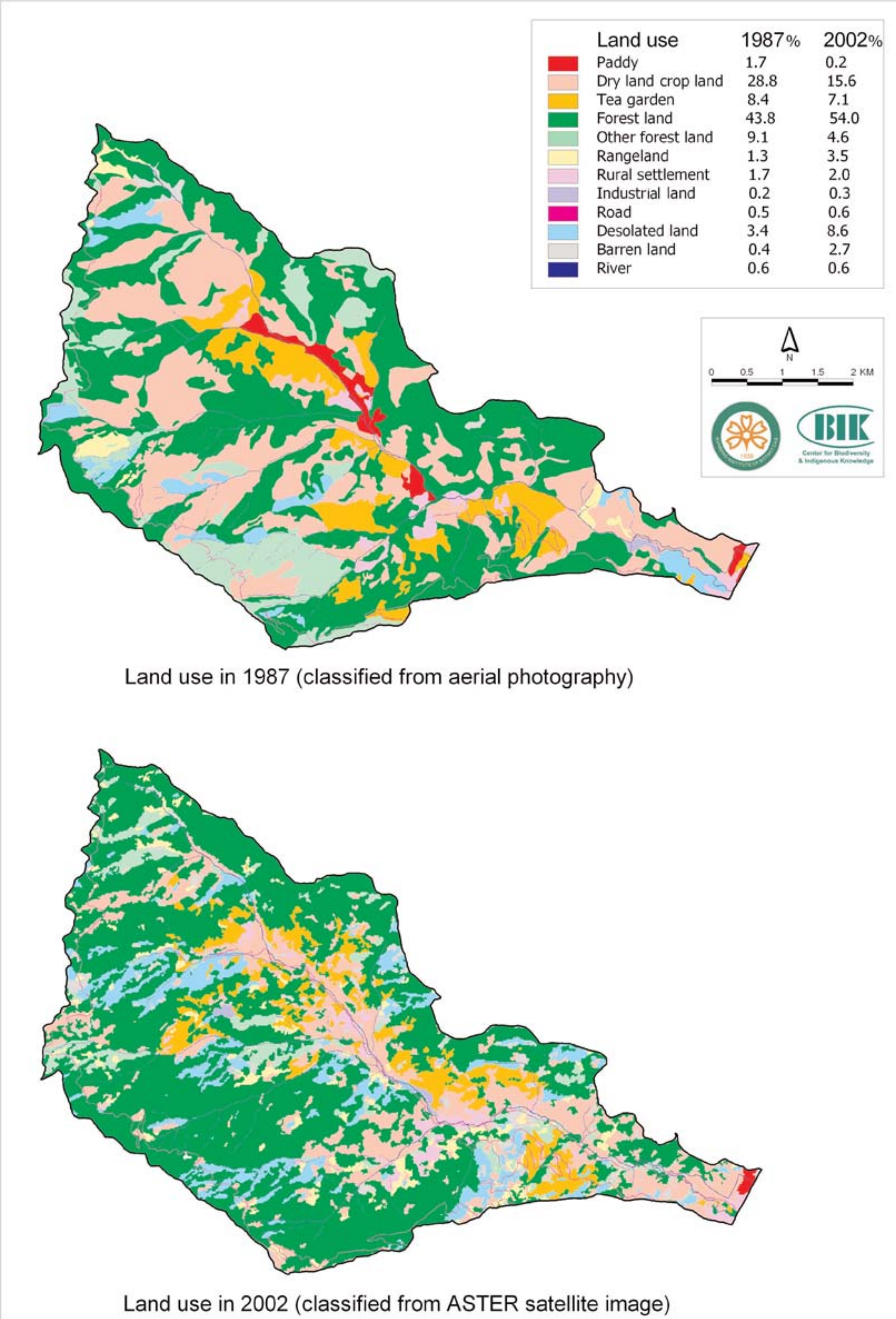

Figure 18.3: **Pattern of land use in the Xizhuang watershed in 1987 and 2002**

Table 18.3: **Land use change between 1987 and 2002 in the Xizhuang watershed**

Land use	Type	Area (ha)		Area change (ha)	Percent total area		% change	Annual land use change index
		1987	2002		1987	2002		
Paddy	11	58.5	5.6	-52.9	1.7	0.2	-1.5	6.0
Upland field	12	991.7	537.9	-453.8	28.8	15.7	-13.2	3.1
Tea garden	13	290.1	244.2	-45.9	8.4	7.1	-1.3	1.0
Forest (dense)	14	1505.0	1858.2	+353.2	43.8	54.1	+10.3	1.6
Forest (sparse)	15	313.1	158.4	-154.7	9.1	4.6	-4.5	3.3
Grassland	16	44.0	121.4	+77.4	1.3	3.5	+2.2	11.7
Settlement	23	58.9	67.6	+8.7	1.7	2.0	+0.3	1.0
Industry land	24	5.7	9.4	+3.7	0.2	0.3	+0.1	4.3
Road	27	15.9	21.9	+6.0	0.5	0.6	+0.2	2.5
Shrub or young plantation	31	118.3	297.5	+179.2	3.4	8.7	+5.2	10.1
Barren land	35	14.4	93.4	+79	0.4	2.7	+2.3	36.6
River	36	22.2	22.2	0	0.6	0.6	0	0
Total area		3437.8	3437.8		100	100		

then. This reflects how many of the old tea gardens (particularly collective ones) were not productive either due to poor management or old varieties, and were uprooted. Individual farmers then began to plant new varieties of tea on their own fields.

Causes of forest recovery

Forest management in Yunnan

Forest management in Yunnan reflects the long history of political struggle and shifting power between the state and local communities (Xu and Ribot 2004). The three main phases have been the period preceding the 1949 Revolution, the 1950 to 1978 era of collectivisation, and the post-1978 period of economic reform and decentralisation.

Most forest lands were privately owned before the 1949 revolution. Some forests were 'owned' in common by communities including the temple, headwater, sacred, and tribal forests. The nature of these common forest properties is significant as Yunnan is traditionally administered by local chiefs (*tusi*). There were also some public forests where part of the income was used for building and maintaining local schools, roads, and bridges.

The land reform laws of June 1950 governed forest resource management for three decades. Between 1950 and 1952 all farmlands and forestlands were nationalised. The state retained management control of large forestlands, but allocated farmlands and traditionally managed forestlands to individuals, particularly the poor. In these areas, the customary institutions were largely respected. The collectivisation process was initiated between 1952 and 1956. Most farmlands and forestlands were collectivised, although private ownership was still recognised in principle. This was followed in 1958 by the establishment of the People's Commune. This

Figure 18.4: **Land use change area 1987-2002**

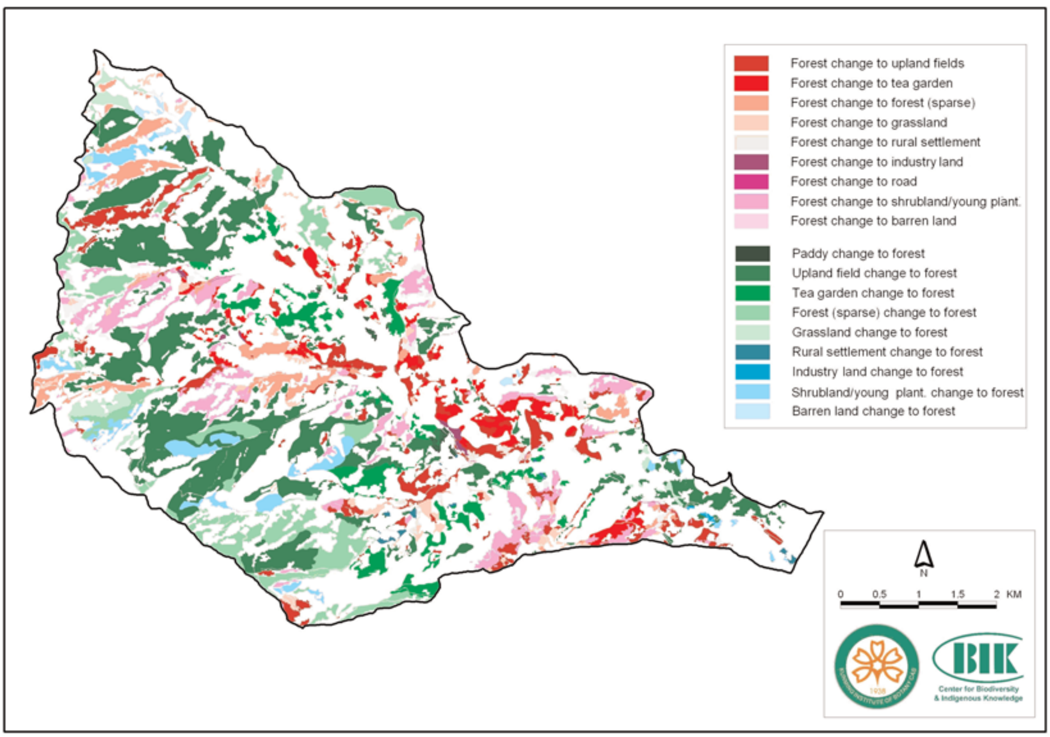

Figure 18.5: **Dense forest change dynamics 1987-2002**

had a profound impact on forest ownership and customary institutions. State and collective ownership replaced private ownership and customary public ownership particularly in peripheral mountainous areas.

The collectivisation policies, especially those enacted during the 1958 Great Leap Forward, resulted in large-scale deforestation. The economic liberalisation reforms began in 1978 with the establishment of the Household Responsibility System. Between 1978 and 1982 agricultural lands such as paddy fields were contracted out to individual farmers, but forests remained under state control. Since the boundaries between state forests and private agricultural lands were often unclear, conflicts occurred between government agencies and local collectives and individuals. To stake their claim to contested forestlands, individuals often cleared forestland to make fields.

Forestry sector reforms began in March 1981 when the state issued its 'Decision on Some Issues Concerning Forest Protection and Forestry Development', otherwise known as the 'Forestry Three Fixes'. This aimed to shift forest management from the state back to local communities and individuals. It provided for both private and collectively-held plots to be leased to individual households. This was the first time in Yunnan's history that local communities received certificates of forestland ownership.

However, these attempts to decentralise forest management and improve security of tenure over forestlands did not solve the problem of forest degradation. The transfer of forest use rights and management responsibility to local farmers did not lead to the regeneration of forests as environmental degradation, soil erosion, and flooding continued. On 1 October 1998, after the most extensive flooding ever witnessed in the Yangtze basin, the Yunnan provincial government introduced a natural forest protection policy in response to a state ban on logging, officially called the Natural Forest Protection Program (NFPP) policy. This ban was immediately followed by the Sloping Land Conversion Program (SLCP), 1999. The SLCP was designed to address the problem of the environmentally damaging cultivation of steep hill slopes. This planned to convert farmland on slopes of more than 25 degrees into forest or grassland. Farmers were encouraged to do this with the distribution of seedlings and government subsidies for grain, education, and healthcare fees. The logging ban and the SLCP have put many indigenous communities in a dire situation as they traditionally rely on forests for their livelihoods.

State afforestation

Following the forestry three fixes policy, the local forestry bureau in 1985 carried out aerial seeding of pine tree seeds over the most degraded forest lands. In some places local people planted pine and eucalyptus seedlings on their forestlands in areas difficult to reach by aerial seeding. Supplementary aerial seeding was carried out in 1991.

The harvesting of timber and fuelwood and grazing in the forestlands is highly regulated. Villagers have to apply for a quota to cut timber. Fuelwood collection is only allowed in certain forests for two weeks during the winter. Villagers have to pay for these forest products at the rate of \$14/m^3 for timber for domestic use, \$42/m^3 for timber for commercial use, and \$1.2 per backload of fuelwood. The township forestry station has been responsible for issuing these quotas since the system began in 1983.

Table 18.4: **Changed and unchanged land use 1987-2002 (hectares) in the Xizhuang watershed**

YEAR	2002												
	Category	Paddy	Upland field	Tea garden	Forest (dense)	Forest (sparse)	Grassland	Settlement	Industry land	Roads	Shrub or new plantation	Barren land	Rivers
1987	Paddy	1.6	37.5	5.1	6.7	0	0.2	4.3	0	1.3	0.3	1.5	0
	Upland field	0	211.9	91.1	519.5	25.7	40.2	11.5	4.4	1	59.3	27	0
	Tea garden	2.6	61.3	48.2	108	11.7	14	6.7	0	1.7	20.1	15.9	0
	Forest (dense)	0	160	85.6	893.6	102.1	45.9	9.7	5	0.9	166.3	36.1	0
	Forest (sparse)	0	24.1	12.5	215.3	6.3	7.3	0.6	0	0	45	2.2	0
	Grassland	0	6.5	0	29.8	5.2	2.4	0	0	0	0	0.1	0
	Settlement	1.4	7.2	1.1	5.5	1.5	3.2	32.8	0	0.7	1	4.4	0
	Industry	0	1.9	0	1.3	1.8	0	0	0	0.3	0	0.4	0
	Road	0	0	0	0	0	0	0	0	15.9	0	0	0
	Shrub or new plantations	0	26.7	0.8	69.8	3.6	6.1	2	0	0.2	5.5	3.8	0
	Barren land	0	0.9	0	8.8	0.6	2.1	0	0	0	0.2	1.8	0
	River	0	0	0	0	0	0	0	0	0	0	0	22.2

Note: the hectare figures under the same category for the two years are the unchanged areas

Drawing a picture of a cake to feed the stomach

Although the implementation of the three fixes policy broke up state ownership, this decentralisation has so far failed to give local communities adequate control over their forest resources, especially in areas like Yunnan, where the ethnic minority population heavily depend on these resources for their livelihoods (Xu and Ribot 2004). The increase in forest cover has mostly happened at the expense of high elevation former buckwheat fields. One farmer said that planting trees is like "drawing a picture of a cake to feed the stomach" due to the restrictions on timber harvesting. The illegal cutting of trees has been made a criminal offence.

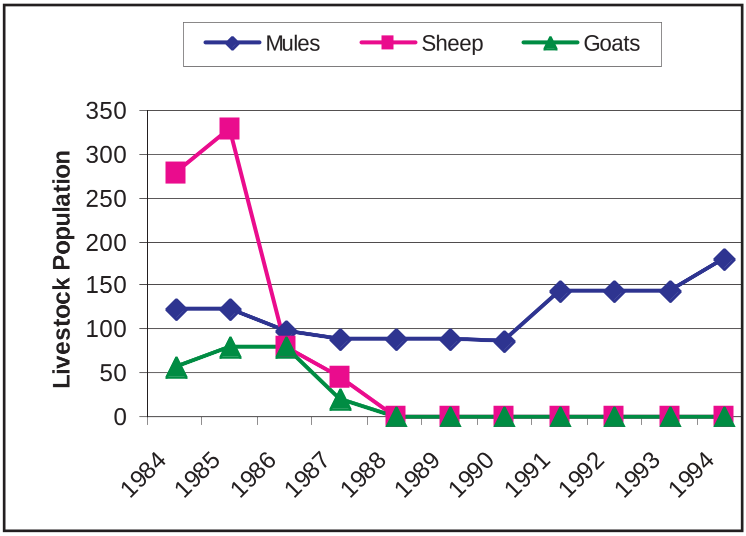

Figure 18.6: **Change in livestock population after reforestation in Lijiashi Village**

The impacts of afforestation on local livestock are shown in Figure 18.6. Farmers in the area no longer keep goats or sheep. The handover of responsibilities from state to collectives, and then from the collectives to individual contracts has led to the complete cessation of goat and sheep grazing in the forests. These animals used to provide a main source of income. Local farmers now depend more and more on cash income from tea crops although the market price for tea has not been good. Tea gardens are also encroaching on farmland. The locally produced grains – maize in the summer, and wheat or barley in the winter – mostly go for livestock feed. Rice is the main staple food and is brought in from the lowlands. The increasing number of mules (Figure 18.2) are used by farmers to transport pine needles from the forest for use as bedding and fuel and for carrying manure and crops.

The forestlands are unevenly distributed amongst households due to their original uneven distribution and changes in household sizes since forestland allocation. This is a major challenge for forest management in this watershed. To try and maintain equity the forestlands have been divided into very small plots at different locations. For example, one Damaidi farmer has 1.06 hectare of forestlands divided into 11 plots and 0.35 hectares of tea garden over 8 separate plots. Poor accessibility and such fragmented land holdings leads to poor management.

Figure 18.7 shows that in recent times the total area of upland fields peaked in 1986 and then decreased at township level. The remote sensing data shows that upland fields decreased from covering 29% of the total area in 1987 to 16% in 2002. Over the whole watershed there was a more than 30,000 ha decrease in farmland. Many of the shifting cultivation fields at high elevations have been converted into *Pinus armandii* forest or tea gardens. The *Pinus armandii*

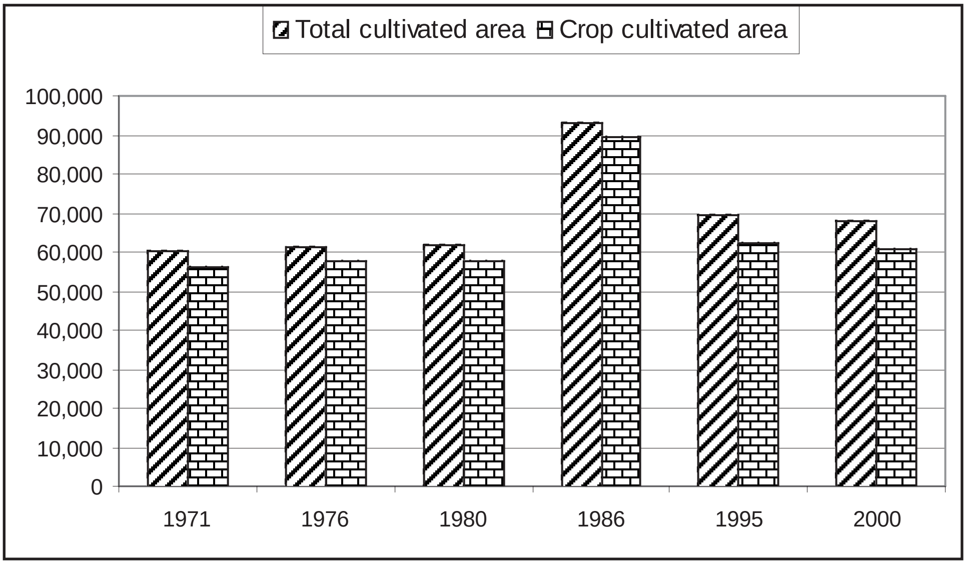

Figure 18.7: **Change in cultivated land 1971-2000, Banqiao Township**
Source: Banqiao township statistics, 2002

forests are the main source of non-timber forest products providing pine nuts, pine needles and wild mushrooms to sell in the market.

The field survey in Damaidi village recorded 22 adults, including two women from 18 households, who spend an average of 6.2 months per year on off-farm work. In 2002 they earned an average of US$74 per month from this work. The survey found that male labourers often spend more than half of the year off-farm, mainly on construction work in nearby lowland areas.

Impact of afforestation on local livelihoods

Dense forest cover increased from 44% in 1987 to 54% in 2002 due to the re-establishment of forest cover by aerial seeding and by local farmers planting pine seedlings. The establishment of pine plantations has increased soil acidity (Sha et al. 2003). The monoculture plantation has also reduced the diversity of non-timber forest products found in the area.

China took tentative steps towards decentralising forest management after the 1981 Forestry Three Fixes. However, even after this the forestry agency and local government were still involved in decision-making that affected people's livelihoods such as the establishment of forest plantations and conservation initiatives. This went ahead without any local participation. Local government authorities often fail to account for local livelihood needs in conservation-related decision making. Although local farmers maintained title over the afforested lands they did not have any decision-making power nor permission to harvest timber.

The new wave of top-down measures for protecting China's degraded environment has challenged upland farmers' livelihoods. Local village leaders say that SLCP aims to convert more than one thirds of existing farmland into forest. They see this as having a very detrimental effect on local livelihoods. As a result off-farm work has become a more important livelihood activity.

Conclusions

This land use change analysis shows the success of state driven reforestation and conservation programmes in reforesting upland areas of the Xizhuang Watershed. Forest land has significantly increased mainly at the cost of agriculture land. Land use changed at the rate of over 2% per year between 1987 and 2002. Upland farmers in the watershed have tried to compensate for their loss of cropping land by intensifying the use of their remaining cropland by introducing high yield varieties and the heavier use of chemical fertiliser and pesticides, by turning to off-farm work, and by spending more time harvesting non-timber forest products. The impact of monoculture pine forests on the local environment remains to be assessed.

The overall conclusion of this paper is that state policies have changed land use in the area without involving local people in decision-making. This will not encourage the sustainable management of the area's forests.

Acknowledgements

The authors acknowledge the financial assistance of the International Development and Research Center (IDRC-Canada), Swiss Agency for Development and Cooperation (SDC), the International Center for Integrated Mountain Development (ICIMOD), and the People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP). The local people of Xizhuang Mountain watershed deserve special thanks. We also thank Yang Lixin, Gao Fu, and Zhen Xuechong for carrying out some of the interviews and Andrew Willson and Laetia Kress of the Center for Biodiversity and Indigenous Knowledge who provided valuable comments on drafts of this paper.

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Agrarian Transformation in the Mountain Watersheds of Yunnan

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Abstract

The social and other changes brought about in China after the decollectivisation of land ownership has been an important area of study. This paper examines the dynamics of land and forest ownership over the past two decades in the mountain watersheds of Yunnan in southeast China. It examines farmers' access to land and forests and argues that the recent Sloping Land Conversion Program has recentralised control over natural resource by restricting farmers' access to land and forests. The paper shows how achievements have been limited by many poor farmers lacking information about the programme. It concludes that the failure to reorganise property relations and the programme's poor governance structure have prevented it from achieving its social and ecological objectives.

Introduction

Several studies have shown how agrarian transformation has had dramatic positive changes on developing societies (Hart et al. 1989, Sikor 2001). However, this process has also had negative impacts on rural societies in particular where rapid urbanisation has led to uneven development. Studying the conditions of agrarian transformation should help rural societies to find alternative means of improving local livelihoods.

The factors that have a significant impact on agrarian transformation at the grassroots level in China have come from land reallocation, environmental protection programmes, and reforms of village administrations. In China it is essential to look at macro-political changes to understand agrarian transformation at the grassroots level. Political changes have led to changes in control over and access to natural resources (land, forest, and water). These changes have affected farmer's livelihoods.

Over the last two decades the Chinese people have experienced dramatic changes with the introduction of the Household Responsibility System and the socialist market economy. These have been the main forces behind the push for agrarian transformation. In addition, Yunnan in southwest China, as a remote mountainous area with a rich forest cover, has been heavily affected by the environmental protection policies and the process of decentralisation. These policies are designed to conserve the environment and strengthen local livelihoods. The main policies are the Policy on Nature Reserves and Biodiversity Conservation, 1985, the Natural Forest Protection Program, 1998 (NFPP), the Village Organic Law and Building Grassroots Democracy Programme, 1998, and the Sloping Land Conversion Program, 1999 (SLCP).

The implementation of these policies has fundamentally changed agrarian relations and local resource management practices in Yunnan's upper watersheds. They are characterised by de-collectivisation and market liberalisation and have strengthened local control over natural resources and improved local livelihoods. The implementation of these policies has contributed to China's rapid economic growth that has lifted millions out of poverty.

Questions were raised at the time these policies were introduced about how they would effect farmers' access to resources. There were concerns that environmental protection policies could undermine local livelihoods and make some people poorer. The accompanying strict regulations might undermine local sustainable practices and the diversification of resource use and lead to conflicts over access to natural resources.

This study investigates the effect of the implementation of the Sloping Land Conversion Program (SLCP) in Baoshan prefecture, Yunnan Province, China. It moves from a historical comparison of agrarian transformations and their effects on farmers' access to land to the impact of the programme on farmers' access to land. Some important terms are defined in Box 19.1.

Box 19.1: **Key concepts relating to agrarian transformation in Yunnan**

Access – Resource access is composed of direct physical access, market access, labour access, access to capital, access to social relations, and access to knowledge;

Institutions – for environmental issues, institutions are the mediator of the people-environment relationship. Institutions constrain some activities and facilitate others. Some actors may attempt to bypass these constraints by creating new institutions that better suit their interests (He 2002:39)

Governance – governance is the framework of social, cultural and economic systems and legal and political structures within which humanity organises its affairs (Hillman 2003). It is the science of decision-making; and

Power relations – power is the capability to influence or dominate others to achieve a goal, despite resistance or rebellion (Pattana 1999). Studies on access to natural resources must look at the underlying bundles of power relations that govern people's access to resources.

Macro policies and the market are the key factors affecting governance at the local level. Local institutions and governance systems change in line with changes in policies and the market situation. Local institutions and governance systems structure local power relations that govern people's access to natural resources. The current research looks at the influence of gender, socio-economic status, age, politics and other factors that influence access to resources and looks at how far local people's rights and access are differentiated by power relations. It also explores how the local governance system affects farmers' access to natural resources. Figure 19.1 gives the conceptual framework of how the present study was carried out.

Policy Dynamics and Agrarian Transformation in China

In China over the last fifty years several dramatic changes have led to agrarian transformation. These policies have affected hundreds of millions of rural peasants.

The Mao era

Events in the Mao Era (1949-1978) had huge effects on social transformation in China. The first land reform (1947-1952) redistributed land ownership rights. It eliminated the largest

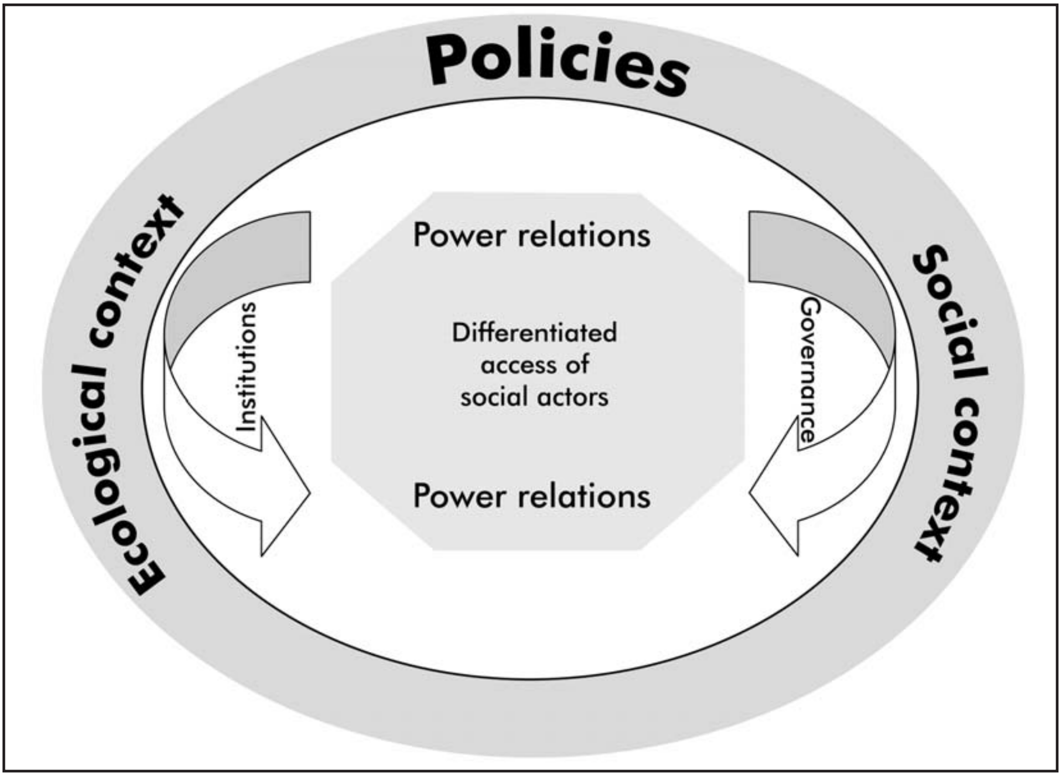

Figure 19.1: **Conceptual framework of agrarian transformation**

inequalities in property ownership at village level whilst affirming the ownership rights of individual cultivators (Selden and Lu 1993, Ho 2001). It promoted the changeover from feudal to socialistic means of grain production. This reform enhanced farmers' access to land and increased social equity.

Maoist agrarian policy continued through collectivisation. This happened from 1955 to 1978 through the abolition of private land ownership. Formal ownership rights to land and other means of production were shifted from individuals to collectives at the village or village sub-unit levels (Selden and Lu 1993, Hu 1997). The collective system controlled which crops farmers grew, the availability and distribution of inputs, prices of inputs and crops, and marketing. An important complement to this collective-state control of land rights were private plots (*ziliudi*) (Selden and Lu 1993). Rural households were allowed to cultivate about five percent of local cultivable areas where they could choose which crops to grow and what inputs to apply, and whether to consume or market the produce. Collectivisation also applied to forest lands.

Collectivisation increased poverty and food shortages. It led to the widespread misuse of forest resources and discouraged farmers from producing grain. Farmers lost access to and control over land and were not able to choose which crops to plant and how to grow and market them. Government policy had mandated the formation of agricultural collectives and subjected the allocation of agricultural inputs to administrative decisions.

Post-Mao land reforms

The lessons learned in the Mao Era led, in the early 1980s, to the Chinese government instituting reforms based on individual household land tenure. Farmland was reallocated to peasant households on the basis of their size. The farmers made contracts with collectives. Farmers were given the right to farm contracted lands (*zheren tian*) for 15 years – a system known as the Household Responsibility System. These lands are distinguished from the private plots (*ziliu di*) that farmers were given rights to in the 1950s. The Household Responsibility System is a sort of tenant farming system where the collective ownership of land is combined with private ownership of capital and household use-rights (Hu 1997).

This system promoted decentralisation and deregulation (Zuo and Xu 2001, He 2002) as the government allows farmers to make all decisions related to production, although farmers must fulfil state quotas for grain and cotton. Therefore, throughout the Chinese countryside rural households have become semi-autonomous producers operating within a collective framework (Selden and Lu 1993). This expanded role of rural households and the reduction of, and in many regions the elimination of, collective agricultural production has restructured land ownership rights across rural China.

The consequences have been mostly positive with rapid economic growth. This came about as farmers now had incentives to produce crops. Market liberalisation has given farmers more opportunities to market surpluses.

Along with the redistribution of agricultural land the government also reallocated forest lands through the Two Mountain System. This system recognises freehold forest land (*ziliu shan*) and responsibility forest land (*zheren shan*). Freehold land was generally poorly forested or barren and is relatively close to settlements. This land was allocated to farmers to grow trees for their subsistence needs (Zuo 1995). Responsibility forest land is leased to households or collectives to encourage forest conservation. Freehold land is leased on an unlimited-time basis, whilst the length of contracts for responsibility land are negotiated between villages and households (Zuo 1995).

However, the Two Mountain System has not worked as well as the Household Responsibility System. Studies have found a decline in forest areas as market forces have led to many forests being cut for cash incomes. This has led to social conflicts over access to forest resources.

To sum up, the Household Responsibility System and the Two Mountain System were the main land reform strategies carried out after the Mao Era. This period is referred to as the Deng era as they were carried out under the leadership of Deng Xiaoping. The Household Responsibility System motivated farmers to produce crops and led to rapid economic growth. The de-collectivisation of benefit distribution and land access and the decentralisation of decision-making strengthened farmers' access to land and forestry resources. This, however, led to social inequality and environmental degradation. While decollectivisation allowed for individual development, the lack of access to information, policy support, and socioeconomic differences led to a widening of the gap between rich and poor people.

At this time increasing environmental degradation became a serious problem. The over-exploitation of land (Hu 1997), forests (Zheng et al. 2001), and the short-sighted management of natural resources were encouraged by the short tenure periods and ambiguities in land property rights. People who worked their land irresponsibly, exploiting it for short term gain, gained more than people who worked it responsibly.

Environmental conservation in the post-Deng era

Two decades of Deng's reform policies had serious negative impacts on the environment (Muldavin 1996, Hu 1997, Zheng et al. 2001, He 2002). The following government launched environmental protection policies such as the Policy on Nature Reserves and Biodiversity Conservation, 1985, the Natural Forest Protection Program, 1998 that recognises the environmental services provided by forests, and the Sloping Land Conversion Program (SLCP), 1999.

The SLCP aims to reduce erosion and soil loss and promote more sustainable agriculture by converting agricultural land with slopes exceeding 25 degrees into forested land with compensation for affected farmers. This policy has led to the need to find alternative food and income sources for households that give up farmland.

Farmers carry out cropland conversion according to set amounts and schedules, and forestry agencies examine and check its implementation. Farmers who convert their farmland are compensated with grain – 150 kg of unprocessed grains per mu of land (1 ha = 15 mu) per year in upper reaches of Yangtze river and 100 kg per mu in upper Yellow river, and cash payments (US$2.4 per mu per year). Farmers need completed cropland conversion task cards and examination certificates to get this compensation. These subsidies have strengthened rural economies.

The SLCP-driven conversion of agricultural land into forest land has fundamentally changed peasants' control over access to land. SLCP is associated with bundles of regulations that regulate peasants' use of land.

Five types of land

The various land reforms and policies have left five main types of land where farmers have rights to personal benefit (Table 19.1). This table shows the official legal position although, as the next section shows, the situation differs in practice.

Effects of the Land Conversion Programme

Access to land

SLCP has raised many issues about access to land. Property rights are fundamental to the means of production. Chinese political scientists were previously much concerned with analysing the conflict between socialism and capitalism. The focus has now shifted from questioning capitalism or socialism and ownership to questioning the bundles of rights associated with properties that farmers can exercise and the security of those rights.

The distinctive Chinese concepts of landownership become comprehensible when they are broken into their component elements (Selden and Lu 1993). Land rights in China have been organised around the following elements since 1955:

- formal land ownership rights;
- use rights over the cultivation, investments, industry, mining and construction of land;
- transfer rights over the purchase, sale, rent, contracting, or inheritance of land;

Table 19.1: **Official land types in China, 2003**

Types of land	Basic Characteristics
Private plots (*ziliu di*)	• small pieces of land allocated to households that are owned by communities with households having use rights • farmers have the right to cultivate these plots including crop choice, control of the labour process, and consumption and marketing rights
Responsibility land (*zheren tian*)	• allocated collective land with households having contracted use rights • farmers must fulfil a state procurement quota for grain and cotton that can be fulfilled in cash
Private forest land (*ziliu shan*)	• barren lands owned by communities and allocated to farmer households for afforestation • farmers own the trees, but large-scale use of trees or bamboo needs license from forest department
Responsibility forest land (*zheren shan*)	• collective forested lands classified based on administrative boundaries, forest statutes, and age, and allocated to farm households who have partial management rights • managed by farmer households individually or collectively • farmers own non-timber forest products. Harvesting needs permits from forest department
Converted land (*tuigeng di*)	• agricultural land converted into forests or grasslands and compensated for by the government • strict management regulations with no grazing and intercropping allowed and fixed patterns for plantations • belongs to collectives, but when farmers renew their contracts land is reclassified as converted agricultural land

- product rights over the consumption and sale of products from the land; and
- rights over the labour of those attached to the land.

However, actual land ownership rights in China are 'ambiguous' (Ho 2000 and 2001). Although village land is legally owned by collectives, what is collectively owned has not been clear since the so-called decollectivisation process. The lack of real power to make decisions on leasing land and the lack of a collective governance structure has made land ownership ambiguous at the collective level. Although farmers do have more decision-making power, the state does not allow the existence of private property. The SLCP has added to this ambiguity and complexity.

The SLCP conversions saw local people's rights shift from having tenure over agricultural land to tenure over forest land. This changes what the farmers can do with these lands. The programme's strict regulations forbid grazing and intercropping. Nobody knows about the future of those lands and in particular what rights farmers have to use these area's forest resources. This ambiguity makes tenure insecure.

Although trees on converted land belong to farmers, it is not clear whether or not they can freely use them. Farmers can use private forest land and responsibility forest land as long as they do not damage trees. Timber harvesting is permitted by license. On converted lands, farmers have the right to use and market fruits from trees planted for economic reasons. It is not however clear whether farmers can cut trees down if the market for a type of fruit has a bad future and whether or not they can harvest timber from trees planted for ecological reasons. Government subsidies end after five years for economic tree plantations and after seven years for ecological tree plantations.

Farmers have to apply for licenses to harvest trees from private forest and responsibility forest land. However, these are hardly ever given. This study found that in Baoshan 91% of farmers were concerned about their rights to harvest trees once government subsidies ended. A number were also unsure whether or not they would be able to use the land in other ways by grazing their livestock, intercropping, and harvesting non-timber forest products. Some were concerned about the security of their tenure whilst some were concerned about whether or not they could pass the land on to their children. The main concern was over the stability of SLCP policies with the general feeling being that major policy changes could well take place.

Access to information

Access to information is crucial in rural transformation. The most important information is about markets and policies. The SLCP has strict regulations and prescribed means of compensation. It also advocates tree planting and subsidies to reduce poverty. The system of subsidies and benefit calculation is complex. The dissemination of this complicated policy has been difficult for local government.

This study found that farmers who lacked information about SLCP were at a disadvantage. For example, many people in remote and poor villages in Baoshan had never heard of SLCP. In Bawan village it was found that several outsiders had taken over contracts for cultivating sloping areas of land by paying local villagers US$6 per mu of land per year. The outsiders promised that they would give up the contract after seven years leaving the forest belonging to the village. Later these outsiders took part in the SLCP conversion programme. The outsiders thus made a good profit receiving 150 kg of grain per mu and US$6 for tree seeds and US$2.5 for education compensation per mu of converted land.

Cases were also found where outsiders rented land at US$4 per mu per year for 10 years. These peasants from other villages had come to know about the benefits. The study found that several farmers in Baoshan misunderstood SLCP due to their lack of information and lack of access to the authorities. Access to information shapes farmers' access to participation in SLCP and leads to uneven rural development.

Much of this area's farmland has a slope of more than 25 degrees. The main crop is maize with average yields being only 100-150 kg per year. These poor villagers hoped that SLCP could improve their livelihoods and help them find new sources of income.

Although many villagers know about the benefits of SLCP, they often do not know how to take part. In fact, taking part simply involves applying to the local government. But, one villager said that the local authorities never replied to his applications.

Strangely some lowland villages with farmland having slopes of less than 25 degrees have been accepted into the programme. These villages have social relations with the local government and forest authorities giving them good access to information.

Governance of implementation

The six line agencies involved in implementing SLCP are the Planning Commission of Minority Nationality Affairs, the Department of Finance, the Department of Grain Supply, the Department of Land, the Department of Forestry, and the Department of Animal Husbandry. This makes the SLCP difficult to coordinate.

The SLCP's centralised approach gives little space for local people to participate. The forestry sector, with the assistance of township governments, dominates the process. Every year, in accordance with the prescribed quota, the Baoshan Forestry Bureau distributes quotas for land to be converted in each township. The townships fulfil these quotas in accordance with applications and ecological priorities.

SLCP is supposed to be implemented in line with local people's wishes. However, this principle is ambiguous and has been interpreted as only meaning local people's willingness to participate rather than their wishes to see the programme taking a certain shape. In practice, locals' willingness to participate is respected, but their needs are not. In Baoshan, for example, many farmers wanted to plant a mix of tree species; but were not allowed. Only walnut trees were planted in most villages. The official view is that these trees are an ecological tree that gives future economic benefits, and so farmers can get seven years of subsidies from the ecological tree and in the future get cash incomes from selling walnuts. However, this is not actually true as the density of tree planting should be 85 trees per mu for an ecological tree plantation but only 30 trees per mu for producing walnuts. The trees will not produce saleable walnuts at the closer spacing.

Such uncertainties cause village people to be concerned. The study found that they were not sure whether they could thin out the walnut plantations to promote nut production. Doing this would convert the ecological forest into an economic forest which would conflict with the programme's main objective of soil conservation. Another concern was that a great increase in walnut production would lead to a drop in market prices. Experiences with previous government programmes such as the large-scale planting of sugar cane, worries them. In spite of its claim to be promoting decentralisation the stipulation of which species to plant points to continued centralised governance.

In addition, the selection of priority target areas, the preparation and distribution of seedling trees, and monitoring are all centralised with the forestry line agency and township governments. A major problem is that local government agencies often neglect remote areas where it is more difficult to work but where the needs for environmental improvement are greatest.

The rushed implementation of SLCP means that it has produced sub-optimal results (Zuo 2002). The burden on local government personnel has been high as it often takes up two month's-worth of all their staff's working time. This centralised structure of governance framework might not achieve both ecological and economic development in the mountainous areas of Yunnan.

Comparison of access to five types of land

The institutional arrangements means that the practice of rights to land is ambiguous at the grassroots level. Table 19.2 explains the five land types that people in the Yunnan mountainous watersheds have rights to.

Table 19.2: **Access status in the five official land types in mountainous Yunnan**

Land types / Access	Private plots (Ziliu Di)	Responsibility land (Zhenren Tian)	Private forestland (Ziliu shan)	Responsibility forest land (Zheren shan)
Formal ownership	collectives	collectives	collectives	collectives
Formal use rights	farmers	farmers	farmers	farmers
Form of use entitlement	land titles	30-50 year contracts with collectives	forest land titles	50-70 year contracts with collectives
Tax system	yes	yes	none	none
Species choice	no restrictions	limited self-determination in accord with state quotas and guidance	no restrictions	no restrictions
Harvesting	no restrictions	no restrictions	no restrictions on small scale timber harvesting. Permits needed to cut large trees	no restrictions on cutting fuelwood and gathering non-timber forest products. Need permits to cut large trees
Marketing products	self-determinations	self-determination after meeting state quotas	centralised control of timber market	non-commercial use of timber

Conclusions

This paper is only a preliminary study and the following findings should not be generalised. These concluding remarks raise several practical considerations for improving SLCP.

Ecological aspects

SLCP is an ambitious programme by which the government hopes to readjust the negative impacts of rapid economic development on the ecological environment. It is also the main programme to address soil erosion in mountain watersheds. However, the weakness of programme implementation has led to only limited achievements. The poor definition of priority target areas has been the main reason for this. Studies have found that productive lands with less steep slopes have been converted. As a result, in comparison with agricultural cultivation, the control of soil erosion through this programme has been problematic. Strictly obeying the policy in defining priority areas would have avoided such problems.

Moreover, due to the short-cut implementation of SCLP, the less choice in tree species, and centralised control of tree selection has resulted in the new problem of monocultures. Monoculture plantations can cause market surpluses and ecological instability due to pest infestations. The diversification of species in plantations is crucial. Promoting local participation in decision-making on tree selection is the key to improving the output of SLCP. Officials should respect local willingness and consider local needs more carefully.

Socioeconomic aspects

The SLCP, with its land conversion and poverty reduction focus is a major force for agrarian transformation in China. The conversion of less productive land and the provision of subsidies is helping to balance out inequalities caused by differences in geography. However, poor programme implementation has increased social differentiation. Remote villagers' lack of access to information has prevented them from benefiting. In contrast, villagers with good access to information have benefited more from the programme. In many cases benefits meant for poor people have gone to the better off. Therefore, transparency of information and improved information dissemination is essential.

One risk of the programme is that planting only one or two species of fruit tree will lead to a glut in the market. SLCP should consider promoting the diversification of rural production. Increased local participation in decision making would help diversify local production and improve local economies.

Political aspects

The SLCP's ecological and socioeconomic goal can be achieved by making political adjustments. The negative and unexpected consequences all result from a politically weak government framework. As well as improving access to information and increasing local participation in decision-making the following needs to be done.

Tax reform – The taxation system on agricultural land continues to be applied to the converted land that is no longer under agriculture. The SLCP does not allow farmers to grow crops on the converted land but still taxes them at the rate for cropping land. This increases transaction costs and causes local suffering.

Property rights – The security of property rights is a fundamental issue governing whether or not farmers take part in the scheme. Privatisation is not necessarily the best way to secure land tenure, but respect for local rights to resource use and an extension of contract periods should be implemented. In addition, rights to the use of land and forests should be allowed to be passed from parents to children. Village courts should be established to defend local rights.

Decentralisation – Thirdly, SLCP is a centralised programme. The democratised local bodies are little involved in the programme. The centralised programme has increased the burden of local government and made it inefficient and ineffective. Increasing the role of democratised local bodies in programme implementation would improve the ecological, economic and social outcomes of SLCP.

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20

The Culture of Access to Mountain Resources: Policy Processes and Practices

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An earlier version of the full 110 page paper was presented at the workshop. This two-page summary is based on a review of the paper produced by ICIMOD's Culture, Equity, Gender & Governance (CEGG) integrated programme.

It has long been recognised in development circles that to improve the livelihoods of the very poor and powerless in rural areas means increasing their access to natural resources and economic opportunities. Past analysis of these issues, however, has mostly concentrated on the institutions and social relationships of communities at local levels, almost to the exclusion of examining the national and international levels of discourse and action. This study shifts the focus to policy processes, institutions, and development practice at the macro-level. It investigates how the behaviour of government officials, aid donors, and other actors deeply affects the access of the poor to resources and opportunities.

The study argues that policy and institutional analysis that is oriented towards sustainable poverty reduction and social inclusion should be time, sector, and country specific. In keeping with this, the study looks in detail at the forestry sector during the last fifteen years in Nepal to illustrate the importance of this approach.

The study is based on an extensive literature review and the considerable experience of the two authors. It presents case studies on community forestry, leasehold forestry, a leading federation of community forestry users, and the growth of the handmade paper industry as evidence. These case studies investigate how the behaviour of macro-level actors has affected access and economic opportunities at local levels. The study examines how coalitions of government, local and donor actors have, over time, been more or less effective in bringing about changes in the legal framework and institutional mechanisms for developing access to resources for poor and marginalised people in Nepal.

The paper's actor analysis looks at rent-seeking behaviour, government revenue collection, the lack of 'learning and change' by donors, bureaucrats, and other policymakers, social responsibility in the private sector, consultancy contracts, and the ways some groups have achieved an effective voice in policy processes and programme design and implementation whilst others have not.

Some of the findings and ways forward recommended by the paper are:

1. **Acting upon findings at the macro level.** There is an enormous empirical literature, both local and international, that shows why the promotion of development initiatives such as forest user groups in the name of poverty reduction and social inclusion does not necessarily lead to poverty reduction and social inclusion. It appears, however, that many donor, government, and NGO actors at the macro-level are either unaware of these findings or do not act on them. Useful ways forward involve analysing and finding effective ways to change the cultures and reward systems in which development actors work at the macro-level.
2. **Encouraging transparency at the macro-level.** In Nepal, NGOs, aid agencies and government offices are gradually opening up their organisational 'black boxes' and are increasingly making 'internal' reports available to outsiders. These moves towards greater transparency and accountability at the macro-level are to be encouraged.
3. **Effective decentralisation.** The study confirms the findings of many earlier reports that effective devolution and decentralisation are still needed in Nepal.
4. **Expertise needed more than ever.** In some quarters, the promotion of short-term training on such topics as participatory rural appraisal and gender awareness, while often useful, has led to the illusion that strong disciplinarily-trained economists, anthropologists and other social scientists are no longer needed to carry out design, analysis, monitoring and assessment tasks in macro-level organisations. In Nepal this attitude needs to change if issues of access by the poor to resources and opportunities are to be effectively addressed.
5. **Proactive search for positive institutional innovations.** While many past development policies, programmes, and projects have not led to significant poverty reduction and more social inclusion, many case studies show how coalitions of actors have brought about positive changes, often outside the planned impacts of formal development interventions. It is suggested that more effort is needed by macro-actors to search out, understand, and build on these positive social processes that are already occurring in many places in Nepal.
6. **Personnel commitment to values.** Finally, and most importantly, it has often been the strong personnel commitment of members of the involved alliances and coalitions that has led to positive change taking place in policy processes and development practice resulting in sustained poverty reduction and social inclusion.

The study concludes by briefly looking at other sectors and countries to illustrate why the culture of policy processes and development practice are location-specific and should only be analysed in the specific political context of each country. The ongoing conflict which is greatly affecting the behaviour of policy and development actors in Nepal at the time of this study illustrates this point well.

Paper details: Biggs, S.D.; Messerschmidt D. (2003) The Culture of Access to Mountain Resources: Policy Processes and Practices. Report submitted by ICIMOD to the U.N. Food and Agriculture Organisation (FAO), Livelihood Support Programme, December 2003.

The paper is available from FAO's Livelihood Support Programme (lsp@fao.org) and online at http://www.fao.org/sd/dim_pe4/pe4_040501_en.htm

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Equity and Poverty Linkages in the Management of Commons in the Hindu Kush-Himalayas

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Abstract

This paper provides an overview of equity issues in the management of common property resources in the Hindu Kush-Himalayas. It gives pointers on how the management of common property resources can better support the livelihoods of poorer and marginalised people in mountain communities. Current mechanisms for access and control over commons, often through community management as in community forestry, in many cases do not produce equitable outcomes for poorer and marginalised communities. The paper concludes that areas needing urgent attention are 1) to take more of a livelihood focus in commons policies, 2) to end the assumption of homogeneity in community management, and 3) to build on existing customary rights.

Background

The Hindu Kush-Himalayan (HKH) region extends 3500 km from Afghanistan in the west to Myanmar in the east. It sustains approximately 150 million people and affects the lives of more than three times as many people in the plains and river basins below. This region is the world's highest mountain region and the most populous and fragile mountain area. It has an area of over 354 million hectares of which 11% is cropland; 17% forest; 41% pasture and rangeland, and 11% in protected areas. The last three categories of land use are the common property resources. Even after disregarding the parts of these areas that are inaccessible to mountain communities, common property resources constitute a major source of livelihood for local communities.

Common Property Resource Management in the HKH

The common property resources of water, timber and fodder are finite and their depletion leads to the degradation of remaining resources. These resources need to be systematically managed.

In the HKH, common property resources are in most instances managed within more than one type of institutional framework. Protected areas, such as national parks, increased from covering only 2.5% of the area in the early 1990s to 11% by 2002. The last decade has also seen increased commitment by the state to the community management of common property resources. The participatory management of commons through community forestry and joint forest management were introduced in the 1980s and 1990s. Also, forests and rangelands have been given on long term lease to households to use. Examples include the Household Responsibility System in China and the Leasehold Forestry Programme in Nepal.

Traditional institutions for managing these resources are found across the HKH. In India constitutional decrees recognise such institutions in Northeast India. In Uttaranchal, northwest India, the community management of village forests by elected forest councils (*ban panchayats*), has existed for more than 70 years. There are more than 6000 unofficial community managed forestlands that predate the formally constituted ones (Sarin 2001).

Some major problems encountered in the management of common property resources are related to the enforcement of rules. The inability of right-holders to enforce rules sometimes leads to them losing control over these resources. Many traditional common property resource institutions are declining because of external processes such as the inroads made by marketisation, or the introduction of new institutions that coopt community rights.

Poverty and Common Property Resources

Poverty means not having enough food, income and other inputs to maintain an adequate standard of living. A household's standard of living is also related to its access to natural, physical, financial, human, and social assets. It is usually the lack of an appropriate mix of assets that constrains people from generating and sustaining adequate livelihoods. Livelihoods are the capabilities, assets and activities needed for a means of living, and are sustainable when they can cope with stresses and shocks and maintain or enhance their capabilities.

A number of factors account for the widespread poverty amongst the people of the HKH. This area is largely outside the mainstream development process. It lacks sufficient infrastructure and development policies are biased to developing plains areas. As a result mountain areas experience high rates of out-migration. The HKH only offers limited alternatives to relying on local natural resources for supporting livelihoods.

Common property resources are a vital asset for HKH communities and it is particularly poor people who rely on them for their livelihoods. Loss of access to and control over them undermines people's livelihoods and exacerbates poverty. This leads to the loss of local and indigenous knowledge and in the long term degenerates the institutions that have traditionally maintained the commons. It is therefore crucial for the most vulnerable and needy groups to be assured access to and control over common property resources.

Equity in the Management of HKH Common Property Resources

The inequitable management of common property resources is a major impediment to alleviating poverty. Poor and socially marginalised people are often unable to influence life around them and the socio-politico system means they have little say on decisions to do with access to common property resources. Also, their lack of land, livestock, and other assets limits their opportunities to exploit available resources.

The main issues related to equity in the management of common property resources in the HKH are social and gender concerns, the exclusion of distant resource users, the asset poverty of poorer groups, and the rights of recent settlers.

Social and gender issues

Local social structures and power relations have a strong influence on shaping, supporting, and sometimes thwarting the sustainable management of common property resources. In Nepal, influential forest user group members are often mostly from economically advantaged groups and disadvantaged groups are often excluded (Graner 1997). Existing power structures, like patron-client relationships among users of common property resources, are characterised by a complex web of interdependent contracts which often restrict the inclusion of socially marginalised groups. Especially concerning decision making, the relative strength of some members often prevails over others. There is little evidence to suggest that more powerful interest groups want to facilitate equitable access for less powerful groups. This pertains to gender issues where traditional norms, social barriers, and the attitudes of fellow members often prevent women's involvement in making decisions.

Exclusion of distant resource users

In the participatory management of common property resources, such as community forestry and joint forest management, distant resource users such as seasonal grazers, have often been excluded from equitable access. The British government has supported many forestry projects in South Asia. Case studies of a number of these projects in India and Nepal (ODA 1996) found that certain groups such as seasonal graziers and pastoralists were excluded from benefiting from these initiatives. This is despite of the fact that participatory management regimes, like for example community forestry in Nepal, are meant to include all traditional users. Moreover, movement across countries in high altitudes which previously used to be effectively open, have become more restricted and pastoral groups have lost access to traditional grazing grounds. As a result these groups are restructuring their livelihood strategies often by out-migrating.

Poorer groups and resource endowments

Access and the 'harvesting' of resources from commons is often based on standard rules applicable to all members. This gives well-off groups, who have more assets such as land and livestock, a better opportunity to exploit resources. Within institutional rules each appropriator of common property resources will want to maximise their payoffs in terms of their differing needs for quantity and types of resources. So, more than often, the demands of economically poorer households are much less. Resource management in such a case will only be equitable if the poorer households increase their assets or identify other means through which they can benefit. The latter strategy has been little considered whilst formulating policies for managing common property resources.

Recent settlers and the management of commons

Customary laws are now being considered as a positive factor in the search for appropriate property regimes for the better use of common property resources. However, these laws are in some ways problematic. Traditionally unequal power relationships greatly affect how resources are distributed and managed. In many local societies gender relations are systematically skewed against equal rights to common property resources. Besides this, recent settlers in more permanent communities often have to abide by different rules that limit their access to common property resources. Customary laws are often far from democratic or equitable. In some cases, recent regimes for participatory management of common property resources reinforce customary inequities and sometimes introduce new inequities.

The Way Forward

Equity issues should be analysed and addressed from the global and national levels down to the inter- and intra-community and household levels. Each level has complex power relations that result in dominant groups getting disproportionate benefits. Social constructs of gender and patriarchy apply at the household level while caste issues arise within communities. Ethnic and tribal identities apply between communities levels while the interests of nation states influence control over resources and the distribution of benefits at the global level.

Current mechanisms for access and control over commons, be they through global processes or national policies, often do not produce equitable outcomes for poorer and marginalised communities. Some of the areas that need urgent attention are the need for a livelihood focus in commons policies, an end to the assumption of homogeneity in community management, and the need to build on existing customary rights.

More livelihood focus in commons' policies

Current policies for managing commons in the HKH tend to give more importance to conserving the environment than strengthening livelihoods. Policies have been formulated mainly as a response to resource degradation. These responses include social forestry, the leasing out of degraded areas for regeneration, decentralising resource management, stricter penalties for illegal use, and bans on certain uses such as grazing and the felling of green trees. In the HKH there is a need for a shift towards promoting local livelihoods to increase the participation of poorer people in managing the commons.

The assumption of homogeneity in community management

A fundamental premise for the success of community management is the assumption of distinct communities that are relatively homogenous. However, in many ways this is not true as within the HKH the many caste, class, gender, and economic differences make communities heterogeneous. This diversity leads to varying power relations that allow differential command over resources. Policies for managing common property resources urgently need to acknowledge this diversity to facilitate the implementation of more equitable outcomes.

Existing customary rights

New developments should recognise the importance of customary rights. This will help to ensure that developments contribute to societies' quality of life, are in harmony with the environment, and do not undermine and destroy mountain peoples' livelihoods. Also, policies need to ensure the rights of mountain communities over their biological resources by giving traditional knowledge and technologies priority over individual or corporate use. It also needs to promote improved governance of these resources by mountain communities.

Local knowledge

The International Convention on Biological Diversity 1992, requires signatories to protect and promote the rights of communities, farmers and indigenous peoples to the customary use of biological resources and knowledge systems (Articles 8j and 10); and requires the equitable sharing of benefits arising from the commercial use of communities' biological resources and local knowledge (Article 15.7). While there is a broad consensus that benefit-sharing should include benefits for local communities, most of the debate on this issue focuses on benefit sharing at the national level. There is a great need to build up the capacity of poor and marginalised communities to press for the equitable sharing of benefits and to assert their control over resources and knowledge systems.

Conclusions

There are insufficient policies in the HKH that mainstream equity and poverty in the management of common property resources. Reasons for this include the lack of voice of marginalised peoples, policy-makers' tendency to ignore the needs of those who do not raise their voices, the lack of advocacy by civil society, and the neglect of the needs of poor and marginalised people.

Inequitable access to benefits from common property resources jeopardises their sustainable management because it causes conflicts and does not allow the participation of marginalised users. There is an urgent need for HKH countries to mainstream equity and poverty issues in policies and practice for the improved management of common property resources.

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Annex

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ISBN 92 9115 143 2